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Stratigraphic position and facies significance of the limestone bands in the subsurface Carboniferous succession of the Lublin Upland

ABSTRACT: The Carboniferous paralic succession (late Viséan – Westphalian *A*) of the subsurface Lublin Basin in eastern Poland yields carbonate deposits, which dominate in the Viséan phase of sedimentation, and become more subordinate towards the younger units (Yoredale-type cyclothems). Numerous, perfectly preserved calcareous algae and microproblematics, as well as fairly frequent conodonts indicate an overlapping of the succeeding uppermost Viséan strata, and precise the position of the Viséan/Namurian and Namurian *B* / Namurian *C* boundaries.

The five conodont zones have been distinguished: the Lochriea nodosa, the Lochriea cruciformis, the Gnathodus bollandensis, the Idiognathodus sinuosus–Idiognathodus delicatus, and the Idiognathoides tuberculatus zones. The lower boundary of the cruciformis Zone is postulated to coincide with the Viséan/Namurian boundary. The presence of Idiognathoides tuberculatus Zone indicates a close relationship of the Lublin Basin with the upper Bashkirian basins of the East European Platform.

A distinction of the five algal zones: the Koninckopora, the Kulikia sphaerica, the Calcifolium punctatum, the Calcifolium okense, and the Masloviporidium–Anthracoporellopsis zones enables to correlate regional complexes as well as distant sections, ranging from northern England to the Ukrainian Lvov-Volhynian Basin, and farther east to the Moscow and Dneper-Donets Basins, in the interval corresponding to the latest Viséan – earliest Namurian.

The microfacies spectrum of limestone complexes and bands, dominated by the lagoonal algal and spiculitic, and the more distal foraminiferal and crinoidal lithotypes, bears evidences of local and temporary shoalings marked by peloid microfacies, featured by structures typical of early cementation and emersion. A comparison of microfacies succession in the Limestone Band *C* (random arrangement) and Limestone Band *F* (shallowing upward), and application of LEEDER & STRUDWICK's sedimentary models indicate a transformation of sedimentary regime in the earliest Namurian. An autocyclic, deltaic pattern of the late Viséan changed into an allocyclic system in the Namurian *A*, with duration of particular cycles estimated as about 500 k.y. This sedimentary turnover is recognized to coincide with the beginning of the Gondwanan glaciation, and thus it suggests a eustatic cause of the lower Namurian cyclicity in the Lublin Carboniferous Basin.

Contents

INTRODUCTION

The aim of the present paper is to describe the limestone complexes and bands recognized within the paralic part of the Carboniferous succession (late Viséan – Westphalian *A*), completely covered by thick Mesozoic sequence, and pierced by deep boreholes situated between Łuków in the north-eastern part of the Lublin Carboniferous Basin and eastern border of Poland (Text-fig. 1).

Generally, the area investigated corresponds with the margin of the East European Platform. A characteristic feature of the late Viséan paleogeography allover Europe is a broadening of the Laurussian shelf and a shifting of shallow water marine deposition to the north and northeast. This process is extremely well seen in the British Isles, where the Asbian and Brigantian sea flooded uplifted blocks in northern England and Scotland (GEORGE 1969, WALKDEN 1987, LEEDER 1988), located on the distant foreland of the Variscan orogen. To some extent a similar pattern of paleogeographic development is observed in eastern Poland. During the late Viséan the sea invaded that marginal part of the East European Platform, that is the Lublin – Lvov area, opening probably a connection with epeiric seas of the Moscow and Dneper-Donets Basins, and remained in this area (latterly only in the form of short ingressions) up to the end of Westphalian *A*. Meanwhile, the area of mobile blocks extending from Cracow, on the east margin of the Silesian Coal Basin, to the Holy Cross Basin, was finally uplifted at the end of the Viséan or at the beginning of the Namurian (*e.g.* BOJKOWSKI 1978, POŻARYSKI & DEMBOWSKI 1984, PASZKOWSKI 1988, POŻARYSKI & *al.* 1992, PASZKOWSKI & SZULCZEWSKI 1995, SKOMPSKI 1995a).

The paralic part of the Carboniferous succession deposited in the Lublin area therefore occupies a significant position in European paleogeography: on the one hand, the local basin is open to the influences of the west European sea, and on the other hand it presents features typical of the extensive epeiric seas of the East European Platform.

A significant feature of the Carboniferous paralic sedimentation, not only in the Lublin Basin, is its cyclicity. Many aspects of this cyclicity have been debated in extremely numerous papers, but some problems, especially the classification and origin of the cycles in particular regions are still an open question (*e.g.* LEEDER 1988, HORBURY 1989, WALKDEN & WALKDEN 1990, RIEGEL 1991, IZART & VACHARD 1994, LUDWIG 1994, PICKARD 1994, HECKEL 1995). Generally, three main sedimentary factors: eustatic changes of sea level, tectonic movements, and autocyclic processes, should be considered as components of the mech-

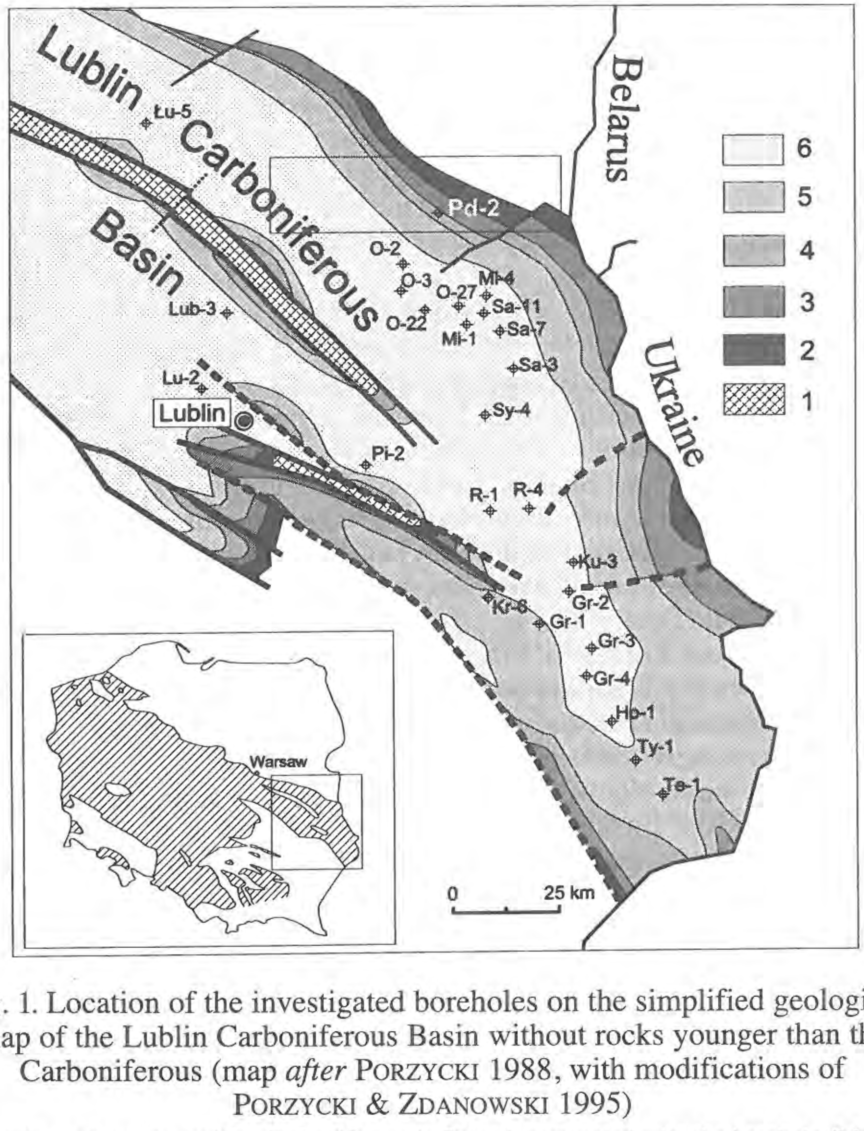


Fig. 1. Location of the investigated boreholes on the simplified geological map of the Lublin Carboniferous Basin without rocks younger than the Carboniferous (map *after* PORZYCKI 1988, with modifications of PORZYCKI & ZDANOWSKI 1995)

Inset shows the extent of the Carboniferous in Poland; rectangled with the borehole *Pd-2* is the Parczew-Włodawa area (with the boreholes Lubień *IG-1*, Łuków *IG-5*, Parczew *IG-6*, Parczew *IG-10*, Przewłoka *IG-1*, Radzyń *IG-10*, Rudno *IG-1*, Włodawa *IG-4*) investigated formerly by the present Author (SKOMPSKI 1986)

1 – Devonian rocks of the Kock Horst-Anticline (northern) and Trawniki Horst-Anticline (southern), **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

Abbreviations of the borehole names: **Gr** – Grabowiec *IG*, **Ho** – Hostynne *IG*, **Ku** – Kumów *IG*, **Lu** – Lublin *IG*, **Lub** – Lubartów *IG*, **Mi** – Michałów *IG*, **O** – Orzechów *IG*, **Pd** – Podedwórze *IG*, **Pi** – Piaski *IG*, **R** – Rejowiec, **Sa** – Sawin *IG*, **Sy** – Syczyn *IG*, **Te** – Telatyn *IG*, **Ty** –Tyszowce *IG* anism of cyclic sedimentation. Their effects usually intermingle with each other and discrimination of one dominant factor is usually difficult, even impossible. Basically, a settlement of this problem needs accurate recognition of the internal structure of cycles, and detailed characterization of their members, as well as precise knowledge of the stratigraphic position of the cyclic succession, for better correlation with adjacent regions. All these aspects formed the guiding principles for the Author in the investigations of limestone bands from the paralic succession of the Lublin Carboniferous Basin. These bands are considered as the most useful marker horizons, since they were deposited on the relatively stable basement and some of them are widely traceable in numerous boreholes, even over the entire basin (sometimes for more than 120 km). They also provide more valuable stratigraphic information than other parts of the succession.

The stratigraphic and correlative tasks have been realized with aim of the conodonts and calcareous algae. The diverse and perfectly preserved calcareous algae are the most specific and commonly occurring component of these carbonates; an analysis of their distribution allowed recognition of a general spatial pattern of the transgressive succession, and facilitated identification of the particular bands. The algae are not only very useful tools for intrabasinal correlation, but some species are significant in most universal, chronostratigraphic context. The conodonts, although rare, particularly in the lower part of the section, allowed the precised positioning of some of the chronostratigraphic boundaries, in particular the Viséan/Namurian and the Namurian *B* / Namurian *C* boundaries. The final part of the work, will be focused on the analysis of microfacies in the limestone bands. It suggests a differentiation of the succession in particular parts of the section. These data allowed verification of the theoretical models of the small-scale cyclic sedimentation mechanisms, proposed by STRUDWICK & LEEDER (1987) and based on observations from the shallow-water zone of the Early Carboniferous sedimentation.

The area of investigations is situated to the north-east of the Kock anticline-horst structure (northern subcrops of Devonian rocks *in* Text-fig. 1), and includes the southern portion of the Mazowsze-Lublin Trough (POŻARYSKI & *al.* 1992, POŻARYSKI & TOMCZYK 1993); only single samples have been taken from the central part of this trough. Preliminary results of these investigations have been presented in unpublished works of the Author, prepared under the Project CPBO 1987-1989. Some of them were extended in the unpublished M.Sc. theses (SZWEMIN 1992, WIŚNIEWSKA 1993) prepared under the supervision of Professor P. RONIEWICZ, Dr. A.M. ŻELICHOWSKI, and himself.

LIMESTONE BANDS

GEOLOGICAL SETTING

The paralic part of the Carboniferous succession in the Lublin Basin is subdivided into three Formations (Huczwa, Terebin, and Dęblin, in stratigraphic order), but its highest portion, with the youngest *Dunbarella* marine horizon, slightly overlaps the extremely thick (up to 800 m) coal-bearing Lublin Formation (Text-fig. 6). Extensive description of the lithology of these units and the history of their names is presented in regional papers (*e.g.* CEBULAK & PORZYCKI 1966, PORZYCKI 1979, 1987, 1988; PORZYCKI & ZDANOWSKI 1995); here only brief characteristics of the limestone bands will be reported.

In commonly applied practice these bands were considered as excellent marker horizons, denoted by the letters in alphabetic order (Lst. Bands *A* to *S*). In principle, the particular limestone bands have not been differentiated in macroscopic descriptions. Generally, they have been characterized as gray organodetrital limestones or marly limestones with a rich fauna of brachiopods, crinoids, corals, bivalves, and foraminifers. Early diagenetic processes caused formation of lime nodules of varying diameter (from one to several centimeters), but this feature is randomly scattered in the section (*see* Pl. 17, Figs 1-4). The occurrence of the most distinctive macroelements - solitary and colony corals (KHOA 1977) is basically restricted to the Huczwa Formation. In the higher part of the section only rare solitary corals have been found, even in the *Dunbarella* layer (*e.g.* MUSIAŁ & TABOR 1980, 1988; MUSIAŁ & *al.* 1995). Giant gigantoproductid brachiopods are limited to the Sołokija Member in the lowermost formation, whilst significant accumulations of bivalves are typical rather of the topmost parts of limestone bands from the two higher formations.

The index of limestone essentially was determined according to their characteristic position in the sequence, but this procedure proved correct only in the southern part of the Basin and above the Huczwa Formation. Problems arose during correlation of the long southern sections with those in the north, where the thickness of the succession is several times smaller, but where the relative proportion of the limestones in the section is radically larger. This feature could be caused by the onlap of successive limestone layers and/or the decrease of thickness of particular cyclothems northwardly. According to the lithological correlation (PORZYCKI 1988) both of these possibilities took place, although neither was biostratigraphically proven (*e.g.* MUSIAŁ & TABOR 1988, MUSIAŁ & *al.* 1995). It seems that the best prospect for the elucidation of this problem lies in the examination of the distribution of foraminifers and calcareous algae. In the present paper the indices of limestone bands from above Lst. Band *C* are coincident with PORZYCKI's classification; below this level new names for the complexes are proposed (*A1*, *A2*, *A3*).

The thickness of limestones in the particular formations is diverse in the extreme. In the Huczwa Fm. they form thick (even more than 50 m) complexes intercalated with claystones - these marine members compose on average 70% of the section. In the Terebin Fm. the thickness of the bands is distinctly lower and only in the Lst. Band *F* exceeds 10 m. Typical features of the bands from this formation are their regularity and areal extent - most of them appeared in the entire area of the Basin, usually as the first member of regularly shallowing upward cyclothems. In the Dęblin Formation the limestones and their shaly marine equivalents are subordinate, which resulted in classification of this formation as paralic rock association, contrary to the two older formations, which are considered as marine-paralic associations (PORZYCKI 1987). Some bands of this formation (*e.g.* Lst. Bands *M*, *N*) are extraordinarily constant over the whole Basin, despite their small thickness; others appear only as carbonate lenses inside the claystone complexes. The latter is particularly true for the Lst. Band *S* from the *Dunbarella* marine horizon.

The limestone bands from the Lublin Basin are well known also from its Ukrainian part (Lvov-Volhynian Basin). Their overall macroscopic characteristics (STRUYEV & *al.* 1984, SKOVORODNIKOVA 1991, SHULGA & *al.* 1992) are generally similar to those described from Poland. It is noteworthy that even in the peripheral part of the Basin the limestone bands are remarkably constant (*cf.* SHULGA & *al.* 1992, Fig. 25).

PALEOGEOGRAPHIC CONTROL OF CARBONATE SEDIMENTATION

The main factor generating intensive development of carbonates dominated by algae was seemingly the convenient paleogeographic position of the Lublin Basin in the Late Viséan - Early Westphalian time interval. The Lublin-Lvov area was an isolated embayment, open in the northwest direction, or it was more broadly connected with a strait between West European Sea and Paleotethys Ocean in the south. Both these conclusions have been expressed in the literature (Text-fig. 2). The first possibility was presented by ŻAKOWA (1970), BOJKOWSKI & ŻELICHOWSKI (1980), ZIEGLER (1982), BOJKOWSKI & DEMBOWSKI (1988); the second one was drawn on the maps by PAPROTH (1989).

On the geological map of Poland and adjoining countries, without Mesozoic and Permian Formations (Pożaryski & Dembowski 1984), the Carboniferous strata forms an isolated "sack", open in the north-west direction and closed in the opposite side. It is unsolved question how far this picture corresponds with the paleogeographic reality. No one of the sub-Mesozoic boundaries of the Carboniferous deposits corresponds to the primary extent of the Carboniferous deposition. Southwestern border is strictly tectonic and the large vertical throw of faults in this zone (sometimes more than 1000 m) caused a complete removal of the Carboniferous deposits from the hanging blocks. The other boundaries are also of an erosion nature. One can assume that the shoreline during the maximum of ingressions was positioned several tens of kilometers outwards of the present boundaries, but it does not contradict general idea about a parallelism of original and erosion borders. It is clearly proved by the reconstructed transport directions of detrital material (Żelichowski 1972, Skovorodnikova 1991, Shulga & *al.* 1992), which are radially oriented and point more or less for the depocenter of the basin (several tens of km south of Lublin, *see* Porzycki 1988, Figs 21, 23, 25), during deposition of the Huczwa and Terebin Formations as well as Dęblin Member. It remains unknown the paleogeographic position of the areas located southwardly of the tectonic line, which certainly were primarily covered by the Carboniferous strata. The nearest Carboniferous succession, recognized close to Rzeszów and to the Carpathian overthrust (Zając 1984, 1995; Moryc 1992) are composed of the Tournaisian and Viséan shallow water limestones and dolomites, covered in some places by deep water Culm

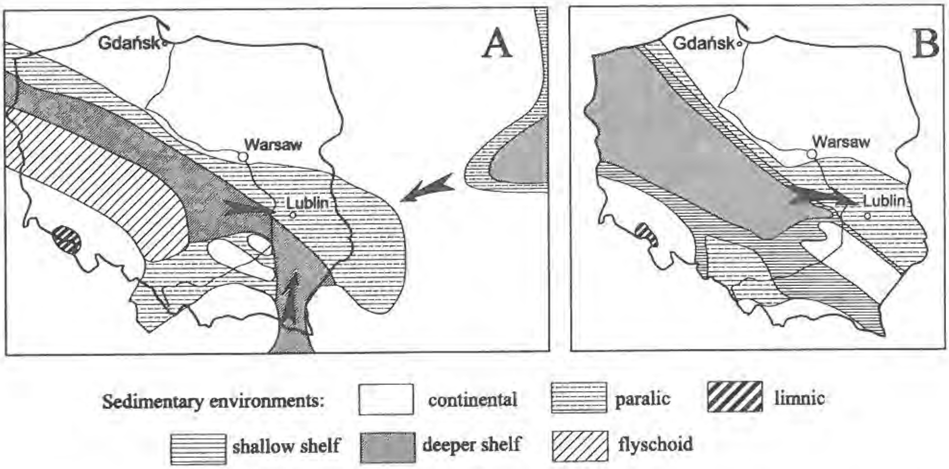


Fig. 2. Two different interpretations of the Lower Namurian paleogeography in Poland: **A** – *after* Paproth (1989); **B** – *after* Bojkowski & Dembowski (1973, 1988)

facies of the Upper Viséan age. This terrigenic sedimentation took place in the relatively narrow troughs, which functioned as the inlets between the northern epicontinental, narrow sea and Paleotethys. However, it should be noticed that in the end of Viséan the inlets have been probably closed, and the deposits have been faulted and uplifted, similarly to the Holy Cross area (*cf*. SKOMPSKI 1995a, Fig. 2).

Generally it seems that the Lublin-Lvov area was connected with the West European Sea by the narrow straits, located north and northeast of the uplifted Holy Cross Mts (Text-fig. 2B). This shallow, broad embayment with normal salinity, not isolated from the influence of the open sea, but in some respect protected from the more dynamic sea activity, was much convenient for development of carbonate sedimentation with so distinct impress of calcareous algae.

CONODONTS

GENERAL CHARACTERISTICS OF THE CONODONT SUCCESSION

The marine members of the cyclothems from the paralic succession of the Lublin Carboniferous Basin are developed in carbonate or shaly argillaceous facies. Both are typical of shallow-water epicontinental seas, but shales seem to have originated in the more proximal, nearshore areas, whereas marine fauna is characteristic of the more restricted or even brackish environments. This explains in some respects the total lack of conodonts in the shales; the conodont collection has been obtained only from the limestone beds. Conodonts were absent also from the limestones in the middle part of the succession, from above the *Posidonia corrugata I* correlation horizon up to the Lst. Band *L* (*cf*. Text-fig. 6), although the present Author collected a few samples from several boreholes (mainly Syczyn *IG-4* and Rejowiec *IG-1*) from this interval.

The limestone beds containing conodonts are grouped around the lower and upper boundaries of the Namurian, and they do not embrace the mid-Carboniferous Boundary (C_1/C_2), located approximately in the middle of the Namurian *A* (the appearance of the conodont *Declinognathodus noduliferus* s.l., at the transition between the *Eumorphoceras* and *Homoceras* goniatite zones). This boundary is sometimes considered to be one of the greatest global biotic extinction events (NEMIROVSKAYA & *al*. 1993, NEMIROVSKAYA, *in press*), which is distinctly visible in conodont microfauna (nearly 90% of extinct genera). A lack of conodonts from this boundary interval has meant the investigated collection consists of the two very distinct assemblages; the Upper Viséan / Lower Namurian (designated herein as Lower Carboniferous) and the Upper Namurian / Lower Westphalian (Upper Carboniferous).

In both assemblages the pectiniform elements outnumber the ramiform elements and in the extremal case in the Upper Carboniferous assemblage the latter elements are practically lacking. This situation is well known from numerous other Carboniferous sections; an example, illustrative and analogous to the situation analyzed here, is cited by REXROAD & HOROWITZ (1990, p. 497) from intertidal sediments, where *Cavusgnathus* is represented only by Pa elements, whereas most of ramiform elements of *Kladognathus* are present. This deficiency of apparatus composition is usually explained by the activity of predators, the varying potential for fossilisation or is interpreted as an effect of synsedimentary selective transport of particular elements (*for review see*: REXROAD & HOROWITZ 1990, MCGOFF 1991). The latter factor can be ignored in the investigated section, since deposition of most limestones discussed, was in a quiet, non turbulent sedimentary environment. More probable seems to be damage and subsequent loss of the more fragile elements, fractured by the sediment compaction. The limestones studied contain a significant proportion of the argillaceous material and early diagenetic calcareous concretions or nodules at various stages of development that document conspicuous level of compaction. The excellent example from the Stonehead Back section (VARKER 1994), quantitatively illustrating a damage of conodonts due to compaction, shows that nearly 80% of conodonts can be lost on this way. It is obvious that this process involves rather the ramiform than the platform elements.

More enigmatic is the total lack of conodonts in the lowermost parts of the sections, generally interpreted as belonging to the lower or middle part of the Upper Viséan (C_{V3b} - according to MUSIAŁ & *al.* 1995). In this interval more than 30 samples were almost barren, with at most single ramiform elements being found. This cannot be explained simply by the appearance of unfavorable facies, which generally are similar to those typical of the upper parts of the sections. Low conodont frequency at this horizon is well known from numerous sections in Europe and the United States (*e.g*. RHODES & *al.* 1969, CONIL & *al.* 1977, KOZITSKAYA & *al.* 1978, WEBSTER & GROESSENS 1990, PERRET & WEYANT 1994) and is coincident with the first phase of post-*anchoralis* low-diversity episode in conodont evolution (ZIEGLER & LANE 1987). Most probably this evolutionary crisis was also connected with a decrease in the number of conodont-bearing animals. The causal link between low abundance and diversity of conodonts, and general eustatic sea level fall, as postulated by AUSTIN & DAVIS (1984) offers a possible explanation, but the mechanism of this process is still waiting detailed explanation.

The incomplete conodont assemblages in respect to pectiniform/ramiform elements has meant that in the present paper the multielement classification is fully employed only for the genera *Kladognathus* and *Synclydognathus*. In the remaining genera only the pectiniform elements have been classified. Because nomenclature misunderstandings could create some confusions in correlation (*see* discussion *in*: WEBSTER & GROESSENS 1990), discrete element (DE) classification is also indicated, especially in plate explanations.

UPPER VISÉAN / LOWER NAMURIAN ASSEMBLAGE

The content of the older assemblage (Text-figs 3-4, 6; and Table 1) is typical of the Yoredale-type facies, as characterized by VARKER (1968), VARKER & SEVASTOPOULO (1985), DAVIES & *al*. (1994) and VARKER (*in*: SKOMPSKI & *al*. 1995). However, the distribution of conodont elements through particular limestone bands is completely different from that in the Yoredale Group. VARKER (1968) indicated a maximum concentration in the top third of each limestone band, while in the Lublin Basin the distribution is random or distinctly higher in the lower half of the band. This observation will be more carefully analyzed in the sedimentological part of this work (*see* Text-fig. 14).

Another distinctive feature is the conodont frequency in different limestone bands. It is very low (several specimens per kG of rock, nearly 50% of samples without conodonts) up to the Lst. Band *C*; in the younger bands, especially Lst. Band *D*, this parameter is considerably higher (20-30 specimens per kG). This difference cannot simply be explained by a differentiation of facies, which are comparable in both intervals. More significant is a comparison with the Moscow Basin, where an identical difference in conodont frequency between the Venevian and Tarussian horizons is stressed in Russian literature (*e.g*. ALEKSEEV & KONONOVA 1993). As described later the strata investigated here are the stratigraphic equivalent of these two Russian units.

A characteristic feature of the assemblage is its mixed ecological composition (Text-fig. 3): the offshore taxa as *Gnathodus girtyi* and *Lochriea* occur together with *Cavusgnathus* and *Mestognathus,* usually interpreted as forms typical of more agitated, nearshore euryhaline environments (AUSTIN 1976, MERRILL & VON BITTER 1984). Even more characteristic of this fauna is proportion of *Synclydognathus*, which according to DAVIES & *al*. (1994) "*...appears to occupy an ecological niche transitional between Cavusgnathus and Gnathodus...*". This type of assemblage composition seems to be typical of the Yoredale limestones. DAVIES & *al*.

Table 1

Conodont distribution within the Upper Viséan/Lower Namurian interval in the Lublin Carboniferous Basin

Part 1

Limestone Band index	*Mestognathus bipluti* (Pa)	*Cavusgnathus naviculus* (Pa)	*Gnathodus bilineatus* (Pa)	*Gnathodus bollandensis* (Pa)	*Gnathodus girtyi girtyi* (Pa)	*Gn. girtyi collinsoni* (Pa)	*Gn. girtyi intermedius* (Pa)	*Gn. girtyi meischneri* (Pa)	*Gn. girtyi rhodesi* (Pa)	*Pseudognathodus homopunctatus* (Pa)	*Gnathodus symmutatus* (Pa)	*Lochriea commutata* (Pa)	*L. commutata* (M) DE *Neoprioniodus montanaensis*	*Lochriea cruciformis* (Pa)	*Lochriea mononodosa* (Pa)	*Lochriea nodosa* (Pa)	*Lochriea senckenbergica* (Pa)	*Lochriea ziegleri* (Pa)
Pos. corr.	0	0	0	314	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	0	1	2	2	49	0	0	7	0	0	0	0	0	0	0	0	0	0
F	1	0	29	0	82	7	0	6	1	0	1	17	8	9	42	8	3	35
E	0	1	20	0	62	1	0	3	0	0	0	12	2	1	5	4	0	4
D	0	1	97	0	77	2	6	30	3	0	7	165	10	4	23	9	0	0
C	0	22	19	0	48	23	0	8	2	10	45	55	28	9	25	10	0	0
A3	11	5	12	0	41	3	0	1	0	1	13	36	12	0	1	9	0	0
A2	2	0	4	0	4	0	0	0	0	3	2	9	2	0	1	0	0	0
A1	0	0	0	0	3	0	0	0	1	0	1	0	0	0	0	0	0	0
Total	14	30	183	316	366	36	6	55	7	14	69	294	62	23	97	40	3	39

Part 2

Limestone Band index	*Kladognathuds tenuis* (Pa-Pb) DE *Magnilaterella*	*K. tenuis* (M) DE *Hibbardella milleri*	*K. tenuis* (M) DE *Neoprioniodus peracutus*	*K. tenuis* (M) DE *Neoprioniodus scitulus*	*K. tenuis* (Sb-Sc) DE *Ligonodina levis*	*K. tenuis* (Sb-Sc) DE *Ligonodina tenuis*	*K. tenuis* (Sb-Sc) DE *Ligonodina sp.*	*Synclydognathus geminus (Pa)* DE *Spathognathodus scitulus*	*S. geminus* (Pb) DE *Ozarkodina laevipostica*	*S. geminus* (M) DE *Apatognathus? librata*	*S. geminus* (S) DE *Apatognathus? chaulioda*	*S. geminus* (S) DE *Apatognathus? gemina*	*S. geminus* (S) DE *Apatognathus? petila*	*S. geminus* (S) DE *Apatognathus? scalena*	*S. geminus* (S) DE *Apatognathus ? sp.*	*Hindeodus cristulus* (Pa) DE *Spathognathodus cristulus*	*Hindeodus minutus* (Pa) DE *Spathognathodus minutus*	**Total**
Pos. corr.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	314
G	0	0	2	1	0	0	1	3	0	2	0	0	2	2	0	2	0	76
F	2	0	8	7	7	0	11	47	5	6	9	1	13	8	13	8	0	394
E	0	0	4	4	7	0	2	6	2	5	2	3	2	1	0	0	0	153
D	2	1	11	7	3	0	11	23	5	2	5	4	8	5	4	2	0	527
C	6	1	4	9	7	1	5	26	8	3	11	18	9	10	0	10	5	437
A3	2	2	5	9	8	1	0	11	2	2	5	6	5	4	0	0	0	207
A2	0	0	2	2	1	3	1	2	1	0	0	0	0	0	0	0	0	39
A1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	8
Total	12	4	36	39	33	5	32	119	23	20	32	33	39	30	17	22	5	2155

(1994) analyzed the conodont distribution of the Gayle Limestone, from the Yoredale Group in England, but they did not find a simple ecological model, dominated by one factor. They argued that the complex of different factors as for the example availability of nutrients and interaction of wave-energy, water-depth and shelf topography, had resulted in the lateral segregation of conodonts. On the other hand, the set of factors defining paleoenvironment, although difficult to precisely decipher from the geological record, should be relatively constant in time. Simple statistic analysis (Text-fig. 4) of the assemblage studied here, shows that the relative abundance of particular groups of taxa is nearly constant in different limestone bands. The most distinct are the curves for the complex *A2* and Lst. Band *G*. This observation could be easy explained by the small number of samples from these limestones, which therefore seems to be not representative. The similarity of the conodont content in the limestones from the Lublin Basin and those from Yoredale Group points generally to a strong and significant environmental stress. The latter also found expression in the extremely luxuriant growth of algae, which is an exceptional feature of this environment in the Lublin Basin, in contrast to the other regions of the Laurussian shelf.

The content of the conodont assemblage (Table 1) in the argillaceous *corrugata I* corellation horizon is completely different from that in the lower beds, since it is monospecific in character (*Gnathodus bollandensis*). It is generally accepted that this type of single species assemblage suggests a restricted environment in which only the most tolerant species throve. This conclusion is in obvious opposition to the general opinion concerning the

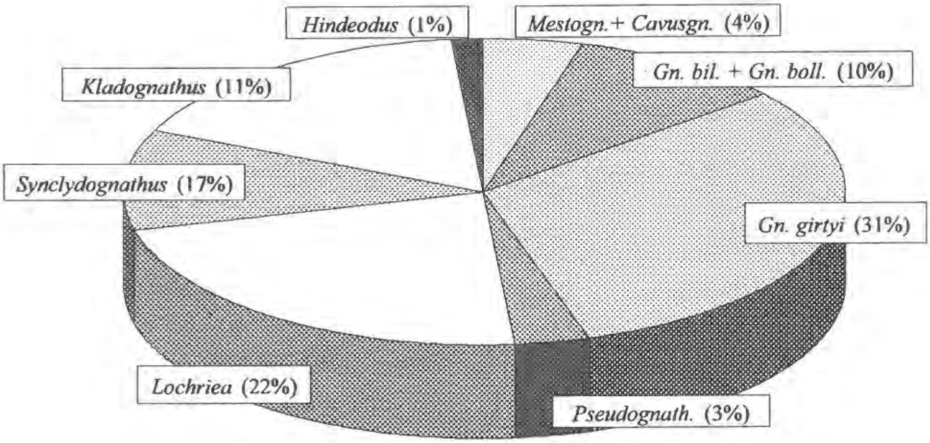


Fig. 3. General statistical characteristics of the Upper Viséan/Lower Namurian conodont assemblage in the Lublin Carboniferous Basin — an average content of the main ecological groups (Lst. complex *A2* to Lst. Band *G*)

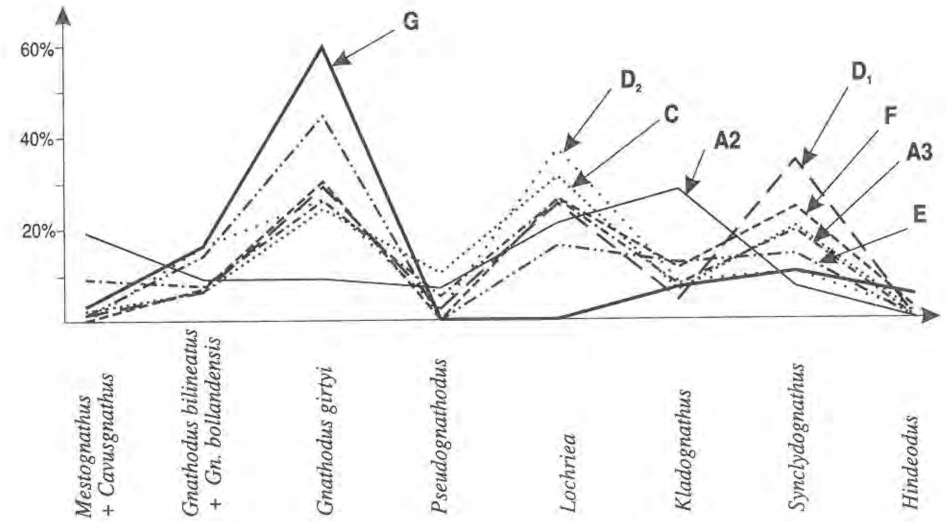


Fig. 4. Frequency of the main conodont taxa (or groups of taxa) in particular Limestone Bands (C, D_1, D_2, E....) from the Upper Viséan/Lower Namurian interval of the Lublin Carboniferous Basin

ecological conditions favorable for the development of the genus *Gnathodus,* since in comparison with other Carboniferous genera, this genus, characterized by nektobenthic mode of life, is regarded as less tolerant and required normal marine conditions (*see* review *in*: Sweet 1988, Rexroad & Horowitz 1990). However, there are numerous examples from the Lower Namurian in which *Gnathodus bilineatus* predominates in assemblages from environments different from normal offshore (*e.g.* Mapes & Rexroad 1986, Varker 1994). In all these cases, and including the one described here, the conodonts were recovered from limestone concretions or thin layers of limestones, formed in an argillaceous nearshore sedimentary environment. Thus, it seems most probable that *Gnathodus bilineatus* and especially its youngest, Lower Namurian forms, are specialized exceptions to the stenotypic mode of life of other gnathodids, being tolerant of muddy bottoms, decreased salinity or temperature changes. The composition of the macrofaunal assemblage in the *corrugata I* horizon represents a restricted environment (Musiał & Tabor 1988), suggesting abnormal salinity as the most probable cause of the monospecific occurrence of *Gn. bollandensis*.

UPPER NAMURIAN / LOWER WESTPHALIAN ASSEMBLAGE

The conodonts of the Upper Namurian / Lower Westphalian assemblage (Text-fig. 6 and Table 2) were collected from limestone intercala-

Table 2

Conodont distribution within the Upper Namurian/Lower Westphalian interval in the Lublin Carboniferous Basin

Borehole	Depth	Limestone Band Index	*Adetognathus lautus*	*Idiognathodus delicatus*	*Id. sinuosus*	*Idiognathoides sinuatus (left forms)*	*I. sinuatus (right forms)*	*I. sulcatus*	*I. lanei*	*I. attenuatus*	*I. tuberculatus*	*Neognathodus bassleri*	*N. symmetricus*	*Declinognathodus noduliferus inaequalis*	*D. lateralis*	*Declinognathodus sp.*	*Spathognathodus sp.*	*Ligonodina sp.*	Total
Orzechów 52	864.3	S				12	30			2	3								47
Orzechów 27	734.4	S				60	35	5		10									110
Orzechów 24	873.1	S				11	10			2									23
Orzechów 22	922,5	S		1		52	40			8	2								103
Łuków 5	1082.7	S				30	30			5	1								67
Telatyn 1	703.8	P		2															2
Orzechów 27	819.8	P		2		7	12		3				8				1		33
Łuków 5	1118.2	P				3	3			1			11	1					19
Orzechów 1	826.1	O-P		3	3	4	4						3						17
Lublin 2	1788.4	O-P		11	10	17	30		2	2				4			2		78
Grabowiec 3	1103.1	O-P		30	11	14	16						4		2		2		79
Telatyn 1	731.2	O		6	3	6	21								1				37
Syczyn 4	980.1	O		7	2		2												11
Orzechów 22	988.4	O		11		4	2					1					2		20
Kumów 3	929.6	O		4		3	3										1		11
Hostynne 1	780.6	O			4														4
Telatyn 1	766.2	N		2		1	1			1					1		1		7
Syczyn 4	1003.7	N	1	16	2	2				1									22
Sawin 25	992.1	N		19	2	9	4		1				1	11			2		49
Sawin 11	1003.2	N		13	19	1	2					1					3	1	40
Rejowiec 1	1049.6	N		2		2	2							1					7
Orzechów 27	933.8	N		20	3	2	1							11				1	38
Orzechów 22	1006.3	N		6	3	3	3												15
Lublin 2	1853.2	N		35	20	5	3						15	3	2				83
Kumów 3	975.8	N		2		3	3												8
Hostynne 1	811.2	N				2													2
Grabowiec 1	1131.1	N		23	3	27	29	2		4			5	19	7				119
Łuków 5	1192.2	N		6		1	2		1				5						15
Łuków 5	1189.9	N		3	1	3	2			1				1			2		13
Tyszowce 1	887.5	M		20		4	3			1		1	1	9			1	1	41
Syczyn 4	1013.1	M	2	29	3	15	13			2			2	7	9		2	1	85
Sawin 11	1023.2	M		10	6	1	4			1							1	1	24
Rejowiec 1	1065.2	M		22		11	7								6		1		47
Rejowiec 1	1065.1	M		3		5	5		1	1				3					18
Orzechów 22	1014.3	M		16		1	2							3					22
Grabowiec 4	971.3	M		34	5	4	4			2			2	2	2				55
Grabowiec 3	1080.5	M		12		2	4		1				2			5			26
Grabowiec 2	1109.8	M		9		3	3		1				2	1	2		1		22
Grabowiec 1	1153.4	M		1		1							4	1					7
Łuków 5	1197.1	M		13	1								1						15
Total			3	393	101	331	335	7	10	44	6	3	66	77	32	5	22	5	1441

tions, extremely thin but stable allover the studied basin, and from carbonate lenses (denoted as Lst. Band *S*) which occasionally occurred in argillaceous *Dunbarella* horizon. Although the sedimentary environment of these carbonates is very shallow, the frequencies of conodonts are high and regular (usually more than 50 specimens per kG of rock). This seems to be a characteristic feature of the late Namurian seas allover the world and was presumably connected with the abundance of the conodont animal. The composition of the conodont assemblages, which are very similar in the lower three limestone bands but different in the uppermost level, is dominated by idiognathodids and idiognathoidids (Text-fig. 5). Declinognathodids and neognathodids occur in accessory numbers, whilst a decrease in declinognathodids towards the younger beds is clearly visible. This composition seems to be typical of this time interval in the seas of the East European Platform (*cf.* Barskov & *al.* 1984, Nemirovskaya 1987, Nemirovskaya & Alekseev 1995), but it differs clearly from English sections (Higgins 1975, 1985). The latter assemblages are characterized by a numerical dominance of declinognathodids or idiognathoidids (in younger units), and a relative scarcity of idiognathodids. It is obvious that this difference reflects ecological changes, but the particular factors determining the environment still remain unknown.

The most important observation is the almost total lack of idiognathodids in the uppermost level (Lst. Band *S*), in contrast with the abundance of these forms in the lower units. The ecological conditions preferred by *Idiognathodus* are well known mainly from the American sec-

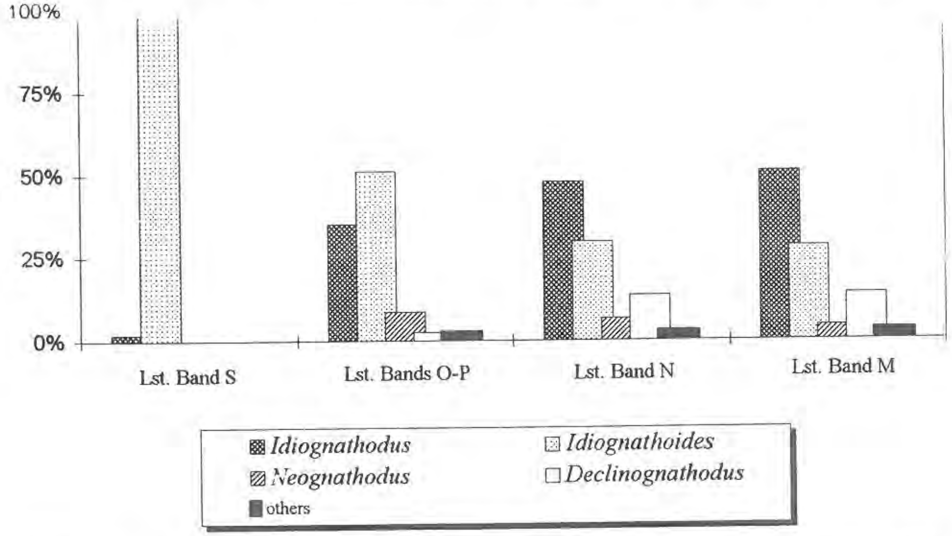


Fig. 5. Composition of the conodont assemblage in particular Limestone Bands from the Upper Carboniferous of the Lublin Carboniferous Basin

tions (*e.g.* SWADE 1985; MERRILL & VON BITTER 1976, 1984; DRIESE & *al.* 1984; MERRILL & GRAYSON 1989; REXROAD & *al.* 1996). The *Idiognathodus-Streptognathodus* plexus is characterized as eurytopic, most typical of intermediate environments between shallow, nearshore waters with variable salinity and much deeper, colder and more dysaerobic environments (SWEET 1988). Some authors have stressed that *Idiognathodus* is less tolerant of salinity and temperature changes than *Cavusgnathus* (MERRILL & GRAYSON 1989) or *Adetognathus* (DRIESE & *al.* 1984), and thus the *Idiognathodus* biofacies, which also includes *Neognathodus*, represents offshore, normal marine deposits (*cf.* similar conclusion *in*: KRUMHARDT & *al.* 1996, Fig. 10C). The environmental significance of idiognathoidids is more uncertain, but generally it corresponds to that of *Idiognathodus*. The genus is best known from low-clastic, open marine, fossiliferous limestones, but LANDING & WARDLAW (1981) drew attention to its presence in more argillaceous, delta-associated limestone lenses. DAVIES & WEBSTER (1985) proposed time-equivalency for the *Declinognathodus/Idiognathoides* biofacies (typical of the Lower Pennsylvanian) and *Idiognathodus/Streptognathodus* biofacies of the Upper Pennsylvanian. HIGGINS (1985) suggested water depth as a controlling factor of the late Namurian conodont faunas (*e.g.* proportion between *Idiognathodus* and *Idiognathoides*). Finally, BOOGAARD & BLESS (1985) tried to explain the differences in abundance of these genera by the content of argillaceous material in the deposits. According to them, *Idiognathodus* seems to be more tolerant for argillaceous substrates and thus is typical of a nearshore environment.

Neither of the latter opinions do not prove correct in the Lublin Basin. The *Dunbarella* horizon unquestionably represents more nearshore and more argillaceous conditions than Lst. Bands *M*, *N*, *O* and *P*, which are composed primarily of calcareous algae and microproblematics particles. However, the difference in depositional depth seems to be too small to produce such distinct changes in the composition of the conodont assemblage. Argillaceous material most certainly was more common in the uppermost marine band (*Dunbarella*), than in the lower units, but *Idiognathoides*, not *Idiognathodus*, is abundant in these limestone lenses. In this case, it seems to be more plausible to correlate a disappearance of idiognathodids in Lst. Band *S* with decreasing salinity or changes in temperature, as in the cases quoted by the American authors. This conclusion is supported by the macrofaunal investigations of the *Dunbarella* Bed, which is predominantly composed of shales with brackish or fresh-water bivalves or lingulid brachiopods (MUSIAŁ & TABOR 1988, 1995). The changes of salinity and/or temperature are rather more typical than unexpected features of a narrow, elongated early Westphalian sea in Europe, and this fact could cause some problems in the interpretation of the appearance and disappearance of conodont taxa in this basin.

STRATIGRAPHIC RESULTS

Viséan/Namurian boundary interval

Many conodont zonations have been proposed for the Viséan/Namurian boundary interval, but their clarity and accuracy is not as good as those achieved for the Tournaisian or Late Devonian. Generally there are two reasons of this:

(*i*). The Upper Viséan and Lower Namurian conodont fauna represents the upper part of the low diversity episode (ZIEGLER & LANE 1987), which started in post-*anchoralis* time and continued to the mid-Carboniferous Boundary;

(*ii*). The information on conodont occurrences is derived mostly from shallow-water successions, frequently interrupted by terrestrial depositional episodes, and characterized by rather low frequency of conodonts.

This disadvantage is enhanced by taxonomic problems concerning the species or subspecies classification in the genera *Gnathodus* and *Lochriea*. This has meant that the proposed zonations are either very precise, but only locally significant (*e.g.* some English schemes) or very general.

The two conodont zones: Gnathodus bilineatus Zone and Paragnathodus (=Lochriea) nodosus Zone are recognized in the discussed interval over much of the world (for review *see* PERRET & WEYANT 1994). The American zonations are however different in that they attach much more importance to the appearance of the cavusgnathodids (*cf.* LANE & STRAKA 1974, TYNAN 1980, WEBSTER 1984). The boundary between the bilineatus and nodosus Zones, as indicated by appearance of the species *Paragnathodus (=Lochriea) nodosus*, is usually regarded as isochronic, but there are data indicating diachronous nature of the appearance of the index taxon (*cf.* discussion of this problem *in*: BELKA 1982). It is however worth emphasizing that the discussed taxon is recognized worldwide, in shallow-water (*e.g.* REXROAD & HOROWITZ 1984, 1990; ARMSTRONG & PURNELL 1987) as well as in deep-water biofacies (HIGGINS & WAGNER-GENTIS 1982). More data are accumulating which point to the simultaneous appearance of *Lochriea mononodosa* and *L. nodosa* (METCALFE 1981, ARMSTRONG & PURNELL 1987, DAVIES & *al.* 1994), and thus the equivalency of the nodosa and British mononodosa Zones.

The upper boundary of the nodosa Zone *sensu lato* is distinctly less problematic. It is defined by the appearance of *Gnathodus bilineatus bol-*

landensis (=*Gn. schmidti* nom. nudum in German scheme; =*Gn. bollandensis* in this paper) and *Adetognathus unicornis*, which are coincident (at least in European regions) with the beginning of the goniatite Eumorphoceras$_2$ Zone.

Broadly defined, the nodosus Zone is relatively long-lasting, and includes a large part of the Upper Viséan (V_{3c}, upper half of Brigantian) and lowermost Namurian. It is therefore understoodable, that many authors have proposed stratigraphic schemes in which nodosa Zone is divided into more detailed units, making use of different species of *Lochriea* or subspecies of *Gnathodus girtyi*. The most far-reaching proposition is the British scheme (RHODES & *al.* 1969, HIGGINS 1975, VARKER & SEVASTOPOULO 1985) with Gnathodus girtyi collinsoni Zone in the uppermost Brigantian and the Gnathodus girtyi simplex-Kladognathus Zone in the Pendleian. The difficulties in recognition of the index subspecies (*cf.* discussion in systematic part of the present paper) mean that these Zones are practically distinguished only in Britain. Another idea is based upon changes in platform ornamentation of *Lochriea* species. The stratigraphical significance of this observations was pointed by WIRTH (1967), MEISCHNER (1970), and HIGGINS (1975), and finally was expressed by the creation of the Paragnathodus (=Lochriea) multinodosus Zone. This zone was distinguished in a formal sense in the Cantabrian Mts (HIGGINS & WAGNER-GENTIS 1982) and Moscow Basin (ALEKSEEV & KONONOVA 1993). These instances provided the impetus for a review of the species classification in the genus *Lochriea* (see NEMIROVSKAYA & *al.* 1994) and verification of the ranges of particular taxa in the most important European localities; the results are summarized by SKOMPSKI & *al.* (1995) who concluded that "*...a group of taxa with numerous nodes or ridges appears at or directly below the Viséan/Namurian (or Viséan/Serpukhovian) boundary. Among them the species L. cruciformis and L. ziegleri occur most commonly and nearest to this boundary...*". However, this conclusion is true only for shelf regions, since in more basinal environments the species appeared somewhat earlier. In consequence, the distingusihing of the cruciformis (or ziegleri) Zone is well-founded only in shallow-water shelf areas. The Lublin area, especially its platform part, from which the investigated collection has been derived, certainly represents such a region.

In the discussed interval, it is possible in practice to determine 3 zones: Lochriea nodosa, Lochriea cruciformis, and Gnathodus bollandensis zones (Text-fig. 6).

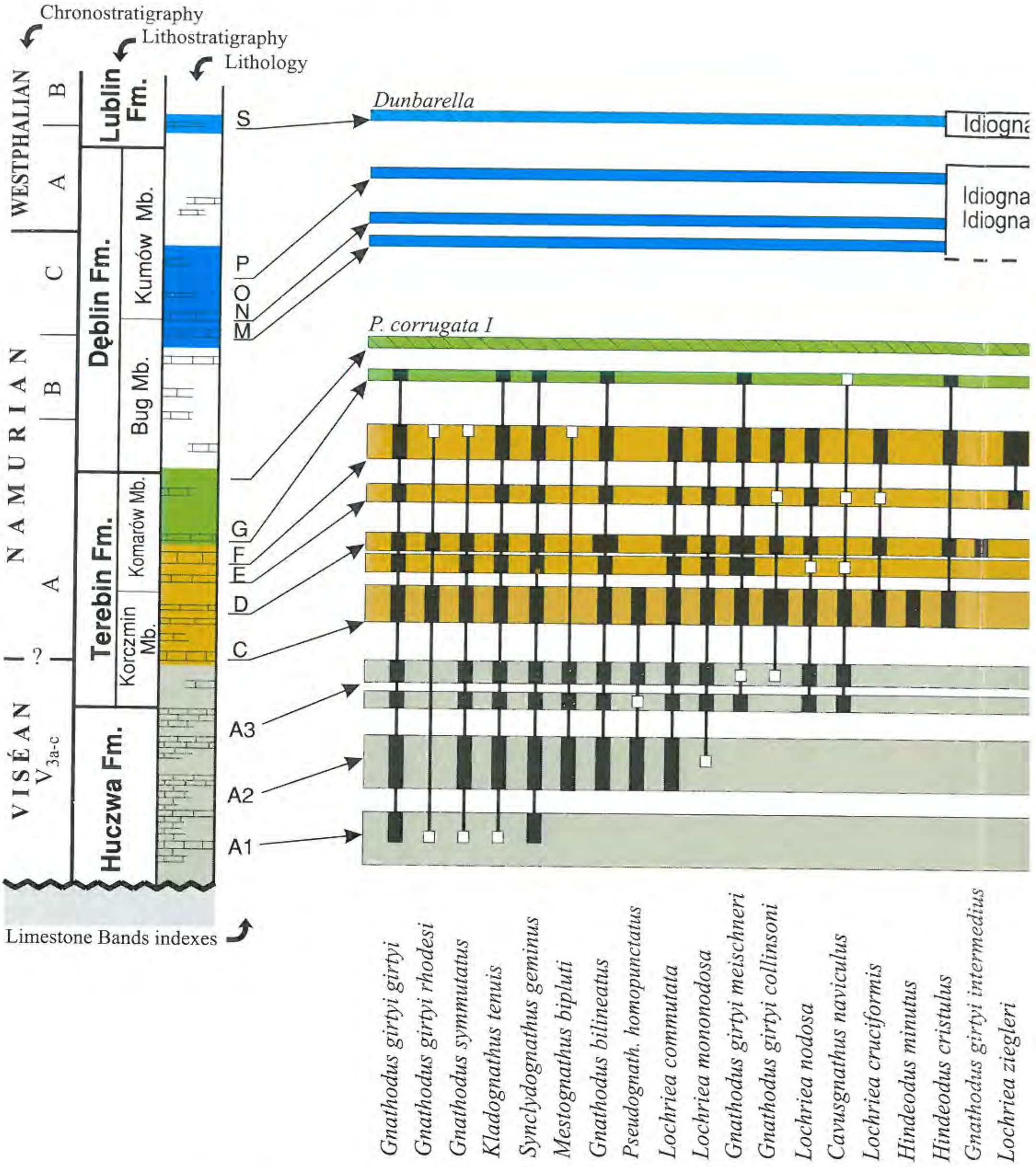
The **Lochriea nodosa Zone** is consecutive-range zone of the index taxon. The lower boundary is appearance of *L. nodosa*, the upper boundary is appearance of *L. cruciformis*. The zone is characterized by an abundance of *Gnathodus bilineatus*, *Gnathodus girtyi girtyi*, *Pseudognathodus sym-*

mutatus, *Lochriea commutata*, *Lochriea mononodosa*, *Lochriea nodosa*, *Kladognathus tenuis* and *Synclydognathus geminus*. It embraces two lower limestone complexes: *A2* - *A3* and, possibly, also *A1*. The index taxon appeared no earlier than in the complex *A3*, but *L. mononodosa* occurred in the complex *A2* (*cf.* earlier remarks on the synchroneous appearance of *L. nodosa* and *L. mononodosa*). The uncommon conodonts found in the lowermost part of the succession (complex *A1*), and the lack of *Gn. bilineatus* or *Lochriea* species almost preclude from including this level to the nodosa or bilineatus Zones. The specific feature is appearance of *Gnathodus girtyi collinsoni* (but only single specimens), *Gn. girtyi meischneri*, and *Cavusgnathus naviculus* in the uppermost one of these 3 complexes. Another feature is the appearance of *Mestognathus bipluti*, which is practically limited to this Zone, because in the higher part of the succession it is represented only by a single specimen in Lst. Band *F*.

The presence of *Gn. girtyi collinsoni* could be regarded as a basis for distinguishing the collinsoni Zone (*sensu* RHODES, AUSTIN & DRUCE 1969) and may lead to the conclusion that only the complex *A3* in the Lublin Basin represents the uppermost part of the Brigantian. However, this conclusion is based only on the appearance of single specimens in an interval of generally low frequencies, and for this reason the present Author resigned distinction of this zone in the Lublin Basin.

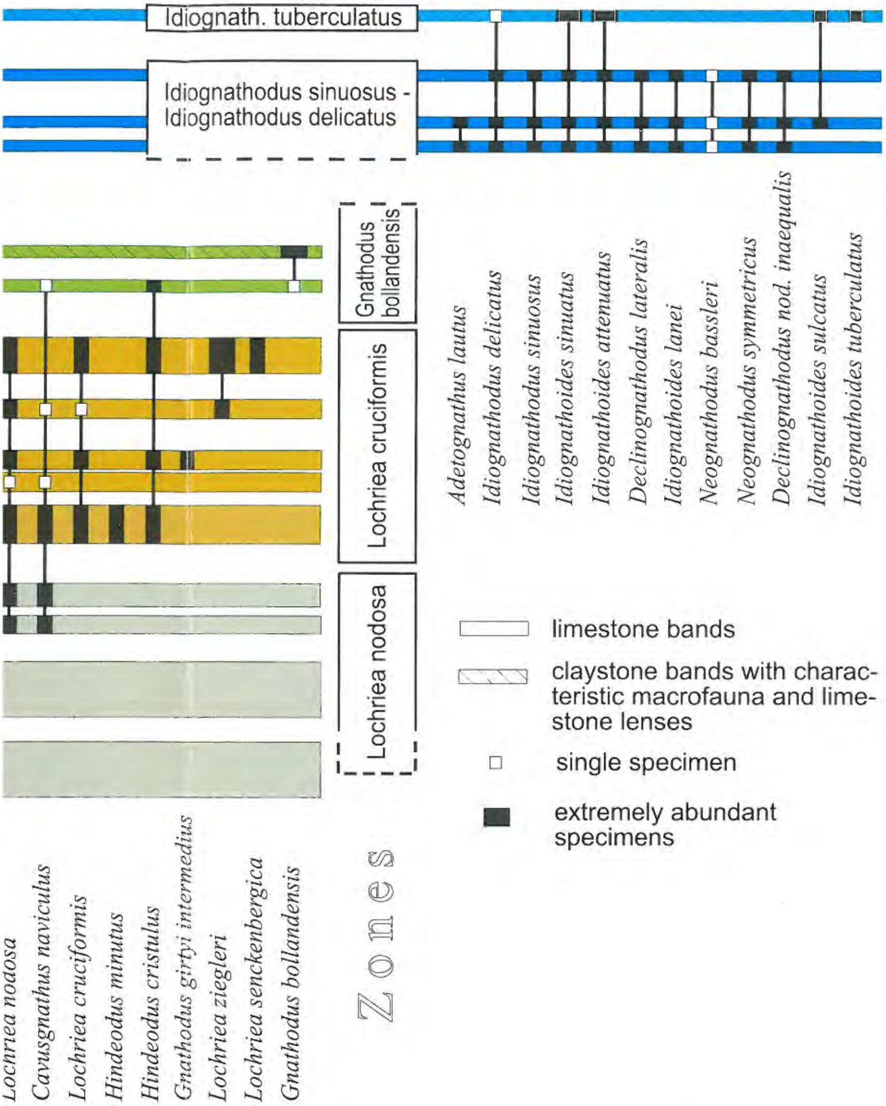
The **Lochriea cruciformis Zone** is determined by the appearance of the index taxon (the lower boundary) and is characterized by the presence of numerous species of *Lochriea* and subspecies of *Gnathodus girtyi*. It embraces Lst. Bands *C* to *F*. The upper boundary is defined as appearance of *Gnathodus bollandensis*. Also very numerous are *Gn. bilineatus* and *Synclydognathus geminus*. In the upper part of the Zone (Lst. Bands *E* and *F*) the species *Lochriea ziegleri*, *Lochriea senckenbergica* and *Gnathodus girtyi intermedius* appear. Generally, it corresponds to the Russian *Paragnathodus multinodosus* Zone (*sensu* ALEKSEEV & KONONOVA 1983) and to the English *Kladognathus-Gn. girtyi simplex* Zone, and in this latter form it was introduced in the preliminary report from the Lublin Basin (SKOMPSKI & *al.* 1989). Doubts concerning the recognition of the subspecies *Gn. girtyi simplex* (*cf.* systematic description of the subspecies *Gn. g. meischneri*) persuaded the Author not to distinguish the simplex Zone in the present report.

The **Gnathodus bollandensis Zone** is easily identified by the presence of *Gnathodus bollandensis*, which occurs in the Lst. Band *G* and in *corrugata I* correlation horizon. The Lst. Band *G* assemblage is dominated by *Gn. girtyi meischneri*; in the claystones of the *corrugata I* horizon the assemblage is monospecific, probably resulting from specific changes



Distribution of conodonts in the Lower and Upper Carbonifero

Lithostratigraphic and chronostratigraphic column *after* PORZYCKI & ŻELICHOWSKI (*in*:
MUSIAŁ & *al*. (1995) and other parts of the 1995 volume "The Carboniferous syste



per Carboniferous of the Lublin Carboniferous Basin

& ŻELICHOWSKI (*in*: PORZYCKI 1979), PORZYCKI & ZDANOWSKI (1995),
le Carboniferous system in Poland" (ZDANOWSKI & ŻAKOWA 1995)

in the sedimentary environment (*e.g.* decrease of salinity). A characteristic feature of the Zone is the total lack of *Lochriea* specimens, which were so abundant in the lower part of the section. The absence of the genus *Adetognathus*, which occurred in the upper part of this Zone in the Moscow, Dneper-Donets, as well as in the English basins, indicates that only the lower part of this broadly recognized Zone is documented by conodonts in the Lublin Basin.

Namurian/Westphalian boundary interval

Stratigraphic interpretation of the younger assemblage is difficult, due mainly to taxonomical divergences in the understanding of the Upper Carboniferous species, characterized in the systematic part of this paper. The secondary reason is a lack of universal zonation, what makes not only an intercontinental correlation difficult, but also creates problems when comparing ranges in basins situated even on the same platform, as for example the Moscow and Donets Basins (*cf.* NEMIROVSKAYA & ALEKSEEV 1995). Nevertheless, some general conclusions are possible.

The most characteristic feature of the conodont fauna from the Lst. Bands *M-P* is the presence of the two species of the genus *Idiognathodus*, *I. sinuosus* and *I. delicatus*, together with different idiognathoidids. This makes possible to refer all these samples to a broadly defined Idiognathodus sinuosus - Idiognathodus delicatus Zone, described originally from China by WANG & *al.* (1987), but recognized also in other regions (Idiognathoides sinuatus - Idiognathodus primulus Zone established in Great Britain by HIGGINS 1975, 1985; I. sinuosus and I. klapperi Zone in North America - LANE 1977; I. sinuosus and Streptognathodus expansus - S. suberectus Zone in the Dneper-Donets Basin, I. sinuosus and Declinognathodus marginodosus Zone in the Bashkirian Mountains - NEMIROVSKAYA & ALEKSEEV 1995; for other references *see* PERRET & WEYANT 1994). More problematic is the estimation of the chronostratigraphic position of the boundaries of this zone, even when comparing only European sections. The problems with the discrimination of the two species of the genus *Idiognathodus* mentioned above results in the ranges being differently presented. In Great Britain the species *I. delicatus* s.l. appears as the single specimens in the Marsdenian, but more significant occurrences are known from Yeadonian (G_1 in the goniatite zonation). In Germany *Idiognathodus fiebigi* (nomen nudum in MEISCHNER, 1970, but without doubt corresponding to *I. delicatus* s.l.) appears in the beginning of the Westphalian (G_2 in the goniatite zonation). In the Donets Basin *I. delicatus* and *I. sinuosus* are concurrent as early as the Prikamsky Horizon, which is correlated also with the Yeadonian (WINKLER PRINS 1990). The appearance of neognathodid species in the assemblage investigated does not facilitate further stratigraphic interpretation. The concurrent appearance of *Neognathodus bothrops* and *N. symmetricus* indicates generally the upper part of the Bashkirian, below the tuberculata Zone. Generally similar is the upper boundary of the *Neognathodus* range in Great Britain (up to the end of Yeadonian), but the genus is relatively scarce, and its species taxonomy is still an open question (HIGGINS 1975, 1985).

Thus it seems that Lst. Bands *M-P*, with very rich and diverse assemblages of idiognathodids, represent Upper Namurian strata, not older than Namurian *C*, and are equivalent of Gastrioceras$_1$ in the goniatite zonation. This conclusion is to some extent inconsistent with stratigraphic results based upon the macrofauna (MUSIAŁ & TABOR 1988, 1995). According to these authors the horizons below Lst. Band *N* are included in Namurian *B*, but this conclusion is not supported by goniatites, which appeared just above Lst. Band *N* and indicate G$_1$ Zone age. In the light of the conodont data, the boundary N$_B$/N$_C$ should be lowered to below Lst. Band *M*. A similar opinion has been formulated on the basis of palynological analysis: according to KMIECIK (1988, 1995), the Reticulatisporites carnosus Zone, corresponding to the Namurian *B*, reaches at most the base of the coal bed located beneath Lst. Band *M*. The stratigraphic diagnosis based on foraminifers shifts the boundary N$_B$/N$_C$ even further down. SOBOŃ-PODGÓRSKA (*e.g.* 1988) identified in the Lst. Band *L* an assemblage typical of the Zone 20 (according to the zonation proposed by MAMET & SKIPP 1970) and correlated this Zone with the beginning of Namurian *C*. Although it is difficult to question the identification of the Zone, correlation with the chronostratigraphic interval is very problematic. GROVES (1988) presented instructive example in which he provided two different correlations of the Bashkirian stratotype section from the Askyn river (southern Urals). The Zone 20 distinguished here by Russian authors corresponds to the Namurian *B* (AIZENVERG & *al.* 1979) or Namurian *C* (SEMIKHATOVA & *al.* 1979). It seems that differences in foraminifer assemblages from America and Old World could create difficulties in the worldwide application of the upper Carboniferous part of the zonation proposed by MAMET & SKIPP (1970).

The *Dunbarella* marker horizon, the uppermost bed with conodonts in the succession, represents the Idiognathoides tuberculatus Zone, informally introduced by BARSKOV & *al.* (1987, p. 140) and NEMIROVSKAYA (1990 *and* NEMIROVSKAYA *in*: WINKLER-PRINS 1990). It is easily recognized due to the presence of the rarely found *Idiognathoides tuberculatus*, known mainly from the Vereisky Horizon from the Moscow Basin, which is included by Russian authors into the Bashkirian (BARSKOV & *al.* 1980, 1984) or to the Moscovian (GOREVA

1984). A Moscovian position for the Vereiskian Stage is also proposed by COWIE & BASSETT (1989), who presented the official opinion of IUGS Commission of Stratigraphy, and by WAGNER & WINKLER PRINS (1994a, b). The Neognathodus atokaensis Zone defined by NEMIROVSKAYA & ALEKSEEV (1995) in the stratotype section of the Bashkirian could be regarded as an equivalent of the Vereisky horizon, and the Bashkirian/Moscovian boundary is placed by these authors in the middle of this zone (according to foraminifers). However, the distribution of idiognathoidids was strongly controlled ecologically and the new data presented by NEMIROVSKAYA (*in press*) from the Donets Basin indicate earlier appearance of *Id. tuberculatus,* in comparison to the Moscow Basin. The chronostratigraphic position of the Id. tuberculatus Zone in the western European subdivisions of the Upper Carboniferous could be only indirectly estimated, considering an absence of the index species in those sections. The macrofaunistic and palynological data from the Lublin Carboniferous Basin, mainly the poorly preserved goniatites from the genus *Anthracoceras* (see MUSIAŁ & TABOR 1988, 1995) point to a correlation of the *Dunbarella* marker horizon with the Katharina Marine Band in the Ruhr Basin, and with the Clay Cross Marine Band in Great Britain, which is accepted as the boundary between Westphalian *A* and *B*. This position of the tuberculatus Zone is also proposed by NEMIROVSKAYA (*in press*). Consequently, the correlation of the Vereisky horizon with upper part of the Langsettian (= Westphalian *A*) proposed by WAGNER & WINKLER PRINS (1994a, b) is incorrect, and correlation of this horizon with Westphalian *C* (as suggested by NEMIROVSKAYA, *in press*) is more probable.

SYSTEMATIC ACCOUNT OF CONODONTS

Upper Carboniferous conodont taxonomy has still lagged far behind the knowledge of conodonts in other periods. For this reason the present Author decided to provide short descriptions and/or remarks and photographic illustrations for these taxa (in alphabetic order) which either have never been described from Polish sections (Upper Carboniferous taxa), or whose understanding by different authors is still extremely questionable (as the *Gnathodus girtyi* subspecies). Synonymies are usually selected, confined to the original references and recently published works, which usually include complete older reports. The occurrences are limited to the regions, which are developed in the comparable paleogeographic regime, *i.e.* marginal and epicontinental seas of the Laurussian Continent, from the eastern margin of the East European Platform, through the Ukraine to Great Britain and Ireland in the west.

Genus *Adetognathus* LANE, 1967

Adetognathus lautus (GUNNELL, 1933)

(Pl. 9, Figs 1-2)

1933. *Cavusgnathus lautus* sp.n.; F.H. GUNNELL, p. 286, Pl. 31, Figs 67-68, and Pl. 33, Fig. 9.

1967. *Adetognathus lauta* (GUNNELL); R.H. LANE, p. 933, Pl. 121, Figs 1-3, 7, 10-11, 15, 17.

1974. *Adetognathus lautus* (GUNNELL); R.H. LANE & J.J. STRAKA, p. 64, Fig. 36/17, 21-22, 25-31; Fig. 38/1-4, 6-8, 10-15, 20, and Fig. 39/1-3, 7-14.

1975. *Adetognathus gigantus* (GUNNELL); A.C. HIGGINS, p. 26, Pl. 8, Figs 6-7, 9, 11.

1978. *Adetognathus gigantus* (GUNNELL); R.I. KOZITSKAYA & *al.*, pp. 15-16, Pl. 15, Figs 3-4.

1980. *Adetognathus lautus* (GUNNELL); K.P. BENDER, pp. 8-9, Pl. 4, Figs 26-33.

1980. *Adetognathus lautus* (GUNNELL); M.CH. TYNAN, pp. 1298-1299, Pl. 2, Figs 12-13, 20-22.

1984. *Adetognathus gigantus* (GUNNELL); N.V. GOREVA, Pl. 1, Figs 1-5.

1985. *Adetognathus lautus* (GUNNELL); C.B. REXROAD & G.K. MERRILL, Pl. 2, Figs 5-6, 28-39; Pl. 3, Figs 26-28; and Pl. 4, Figs 22-25.

1987. *Adetognathus gigantus* (GUNNELL); T.I. NEMIROVSKAYA, Pl. 1, Fig. 3.

1987. *Adetognathus lautus* (GUNNELL); T.I. NEMIROVSKAYA, Pl. 1, Figs 2, 5, 8.

1989. *Adetognathus gigantus* (GUNNELL); S. SKOMPSKI & *al.*, Pl. 4, Fig. 7.

1990. *Adetognathus gigantus* (GUNNELL); T.I. NEMIROVSKAYA & *al.*, Pl. 3, Figs 20-24.

1994. *Adetognathus gigantus* (GUNNELL); T.I. NEMIROVSKAYA & A.S. ALEKSEEV, Pl. 2, Fig. 11.

1994. *Adetognathus lautus* (GUNNELL); T.I. NEMIROVSKAYA & A.S. ALEKSEEV, Pl. 2, Fig. 6.

For older synonymy *see* LANE & STRAKA (1974) and TYNAN (1980).

MATERIAL: 3 specimens.

REMARKS: In common with other European localities this species (and genus) is extremely rare in the Lublin Carboniferous Basin. The specimens are badly preserved, with partly broken free blades, which are long enough to indicate that they belong to the genus *Adetognathus* and to distinguish them from other cavusgnathodids. Despite the small number of specimens, both sinistral and dextral elements are present. In left-sided elements the blade rises in height anteriorly; in the right-sided one it is characterized by abnormally large denticle at the posterior end. The specimens exactly correspond with descriptions of *A. lautus* (GUNNELL) and *A. gigantus* (GUNNELL), resepectively. LANE (1968) suggested symmetry (class IIIb) for these two species and, in consequence in LANE & STRAKA (1974) the species *A. gigantus* was included in *A. lautus*, which is considered to be the type species of the genus. In the present paper this concept is fully accepted, although in the literature the previous meaning of *A. lautus* and *A. gigantus* is still used (*e.g.* GOREVA 1984, NEMIROVSKAYA & ALEKSEEV 1994).

OCCURRENCE: Lublin Carboniferous Basin - Bug Mb. and Kumów Mb. of the Dęblin Fm. (Lst. Bands *M-N*); Great Britain - uppermost Arnsbergian-Chokierian; Dneper-Donets Basin - uppermost Serpukhovian to the lower Moscovian; Moscov Basin - Moscovian; Bashkirian Mts - Bashkirian except uppermost horizon (Asatausky H.).

Genus *Declinognathodus* DUNN, 1966

REMARKS: The genus *Declinognathodus* is considered to be the transitional member in the phylogenetic series leading from the Lower

Carboniferous forms of *Gnathodus bilineatus* or *Gnathodus girtyi girtyi* to the Upper Carboniferous *Idiognathodus* and *Streptognathodus*. From the stratigraphic point of view it is one of the most important taxa, since its appearance determines the mid-Carboniferous boundary. An intricate history of separation of this genus from *Idiognathoides* and *Streptognathodus* has been exhaustively presented by DUNN (1966, 1970), AUSTIN (1972), and HIGGINS (1975), and the present taxonomical status of the genus seems to be stable. However, the discrimination of species is still debatable. The most detailed species concept was proposed by HIGGINS (1975, 1985) who distinguished the two species: *Declinognathodus lateralis* and *D. noduliferus*, but both species have been primarily assigned to different genera, respectively to *Streptognathodus* and *Idiognathoides*. In the paper of 1985 HIGGINS included corrections relative to generic affiliation. He distingushed within the species *D. noduliferus* the three subspecies: *D. noduliferus noduliferus, D. n. inaequalis*, and *D. n. japonicus*. Their type specimens are so different and unequivocally determined, that some authors regarded them even as separate species (RILEY & *al.* 1987, VARKER 1990, NEMIROVSKAYA & *al.* 1990; *cf. also* NEMIROVSKAYA 1990). The opposite opinion was presented by GRAYSON & *al.* (1985, 1990) who combined *D. lateralis* and *D. noduliferus* into one species – *"D." noduliferus*, and included within this genus another species, *D. marginodosus,* which was originally recognized as *Idiognathoides*. The GRAYSON's hypothesis was based on the illustrations given by AUSTIN (1972), who showed a complete morphologic transition series from *Idiognathoides noduliferus* to *Streptognathodus lateralis*. However, the most persuasive series presented by AUSTIN (1972, Pl. 1, Figs 1-9 and 11-59) comes from the Homoceras goniatite Zone, *i.e.* from the initial stage of speciation in this genus. In younger deposits, corresponding with the Reticuloceras Zone, the subspecies are distinctly separated, and finally one of them (*D. n. inaequalis*) disappeared earlier than others (HIGGINS 1975, 1985; NEMIROVSKAYA 1987). The problem of the distinction between *D. lateralis* , *D. noduliferus noduliferus* and *D. marginodosus* probably gave rise to the essential differences in the estimation of the disappearance of *D. lateralis*, observable generally between eastern and western Europe (*see* occurrence of *D. lateralis*).

The specimens from the Lublin Carboniferous Basin were derived from the horizons evidently younger than the Homoceras Zone and, according to expectations, there is a distinct difference between species and subspecies of the genus. Consequently, in the description outlined below the present Author has agreed with the species concept proposed by HIGGINS (1975).

Declinognathodus lateralis (HIGGINS & BOUCKAERT, 1968)
(Pl. 8, Figs 9-13)

Selected synonymy:

1968. *Streptognathodus lateralis* sp.n.; A.C. HIGGINS & J. BOUCKAERT, pp. 45-46, Pl. 5, Figs 1-4, 7.

1970. *Declinognathodus lateralis* HIGGINS & BOUCKAERT; D.L. DUNN, p. 330, Pl. 62, Figs 5-7, Text-fig. 9e.

1974. *Idiognathoides noduliferus* (ELLISON & GRAVES); H.R. LANE & J.J. STRAKA, pp. 85-86, Pl. 35, Fig. 7.

1975. *Streptognathodus lateralis* HIGGINS & BOUCKAERT; A.C. HIGGINS, pp. 73-74, Pl. 12, Fig. 8, and Pl. 17, Figs 10-11, 13-14.

1978. *Declinognathodus lateralis* (HIGGINS & BOUCKAERT); R.I. KOZITSKAYA & *al.*, pp. 29-30, Pl. 15, Figs 5-6, 8.

1983. *Declinognathodus lateralis* (HIGGINS & BOUCKAERT); T.I. NEMIROVSKAYA, Pl. 1, Figs 24-25, 30, 32.

1985. *Declinognathodus lateralis* (HIGGINS & BOUCKAERT); A.C. HIGGINS, Pl. 6.3, Figs 3, 5, 8.

1985. *Declinognathodus noduliferus* (ELLISON & GRAVES); R.C. GRAYSON & *al. (partim)*, pp. 163-165, Pl. 1, Fig. 6?.

1987. *Declinognathodus lateralis* (HIGGINS & BOUCKAERT); T.I. NEMIROVSKAYA, Pl. 1, Figs 17-18, 22-24.

1989. *Declinognathodus lateralis* (HIGGINS); S. SKOMPSKI & *al.*, Pl. 5, Figs 3-6.

1990. *"Declinognathodus" noduliferus* (ELLISON & GRAVES); R.C. GRAYSON & *al. (partim)*, pp. 363-364.

1990. *Declinognathodus lateralis* (HIGGINS & BOUCKAERT); T.I. NEMIROVSKAYA & *al.*, Pl. 4, Figs 19, 23, 25-27.

1995. *Declinognathodus lateralis* (HIGGINS & BOUCKAERT); T.I. NEMIROVSKAYA & A.S. ALEKSEEV, Pl. 1, Figs 5-6, 8.

MATERIAL: 32 specimens.

REMARKS: A diagnostic feature of the species is the abrupt fusion of the median carina with one of the ridged parapets. They fuse together to form the row of broad, transverse ridges, which continues to the posterior part of the platform. The diversity of specimens is based mainly on the variable length of the carina. In the specimens from the Lublin Carboniferous Basin it is usually shorter than in the original descriptions and attains one third of the length of the platform.

OCCURRENCE: Lublin Carboniferous Basin - Bug Mb. and Kumów Mb. of the Dęblin Fm. (Lst. Bands *M-P*, more frequent in the Lst. Band *M*); Great Britain - Chokierian to lower Westphalian; Belgium - Namurian to lower Westphalian (H_2 to G_2 goniatite zones); Dneper-Donets Basin - uppermost Serpukhovian to lower Bashkirian; Baskirian Mts - lower Bashkirian.

Declinognathodus noduliferus inaequalis (HIGGINS, 1975)
(Pl. 8, Figs 14-15)

Selected synonymy:

1975. *Idiognathoides noduliferus inaequalis* subsp.n.; A.C. HIGGINS, p. 53, Pl. 12, Figs 1-7, 12; Pl. 14, Figs 11-13, and Pl. 15, Figs 10, 14.

1980. *Idiognathoides noduliferus inaequalis* HIGGINS; I. METCALFE, p. 306, Pl. 38, Fig. 10 (*only*).

1983. *Declinognathodus noduliferus inaequalis* (HIGGINS); T.I. NEMIROVSKAYA, Pl. 1, Figs 26-27.

1985. *Declinognathodus noduliferus inaequalis* (HIGGINS); A.C. HIGGINS, Pl. 6.2, Figs 11-12 and 14.

1985. *Declinognathodus noduliferus* (ELLISON & GRAVES); R.C. GRAYSON & *al. (partim)*, pp. 163-165, Pl. 1, Figs 1, 5, 10.

1987. *Declinognathodus inaequalis* (HIGGINS); N.J. RILEY & *al.*, Pl. 3, Figs 28-40.

1987. *Declinognathodus noduliferus inaequalis* (HIGGINS); T.I. NEMIROVSKAYA, Pl. 1, Figs 6, 10 and 13-14.

1987. *Idiognathoides noduliferus inaequalis* (HIGGINS); Z.H. WANG & *al.*, pp. 126-127, Pl. 3, Figs 1-2, and Pl. 6, Fig. 10.

1990. *Declinognathodus noduliferus inaequalis* (HIGGINS); T.I. NEMIROVSKAYA & *al.*, Pl. 4, Figs 3-18, 20-22, 24, and 28.

MATERIAL: 77 specimens.

REMARKS: The species displays of the carina which in the posterior part is symmetricaly located, and anteriorly is deflected to the outer parapet and merged to the posterior end. Some specimens have a similar arrangement of parapets to the *Gnathodus girtyi* subspecies. However the outline of the parapets in *Gn. girtyi* is usually straight, while in the specimens of *D. nod. inaequalis* from the described collection it is more arcuate. Although some authors use the name *D. noduliferus inaequalis* as equivalent to *D. inaequalis* (*comp.* text and explanations of plates *in*: Nemirovskaya *& al.* 1990), in the present Author's opinion this change of the status of subspecies *inaequalis* needs a more detailed analysis of rich and stratigraphically broad assemblages from the *D. noduliferus* group.

OCCURRENCE: Lublin Carboniferous Basin - Bug Mb. and Kumów Mb. of the Dęblin Fm. (Lst. Bands *M-P*); Great Britain - Chokierian to Kinderscoutian (H_1 to R_1 goniatite zones); Dneper-Donetz Basin – upper Serpukhovian to lower Bashkirian (D_5 to E_6 limestone horizons, equivalent of Homoceras - Reticuloceras Zone).

Genus *Gnathodus* Pander, 1856

Gnathodus bollandensis (Higgins & Bouckaert, 1968)

(Pl. 6, Figs 1-13)

1968. *Gnathodus bilineatus bollandensis* subsp.n.; A.C. Higgins & J. Bouckaert, pp. 29-30, Pl. 2, Figs 10, 13, and Pl. 3, Figs 4-8, 10.

1974. *Gnathodus bilineatus* morphotype *a* ; H.R. Lane & J.J. Straka, p. 73, Pl. 33, Figs 12, 25, 30 *(only)*.

1975. *Gnathodus bilineatus bollandensis* Higgins & Bouckaert; A.C. Higgins, p. 29, Pl. 11, Figs 5, 8-13.

1977. *Gnathodus bilineatus bollandensis* Higgins & Bouckaert; F. Ebner, p. 467, Pl. 3, Figs 5-9 and Pl. 6, Fig. 10.

1978. *Gnathodus bilineatus bollandensis* Higgins & Bouckaert; R.I. Kozitskaya *& al.*, pp. 34-35, Pl. 14, Figs 4-5, ?6.

1981. *Gnathodus bilineatus bollandensis* Higgins & Bouckaert; Z. Va_íek, pp. 169-170, Pl. 1, Fig. 3, and Pl. 2, Figs 1-2.

1983. *Gnathodus bilineatus bollandensis* Higgins & Bouckaert; T.I. Nemirovskaya, Pl. 1, Figs 21, 23.

1984. *Dryphenothus bilineatus bollandensis* Higgins & Bouckaert; A.S. Alekseev *& al.*, Pl. 1, Figs 16-19.

1985. *Gnathodus bilineatus bollandensis* (Higgins & Bouckaert); M. Weyant & D. Massa, p. 90, Pl. 1, Fig. 2.

1985. *Gnathodus bilineatus bollandensis* Higgins & Bouckaert; A.C. Higgins, Pl. 6.1, Figs 4-5.

1987. *Gnathodus bilineatus bollandensis* (Higgins & Bouckaert); Z.H. Wang *& al.*, p. 128, Pl. 1, Figs 7-10.

1990. *Gnathodus bilineatus bollandensis* Higgins & Bouckaert; T.I. Nemirovskaya *& al.*, Pl. 3, Figs 1, 5, 8, 10-12, 14, 16-17.

1992. *Gnathodus postbilineatues* sp.n.; I.M. Nigmadganov & T.I. Nemirovskaya, p. 54, Pl. 8, Figs 2-7.

1993. *Gnathodus bollandensis* (Higgins & Bouckaert); A.S. Alekseev & L.I. Kononova, Tab. 8.

1993. *Gnathodus bilineatus bollandensis* Higgins & Bouckaert; T.I. Nemirovskaya & I.M. Nigmadganov, Pl. 2, Fig. 1.

MATERIAL: 314 specimens.

DESCRIPTION: The consistent features of this species are the triangular to rectangular or semi-ovate outer platform, narrow carina expanded in the posterior segment and specific, diversed ornamentation of the outer platform. Most frequently the ornamentation is reduced to just several nodes and in extreme cases the platform can be completely smooth (Pl. 6, Figs 1, 3). When the randomly scattered nodes are more numerous they are concentrated in the anterior half of the outer platform (Pl. 6, Figs 6-7). The blade is long and composed of fused nodes. The carina consists of nodes in its anterior part and is expanded to transverse ridges in the middle and posterior part. In a few extreme variants a row of small nodes is fused to the carina at the posterior end of platform (Pl. 6, Fig. 10). The parapet is transversely ridged and broadened in its middle part, and narrowed, nodular at its ends. Usually it does not reach the margin of the platform and is separated from the carina by a distinct trough.

REMARKS: The studied specimens comprise a group characterized by a wide range of morphologic variations and generally corresponding with the subspecies *Gnathodus bilineatus bollandensis* HIGGINS & BOUCKAERT. However, the level of dissimilarity of *Gn. bilineatus bollandensis* to the second subspecies *Gn. bilineatus bilineatus* (ROUNDY) is relatively large and comparable with (or even greater than) differences between other species of this gnathodontoid line (*e.g. Gn. delicatus* BRANSON & MEHL, *Gn. praebilineatus* BEŁKA and new species introduced by NEMIROVSKAYA & NIGMADGANOV, 1993: *Gn. aisenvergi, dieteri, raisae* and *einori*). For this reason the present Author postulates a rise in the systematic status of the taxon and treatment of *Gnathodus bollandensis* as a species. In this context it thought to be incorrect to consider *Gn. bilineatus bilineatus* and *Gn. bilineatus bollandensis* only as morphotypes of one species, as proposed by GRAYSON & *al.* (1985, 1990).

The proposal to distinguish these taxa as separated species, was also expressed by NIGMADGANOV & NEMIROVSKAYA (1992). They established a new species *Gnathodus postbilineatus*, characterized by the carina expanded in the posterior part (due to fusion with the parapet) and irregular ornamentation of the sub-oval outer platform. However, their illustrations show fusion of the parapet expanded carina only in the case of one specimen (Pl. VIII, Fig. 2), while in the other specimens illustrated by these authors (Pl. VIII, Figs 3-7), the parapet is shorter than the carina and declines in the posterior part. A similar development of carina and parapet is also observable in the specimens of *Gn. bilineatus bollandensis* illustrated by HIGGINS & BOUCKAERT (1968) and HIGGINS (1975). It also seems that variation of platform ornamentation in *Gn. postbilineatus* (*comp.* extremely narrow platforms illustrated by VARKER & *al.* 1990, and broad carinas *in*: HIGGINS 1975) could be included as intraspecific variability of *Gn. bollandensis* and therefore the former taxon could be considered as a synonym of the latter.

OCCURRENCE: Lublin Carboniferous Basin - upper part of the Terebin Fm. (Lst. Band *G* and carbonate nodules in *P. corrugata I* marker horizon); Belgium - E_{2b2}-H_1 goniatite zones; Great Britain - Arnsbergian (E_2 goniatite zones except its uppermost part); Donets Basin - upper Serpukhovian ($C_1{}^n{}_b$-$C_1{}^n{}_d$ up to limestone horizon $D_5{}^7$).

Gnathodus girtyi HASS, 1953

REMARKS: The species *Gnathodus girtyi* HASS is not only abundant in many European and North American sections of the late Viséan and early Namurian age, but it also appears relatively independent of facies. For this reason for a long time it provoked the interest of biostratigraphers - the species has a long range, but it seems that ranges of particular subspecies are radically shorter and could be treated as stratigraphic indicators. However, the diversity of meaning and the general subtlety of subspecies taxonomy involve difficulties in the stratigraphical usage of these taxa.

The most important attempt at taxonomic unification was undertaken by HIGGINS (1975), who based two zones (uppermost zone of the Viséan and lowermost zone of the Namurian) on the range of particular subspecies of *Gnathodus girtyi* (*Gn. g. collinsoni, Gn. g. simplex*). However, the succeeding papers diverged from this proposition in some details. TYNAN (1980) expressed the opinion that *G. girtyi collinsoni* RHODES, AUSTIN & DRUCE is practically indistinguishable from juvenile specimens of *G. girtyi girtyi*.

METCALFE (1981) postulated the necessity for detailed biometric studies in order to identify subspecies. GRAYSON & *al.* (1990) suggested that *G. girtyi simplex* DUNN, *G. girtyi girtyi* HASS and *G. g. intermedius* GLOBENSKY were ontogenetic stages. On the other hand these reservations have not hindered the creation of new subspecies, *G. girtyi maxwelli* by JENKINS & *al.* (1993).

In the Lublin Carboniferous Basin the species is represented by 466 specimens, classified into 5 subspecies, which are relatively distinctly separated, in spite of the great intraspecific diversity, stressed in numerous papers. It should be noticed here, that VARKER (1964, *unpubl.*) for example was able to distinguish 24 morphotypes of the species in very rich collection from the Yoredale series. From among 5 subspecies distinguished in the present paper, 4 of them precisely correspond with HIGGIN's descriptions. *Gnathodus girtyi girtyi* is most common in the collection (nearly 80% of all *Gnathodus girtyi* specimens) and is characterized by well-developed marginal parapets, noded in the posterior part of the platform and sometimes fused to the carina (Pl. 1, Figs 8-9). Much less common is *G. girtyi collinsoni* (36 specimens), which is devoid of an outer parapet and which has an inner parapet restricted to the anterior part of the platform (Pl. 1, Figs 1-3). *G. girtyi intermedius* appeared in the upper part of the Viséan section (5 specimens). Its both parapets are joined in the posterior part and surround the nodes of carina. The remaining 62 specimens have been included to 2 very similar subspecies, *G. girtyi rhodesi* HIGGINS and *G. girtyi meischneri* AUSTIN & HUSRI. These taxa are sometimes incorrectly identified, therefore the present Author provides here a more detailed descriptions of the specimens.

Gnathodus girtyi meischneri AUSTIN & HUSRI, 1974
(Pl. 1, Figs 4-7 and Pl. 2, Figs 1-2)

Selected synonymy:

1968. *Gnathodus girtyi* sp.n.; A.C. HIGGINS & J. BOUCKAERT; p. 32, Pl. 5, Fig. 12.

1969. *Gnathodus girtyi simplex* DUNN; F.H.T. RHODES & *al.*, p. 100, Pl. 16, Fig.1a-4d.

1969. *Gnathodus girtyi collinsoni* sp.n.; F.H.T. RHODES & *al.* (*partim*), pp. 99-100, Pl. 16, Fig. 7 (*only*).

1974. *Gnathodus girtyi meischneri* sp.n.; R.C. AUSTIN & S. HUSRI, pp. 53-54, Pl. 2, Figs 1-3, 6, and Pl. 9, Fig. 3.

1993. *Gnathodus girtyi meischneri* AUSTIN & HUSRI; M.F. PERRET, Pl. 105, Figs 28, 35.

For more complete older synonymy see: AUSTIN & HUSRI (1974)

MATERIAL: 55 specimens.

DESCRIPTION: The specimens are characterized by two parapets, developed to a different degree. Lateral ornamentation does not extend to the posterior end of the carina, and the parapets are confined to the medial and anterior parts of the platform. The outer parapet is significantly lower and shorter than inner. It is usually developed in the form of a short, narrow ridge, parallel to the carina. Inner parapet is as high as the carina and transversely ridged.

REMARKS: This subspecies, defined by AUSTIN & HUSRI (1974) on the basis of a very rich collection from Ireland (1135 specimens), infills a gap in the classification scheme proposed by HIGGINS (1975), and stresses differentiation of parapets in height and form. It is similar to *Gnathodus girtyi rhodesi*, but differs in the position of the outer parapet. Sometimes it could be erroneously identified as *G. girtyi simplex* or *G. girtyi collinsoni*, but it differs in the presence and form of the outer parapet, which is substituted by nodes only. This similarity created errors in preliminary reports on the conodonts from the Lublin Carboniferous Basin (SKOMPSKI & *al.* 1989, SKOMPSKI 1992), where the specimens of *G. g. meischneri* were included in *G. girtyi simplex* (the specimens were not illustrated). This earlier conclusion was partly induced by a very different understanding of the latter taxon in the European literature (*cf.* RHODES & *al.*1969 and remarks on this subject by TYNAN 1990). It should be emphasized that correct identification of this subspecies and other similar forms practically needs SEM observations.

OCCURRENCE: Lublin Carboniferous Basin - single specimens in the upper part of the Huczwa Fm., most abundant in the lower part of the Terebin Fm. (Lst. Bands *C* to *G*); Ireland - upper Viséan Zones: Gnathodus nodosus and G. g. collinsoni; however, in the collinsoni Zone, it is associated with *G. girtyi soniae*, which in Pennines region in England is characteristic only of lower Namurian strata (*cf.* HIGGINS 1975).

Gnathodus girtyi rhodesi HIGGINS, 1975
(Pl. 2, Figs 7-8)

1968. *Gnathodus girtyi* subsp. nov.; A.C. HIGGINS & J. BOUCKAERT, p. 32, Pl. 5, Fig. 12.
1969. *Gnathodus girtyi simplex* DUNN; F.H.T. RHODES & *al.*, pp. 100-101, Pl. 16, Figs 1-3 (*only*).
1975. *Gnathodus girtyi rhodesi* subsp. nov.; A.C. HIGGINS, pp. 32-33, Pl. 10, Figs 3, 4(?)
1980. *Gnathodus girtyi rhodesi* HIGGINS; I. METCALFE, p. 304, Pl. 38, Fig. 6.
1983. *Gnathodus girtyi rhodesi* HIGGINS; T.I. NEMIROVSKAYA, Pl. 1, Fig. 3.

MATERIAL: 7 specimens.

DESCRIPTION: The rarely found specimens of *G. girtyi rhodesi* are characterized by 2 marginal parapets, of which only the outer one reaches the posterior part of the platform. The inner parapet is restricted to the anterior part. In the specimens here investigated, the inner, transversely ridged parapets are fully developed at the anterior end; to the the posterior they are continued in the form of nodes. Generally, both parapets are asymmetrically located in relation to the carina.

OCCURRENCE: Lublin Carboniferous Basin - Huczwa and lower part of the Terebin Formations (Lst. complex *A1* to Lst. Band *F*); England - upper Brigantian and early Namurian; Dneper-Donets Basin - upper Viséan and lowermost Serpukhovian.

Genus *Idiognathodus* GUNNEL, 1931

REMARKS. This Upper Carboniferous genus is conspicuous for the uncommonly variable ornamentation of its platform. An extremely typological mode of taxonomy applied by the early creators of species (mostly: GUNNELL 1931) resulted in the establishment of a large number of taxa, and taxonomical disorder, which has prevailed practically to the present day. SWEET (1975) considerably reduced the number of species, but conodont investigations in the Dneper-Donets and Moscow Basins in the following years resulted in the creation of other new species (BARSKOV & ALEKSEEV 1975, KOZITSKAYA *& al.* 1978). There followed attempts to stabilise the taxonomy at the end of 80's, but Russian and American opinions were divergent. GRAYSON *& al.* (1989, 1990) recognized only 6 species-complexes in the time-span of the middle Morrowan to early Missourian (Pennsylvanian) and proposed a precise phylogenetic model for the group. BARSKOV *& al.* (1987) maintained a relatively greater number of species, although these authors stipulated that they described only those taxa which were more or less unequivocally understood. Despite the omission of some American species from the Russian description, it seems that the key for the genus *Idiognathodus* presented by BRASKOV *& al.* (1987) is more clear. As a result some of these taxonomical suggestions have been accepted by American paleontologists (*e.g.* BARRICK & BOARDMAN 1989). In the present description this classification has been applied, since it was the only way to compare the stratigraphic ranges of species from the Lublin Carboniferous Basin with those of the Dneper-Donets Basin.

Idiognathodus delicatus GUNNELL, 1931
(Pl. 10, Figs 6-12)

Selected synonymy:

1931. *Idiognathodus delicatus* sp.n.; F.H. GUNNELL, p. 250, Pl. 29, Figs 23-25.
1975. *Idiognathodus delicatus* s.l. GUNNELL; A.C. HIGGINS, p. 47, Pl. 17, Fig. 7; Pl. 18, Figs 1-3, 7.
1975. *Idiognathodus magnificus* STAUFFER & PLUMMER; W.C. SWEET, pp. 175-176, Idiognathodus-Pl. 1, Figs 7a-b.
non 1975. *Idiognathodus delicatus* GUNNELL; W.C. SWEET, pp. 169-170, Idiognathodus-Pl. 1, Figs 1g-h.
1978. *Idiognathodus delicatus* GUNNELL; R.I. KOZITSKAYA *& al.*, Pl. 21, Figs 2-3, 5-10.
1980. *Idiognathodus delicatus* GUNNELL; K.P. BENDER, pp. 10-11, Pl. 3, Figs 4-8, 10-11, 16, 28-31, 33-38.
1983. *Idiognathodus delicatus* GUNNELL; T.I. NEMIROVSKAYA, Pl. 1, Fig. 33.
1985. *Idiognathodus delicatus* GUNNELL; M. VAN BOOGAARD & M.J.M. BLESS, p. 146, Figs 7/1-5, 9/8.
1985. *Idiognathodus delicatus* s.l. GUNNELL; A.C. HIGGINS, Pl. 6.4, Fig. 9.
1987. *Idiognathodus delicatus* GUNNELL; I.S. BARSKOV *& al.*, p. 77, Pl. 18, Figs 10-13.
1989. *Idiognathodus claviformus* (GUNNELL); R.C. GRAYSON *& al.*, pp. 88-90, Pl. 1, Figs 1-5, 8-15, 20.
1989. *Idiognathodus delicatus* GUNNELL; J.E. BARRICK & D.R. BOARDMAN, Pl. 1, Fig. 21.
1989. *Idiognathodus delicatus* s.l. GUNNELL; S. SKOMPSKI *& al.*, Pl. 4, Figs 2, 5-6, 8-11.
1995. *Idiognathodus delicatus* GUNNELL; T.I. NEMIROVSKAYA & A.S. ALEKSEEV, Pl. 3, Figs 1, 12.

MATERIAL: 393 specimens.

DESCRIPTION: The Pa elements are characterized by a more or less symmetric lanceolate outline of the platform in upper view and the presence of accessory lobes or rows of nodes (in juvenile specimens) on both sides of the anterior end of the platform. A short carina extends only for about 1/3 of its length onto the platform. The posterior end of the platform is covered with 6-9 transverse parallel ridges, the number increasing in the adult specimens. The accessory lobes are weakly separated from the platform; during growth of the specimen the lobes have enlarged. Abrasion of ornamentation in the anterior half of the platform is characteristic of gerontic specimens (Pl. 10, Figs 10-11).

REMARKS: It is possible to compile an ontognetic series of specimens which illustrate the characteristic features of the growth process: increasing number of transverse ridges and the transformation of ridges which flanked the carina into accessory lobes. The species differs from *I. sinuosus* in its generally symmetrical outline.

OCCURRENCE: Lublin Carboniferous Basin - upper part of the Dęblin Fm. and lower part of the Lublin Fm. (Lst. Bands *M-P*); Donets Basin - appearance in the lst. bed G$_1$ (middle Bashkirian); Great Britain - appearance in the Marsdenian (R$_2$ goniatite zone), acme in the Yeadonian (G$_1$ zone); Bashkirian Mts - appearance in the Askynbashsky Horizon (upper part of lower Bashkirian).

Idiognathodus sinuosus Ellison & Graves, 1941

(Pl. 10, Figs 1-5)

Selected synonymy:

1941. *Idiognathodus sinuosus* sp.n.; S.P. Ellison & R.W. Graves, p. 6, Pl. 3, Fig. 22.

1966. *Idiognathodus humerus* sp.n.; D.L. Dunn, p. 1300, Pl. 158, Figs 6-7.

1974. *Idiognathodus sinuosis* Ellison & Graves; H.R. Lane & J.J. Straka, pp. 81-82, Pl. 37, Figs 10-13, 21, Pl. 42, Figs 1-11, and Pl. 43, Figs 1-8, 10-15, 19, 20.

1975. *Idiognathodus sinuosus* Ellison & Graves; W.C. Sweet, pp. 179-180, Idiognathodus-Pl. 1, Fig. 3.

1978. *Idiognathodus humerus* Dunn; R.I. Kozitskaya, p. 49, Pl. 21, Fig. 1.

1978. *Idiognathodus sinuosis* Ellison & Graves; R.I. Kozitskaya & *al.*, Pl. 21, Fig. 4.

1980. *Idiognathodus sinuosis* Ellison & Graves; K.P. Bender, p. 11, Pl. 3, Figs 17-19.

1985. *Idiognathodus magnificus* Stauffer & Plummer; M. van Boogaard & M.J.M. Bless, p. 148, Pl. 8, Figs 1, 3.

1987. *Idiognathodus sinuosis* Ellison & Graves; I.S. Barskov & *al.*, p. 80, Pl. 18, Figs 4-9.

1989. *Idiognathodus delicatus* s.l. Gunnell; S. Skompski & *al.*, Pl. 4, Figs 1, 3-4, 12.

1990. *Idiognathodus sinuosus* Ellison & Graves; R.C. Grayson & *al.*, pp. 369-370, Pl. 2, Fig. 1.

1995. *Idiognathodus sinuosus* Ellison & Graves; T.I. Nemirovskaya & A.S. Alekseev, Pl. 3, Figs 4, 6, 8-9, 11.

MATERIAL: 101 specimens.

DESCRIPTION: The elements are characterized by an asymmetrical, lanceolate outline of the platform in upper view. The weakly developed, noded or ridged accessory lobe is situated only on the inner side and extends anteriorly (Pl. 10, Figs 2-3). The outer side of the platform is strongly incurved and usually flanked by a single row of nodes. The posterior part of the platform is transversely ridged by 6-10 ridges, which are arranged perpendicularly to the outer side of platform. In juvenile specimens the number of platform ridges, which are occasionally undulated in the axial part, is evidently smaller and an accessory lobe is developed only in the form of 1-2 rows of nodes.

REMARKS: An asymmetry of platform is the most characteristic feature of the species which allowed it to be distinguished from *I. delicatus*. In a preliminary report on conodonts from the Lublin Carboniferous Basin (SKOMPSKI & *al.* 1989) specimens presently described as *I. sinuosus* were included in *I. delicatus* s.l. GUNNELL. More complete and numerous material showed that the differences between the specimens are so distinct that they enable two species to be distinguished, contrary to the very broad definition of *I. delicatus* s.l. proposed by BAESEMANN (1973).

OCCURRENCE: Lublin Carboniferous Basin - upper part of the Dęblin Fm. and lower part of the Lublin Fm. (Lst. Bands *M-P*); Donets Basin - the species appeared as a first *Idiognathodus* in the limestone bed F_1^2 (the lower part of Bashkirian); Bashkirian Mts - it appears together with *I. delicatus* in the Askynbashsky Horizon (upper part of lower Bashkirian).

Genus *Idiognathoides* HARRIS & HOLLINGSWORTH, 1933

REMARKS: The taxonomy of the genus *Idiognathoides* is still a subject of discussion, as in the case of that other commonly found genus *Idiognathodus*. However the intraspecific variability of the former taxon is thought to be less complex than that of the latter. At least 6 species have been recorded in the European successions: *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH, *Id. corrugatus* HARRIS & HOLLINGSWORTH, *Id. attenuatus* (HARRIS & HOLLINGSWORTH), *Id. sulcatus* HIGGINS & Bouckaert, *Id. tuberculatus* NEMIROVSKAYA and *Id. lanei* NEMIROVSKAYA (besides the species which have been recently included in the genus *Declinognathodus*). Some of them should be without doubt merged into one species; it concerns mostly *Id. sinuatus* and *Id. corrugatus*, which represent sinistral and dextral elements of the same apparatus. This concept was convincingly documented by LANE (1967, 1968), who introduced on the basis of these two morphologically different forms a new class of symmetry (class IIIb). The numerical distribution and stratigraphical ranges of these "species" from the Lublin Carboniferous Basin (Table 2) confirms once more the validity of this idea. AUSTIN (1972) argued that these 2 species have a different stratigraphic range, but more recent data indicate a very similar or even identical ranges for the species (*e.g.* HIGGINS 1975, 1985, WANG & *al.* 1987). Nevertheless, some authors still consider the left and right forms as separate taxa (*cf.* NEMIROVSKAYA & NIGMADGANOV 1993).

The other species of *Idiognathoides* are sometimes considered to be only morphotypes of one broadly defined species (*cf.* remarks on the taxonomy of the *Id. opimus* in BENDER, 1980). The most extreme taxonomic suggestion was expressed by GRAYSON & *al.* (1990), who included all of the above mentioned taxa (except of *Id. sulcatus*) into the one species *Id. sinuatus*. However, in this strictly morphological treatment of taxonomy, the stratigraphical ranges of some species had been omitted. The data reported for example by HIGGINS & BOUCKAERT (1968), HIGGINS (1975, 1985) and NEMIROVSKAYA (1978) pointed to a later appearance for *Id. tuberculatus, Id. lanei* and *Id. attenuatus* than for *Id. sinuatus* or *Id. sulcatus*. Frequently these taxa are the only stratigraphic indicator in the discussed interval. For this reason in the present work the traditional "splitting" concept of species has been accepted, except of synonymy of *Id. corrugatus* and *Id. sinuatus*.

Idiognathoides attenuatus (HARRIS & HOLLINGSWORTH, 1933)
(Pl. 8, Figs 1-5)

1933. *Idiognathoides attenuata* sp.n.; HARRIS & HOLLINGSWORTH, p. 203, Pl. 1, Fig. 9.

1968. *Idiognathoides attenuatus* (HARRIS & HOLLINGSWORTH); A.C. HIGGINS & J. BOUCKAERT, p. 39, Pl. 4, Fig. 10.

1975. *Idiognathoides attenuatus* (HARRIS & HOLLINGSWORTH); A.C. HIGGINS, p. 48, Pl. 15, Fig. 1.

1989. *Idiognathoides attenuatus* (HARRIS & HOLLINGSWORTH); S. SKOMPSKI & *al*., Pl. 5, Figs 7, 11-13.

1987. *Idiognathoides corrugatus* (HARRIS & HOLLINGSWORTH); Z.H. WANG & *al*., Pl. 2, Figs 2, 7.

MATERIAL: 44 specimens.

REMARKS:The exceptional subtlety of the features which allow distinction between *Id. attenuatus* and right elements of *Id. sinuatus*, *i.e.* the lack of a median sulcus and a straight or concave outline of the inner platform, probably resulted in this species not being recorded in the American and Russian sequences. However, in West European sections it is quite numerous and appeared later than *Id. sinuatus*; only for this reason did the present Author decide to distinguish this questionable species. An interesting feature observed in the assemblage investigated is the deepening of the median sulcus in the gerontic stage (Pl. 8, Figs 4-5); it is extended nearly to the posterior end of platform. The specimens with a long deep sulcus are practically undistinguishable from *Id. fossatus* (BRANSON & MEHL), which is characteristic mainly of the lower Moscovian.

OCCURRENCE: Lublin Carboniferous Basin - upper part of the Dęblin Fm. and lower part of the Lublin Fm. (Lst. Bands *M-S*); Great Britain - Marsdenian to lower Westphalian (R_2 to G_2 goniatite zones); Belgium - R_{2a2} to G_2 goniatite zones.

Idiognathoides lanei NEMIROVSKAYA, 1978
(Pl. 7, Figs 4-8 and Pl. 9, Fig. 9)

1978. *Idiognathoides lanei* sp.n.; T.I. NEMIROVSKAYA *in*: R.I. KOZITSKAYA & *al*., pp. 63-64, Pl. 16, Figs 8-10.

1987. *Idiognathoides lanei* NEMIROVSKAYA; T.I. NEMIROVSKAYA, Pl. 2, Figs 20, 27, 29.

MATERIAL: 10 specimens.

REMARKS: In juvenile specimens, where the "ledge" between left and right parts of the platform is very small (especially at the posterior end) distinguishing this species from sinistral elements of *I. sinuatus* is practically impossible. A diagnostic feature of *I. lanei* is that in older specimens the continuous transverse ridges which spread to the posterior end, are sometimes bent, especially in the middle part of the ridges. In the present paper only these specimens, which showed relatively straight ridges, were attributed to the species *I. lanei*. The number of ridges usually does not exceed 5.

OCCURRENCE: Lublin Carboniferous Basin - upper part of the Dęblin Fm. and lower part of the Lublin Fm. (Lst. Bands *M-P*); Donets Basin - limestone beds E_8 to I_2 (from the beginning to the end of the Bashkirian).

Idiognathoides sinuatus HARRIS & HOLLINGSWORTH, 1933

(Pl. 7, Figs 1-3 and Pl. 8, Figs 6-8)

Selected synonymy:

1933. *Idiognathoides sinuatus* sp.n.; R.W. HARRIS & R.V. HOLLINGSWORTH, p. 201, Pl. 1, Fig. 14.

1933. *Idiognathoides corrugata* sp.n.; R.W. HARRIS & R.V. HOLLINGSWORTH, p. 202, Pl. 1, Figs 7-8.

1968. *Idiognathoides convexus* (ELLISON & GRAVES); A.C. HIGGINS & J. BOUCKAERT, p. 39, Pl. 4, Fig. 3.

1968. *Idiognathoides corrugata* (HARRIS & HOLLINGSWORTH); A.C. HIGGINS & J. BOUCKAERT, p. 39, Pl. 5, Fig. 9.

1968. *Idiognathoides sinuata* HARRIS & HOLLINGSWORTH; A.C. HIGGINS & J. BOUCKAERT, p. 40, Pl. 2, Fig. 14; Pl. 4, Figs 5, 8, 9, and Pl. 5, Fig. 11.

1975. *Idiognathoides corrugatus* HARRIS & HOLLINGSWORTH; A.C. HIGGINS, pp. 48-49, Pl. 15, Figs 2-9.

1975. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; A.C. HIGGINS, pp. 55-56, Pl. 14, Figs 4-6; Pl. 15, Figs 11, 16, and Pl. 16, Figs 1-7, 9-14.

1974. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; H.R. LANE & J.J. STRAKA, pp. 88-90, Fig. 37/14-15, 18, 20, 23-26, and Fig. 41/1-14, 20-27 *(with synonymy)*.

1978. *Idiognathoides corrugatus* HARRIS & HOLLINGSWORTH; R.I. KOZITSKAYA & *al.*, pp. 60-61, Pl. 16, Figs 1-2.

1978.*Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; R.I. KOZITSKAYA & *al.*, pp. 64-66, Pl. 18, Figs 1-3.

1980. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; K.P. BENDER, p. 13, Pl. 1, Figs 17-33.

1981. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; E. LANDING & B.R. WARDLAW, pp. 1262-1263, Pl. 2, Figs 8-21, 15-16, 18-19, 21, *non* Pl. 2, Figs 17, 20 = *Id. attenuatus*.

1983. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; T.I. NEMIROVSKAYA, Pl. 1, Figs 34-35.

1983. *Idiognathoides corrugatus* HARRIS & HOLLINGSWORTH; T.I. NEMIROVSKAYA, Pl. 1, Figs 39.

1984. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; N.V. GOREVA, Pl. 1, Figs 24-27.

1984. *Idiognathoides corrugatus* HARRIS & HOLLINGSWORTH; N.V. GOREVA, Pl. 1, Figs 28-35.

1985. *Idiognathoides corrugatus-sinuatus* (HARRIS & HOLLINGSWORTH); A.C. HIGGINS, Pl. 6.4., Figs 1-3, 5.

1985. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; M. VAN DEN BOOGAARD & M.J.M. BLESS, pp. 148-149, Pl. 9, Figs 1-4.

1987. *Idiognathoides corrugatus* HARRIS & HOLLINGSWORTH; T.I. NEMIROVSKAYA, Pl. 2, Figs 10, 21, 25-26, 30-31.

1987. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; T.I. NEMIROVSKAYA, Pl. 2, Figs 8, 12, 17, 22, 24.

1987. *Idiognathoides corrugatus* HARRIS & HOLLINGSWORTH; Z.H. WANG & *al.*, pp. 129-130, Pl. 2, Figs 1, 6, 8-11, *non* Figs 2, 7.

1987. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; Z.H. WANG & *al.*, p. 130, Pl. 2, 3-5.

1989. *Idiognathoides corrugatus* HARRIS & HOLLINGSWORTH; S. SKOMPSKI & *al.*, Pl. 5, Figs 14-15.

1989. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; S. SKOMPSKI & *al.*, Pl. 5, Figs 9-10.

1990. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; J.R. WHITESIDE & R.C. GRAYSON, Pl. 1, Figs 8, 25-27.

1990. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; R.C. GRAYSON & *al.*, Pl. 1, pp. 366-368, Figs 26-27 (*only*).

1995. *Idiognathoides corrugatus* HARRIS & HOLLINGSWORTH; T.I. NEMIROVSKAYA & A.S. ALEKSEEV, Pl. 1, Figs 11, 13, 15.

1995. *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; T.I. NEMIROVSKAYA & A.S. ALEKSEEV, Pl. 1, Figs 14, 16.

MATERIAL: 331 sinistral (left) elements, 335 dextral (right) elements.

DESCRIPTION: The number of left (sinistral) and right (dextral) elements is nearly equal even in samples with very low frequence (Table 2), but it is surprising that the apparatuses in the investigated succession are incomplete (total lack of ramiform elements). In most of the left elements in the material studied, the left part of the platform is narrower and elevated. The lowered right part of the platform is broader, especially at the anterior part. The amplitude of the "fault" separating these two parts decreases toward the posterior end. In right elements the corrugated platform is usually flat (Pl. 8, Fig. 7), but sometimes the central depression stretches from the anterior to the posterior end (Pl. 8, Fig. 6). Rarely this depression reaches a form of deep sulcus in the anterior (Pl. 8, Fig. 8). The posterior end of the platform is sharply-pointed, sometimes could be rounded.

OCCURRENCE: Lublin Carboniferous Basin - Dęblin Fm. and lower part of the Lublin Fm. (Lst. Bands *M-S*); Great Britain - Kinderscoutian to the lower Westphalian (*Reticuloceras-Gastrioceras* goniatite zones); Belgium - appearance in R_{1a3} zone; Donets Basin - lst. beds D_7 to L_1 (from the end of Serpukhovian to the beginning of Moscovian).

Idiognathoides sulcatus (HIGGINS & BOUCKAERT, 1968)
(Pl. 9, Fig. 8)

Selected synonymy:

1968. *Idiognathoides sulcata* sp.n.; A.C. HIGGINS & J. BOUCKAERT, p. 41, Pl. 4, Figs 6-7.
1974. *Idiognathoides sulcatus* HIGGINS & BOUCKAERT; H.R. LANE & J.J. STRAKA, pp. 90-91, Fig. 36/1-16, 18-20, 23-24; Fig. 2/1-10.
1975. *Idiognathoides sulcatus sulcatus* HIGGINS & BOUCKAERT; A.C. HIGGINS, p. 56, Pl. 13, Figs 11-12 (*only*), and Pl. 15, Fig. 15.
1978. *Idiognathoides sulcatus* HIGGINS & BOUCKAERT; R.I. KOZITSKAYA & *al.*, pp. 66-67, Pl. 18, Figs 4-6.
1980. *Idiognathoides opimus* sensu lato (IGO & KOIKE); K.P. BENDER, pp. 12-13, Pl. 2, Figs 1-38.
1983. *Idiognathoides sulcatus* HIGGINS & BOUCKAERT; T.I. NEMIROVSKAYA, Pl. 1, Fig. 36.
1985. *Idiognathoides sulcatus* HIGGINS & BOUCKAERT; M. VAN DEN BOOGAARD & M.J.M. BLESS, p. 150, Fig. 9/6-7.
1985. *Idiognathoides sulcatus sulcatus* (HIGGINS & BOUCKAERT); A.C. HIGGINS, Pl. 6.3, Fig. 6.
1987. *Idiognathoides sulcatus* HIGGINS & BOUCKAERT; T.I. NEMIROVSKAYA, Pl. 2, Figs 13-14, 16, 23, 28.
1990. "*Declinognathodus* " sp. B; R.C. GRAYSON & *al.*, pp. 364-365, Pl. 1, Figs 16-17.
1995. *Idiognathoides sulcatus* HIGGINS & BOUCKAERT; T.I. NEMIROVSKAYA & A.S. ALEKSEEV, Pl. 1, Figs 12, 17, 19.

MATERIAL: 10 specimens.

REMARKS: Some few specimens assigned to this species are characterized by a narrow platform consisting of two noded parapets separated by a median sulcus. The straight parapets are usually of equal height. LANE & STRAKA (1974), HIGGINS (1975) and KOZITSKAYA & *al.* (1978) reported symmetrical specimens (class II), but in the investigated material the only elements found had a blade joined to left parapet.

OCCURRENCE: Lublin Carboniferous Basin - upper part of the Dęblin Fm. and lower part of the Lublin Fm. (Lst. Bands *N, S*); Donets Basin - limestone beds D_7 to I_2 (from the end of Serpukhovian to the end of Bashkirian); Great Britain - Kinderscoutian to lower Westphalian (*Reticuloceras-Gastrioceras* goniatite zones).

Idiognathoides tuberculatus NEMIROVSKAYA, 1978
(Pl. 7, Figs 9-12)

1978. *Idiognathoides tuberculatus* sp.n.; T.I. NEMIROVSKAYA *in*: R.I. KOZITSKAYA & *al.*, pp. 67-68, Pl. 17, Figs 3-6.
1979. *Idiognathoides tuberculatus* NEMIROVSKAYA; T.I. NEMIROVSKAYA *in*: R.H. WAGNER & *al.*, Pl. 22, Fig. 24.
1984. *Idiognathoides tuberculatus* NEMIROVSKAYA; N.V. GOREVA, Pl. 1, Figs 30-31.

1985. *Idiognathoides tuberculatus* NEMIROVSKAYA; M. VAN DEN BOOGAARD & M.J.M. BLESS, p. 150, Fig. 8/8-10.
1995. *Idiognathoides tuberculatus* NEMIROVSKAYA; T.I. NEMIROVSKAYA & A.S. ALEKSEEV, Pl. 2, Figs 7, 12.

MATERIAL: 6 specimens.

REMARKS: The investigated specimens are characterized, similarly to those originally described by NEMIROVSKAYA (1978), by an arrangement of parapets very close to that of *Idiognathoides sinuatus*, and with single or multiple tubercules located on the inner side of the platform, in its middle or anterior part. BOOGAARD & BLESS (1985) showed that this feature appeared in both sinistral and dextral elements. GRAYSON & *al.* (1990) postulated the inclusion of all these tuberculated specimens in *Idiognathoides sinuatus*, as environmentally controlled varities of this broadly definied species. Unfortunately they did not discuss the time distribution of these forms. Observations of NEMIROVSKAYA (*in:* KOZITSKAYA 1978) showed unaequivocally that additional nodes appeared at the end of the range of *I. sinuatus*. The data from the Lublin Carboniferous Basin confirms this note. It shows that tuberculation is an evolutionary rather than an ecologically controlled feature. An analogous process is observed late in the evolution of *Gn. girtyi* (the appearance of additional tubercules in *Gn. girtyi soniae*) and in the genus *Lochriea* (*cf.* SKOMPSKI & *al.* 1995).

Genus *Kladognathus* REXROAD, 1958

REMARKS. There is a general consensus regarding the composition of the discrete elements in the multielement *Kladognathus* apparatus. REXROAD (1981) reported that this apparatus included elements previously assigned to the form species of *Kladognathus*, *Magnilaterella*, *Hibbardella*, *Neoprioniodus* and *Ligonodina*. However, general controversy exists concerning the position of elements in the apparatus, especially the position of the most characteristic element DE *Magnilaterella*. PURNELL (1993) expressed the opinion (on the basis of well preserved specimens from the Bear Gulch Member, Montana) that *Magnilaterella* occupied the Pa and Pb position, similar to genera from the order Prioniodinida (*comp.* identical suggestions by SWEET, 1988). The earlier concept of REXROAD (1981), HOROWITZ & REXROAD (1982) and REXROAD & HOROWITZ (1990) placed the *Magnilaterella* elements in the Sb position. Consequently, according to the latter hypothesis, P elements were not developed. The specimen investigated by PURNELL (1993), although well preserved, does not resolve this controversy. The notation of element configuration in apparatuses employed in the description of the species below, is based on that of PURNELL (1993), as being more probable than that proposed by HOROWITZ & REXROAD (1982), which was based only on statistical studies.

The second problem is the discrimination of species. REXROAD & HOROWITZ (1990) and MAPES & REXROAD (1986) gave detailed descriptions of two species, which most distinctly differ in their S elements: *Kladognathus tenuis* (BRANSON & MEHL) is characterized by the presence of DE *Ligonodina levis* (Sc element, β morphotype), DE *Ligonodina tenuis* (Sc, α morphotype) and *Magnilaterella robusta* (Sb elemnt), while *Kladognathus complectens* (CLARKE) is best distinguished by the presence of DE *Ligonodina complectens* Clarke. The lack of the latter form-species in the investigated material from the Lublin Basin caused the present Author to include all elements in the species *Kladognathus tenuis*. However, the new PURNELL concept of configuration for the *Kladognathus* apparatus prompts a new outlook on species discrimination in the genus (*see* remarks to *K. tenuis*).

Kladognathus tenuis (BRANSON & MEHL), emend. REXROAD, 1981
(Pl. 4, Figs 1-11)

1941. *Ligonodina tenuis* sp.n.; E.B. BRANSON & M.G. MEHL, p. 170, Pl. 5, Figs 13-14 [S_c elements].

1981. *Kladognathus tenuis* (BRANSON & MEHL); C.B. REXROAD, p. 13, Pl. 2, Figs 19, 21, 24-26 [S_c element, α morphot.], 20[S_c, β].

1990. *Kladognathus tenuis* (BRANSON & MEHL); C.B. REXROAD & A.S. HOROWITZ, pp. 505-506, Pl. 3, Figs 28-30 [M elements], 21-24 [S_a elements],25-27, 33 [S_b elements], 16-20 [S_c elements], 12-15 [S_d elements], *with full synonymy*.

1992. *Kladognathus tenuis* (BRANSON & MEHL); M.A. PURNELL, p. 39-40, Pl. 8, Figs 2-3.

1994. *Kladognathus tenuis* (BRANSON & MEHL); W.J. VARKER, pp. 309-310.

MATERIAL:

Pa-Pb elements (Pl. 4, Figs 1-4) – 10 specimens.
Magnilaterella clarkei RHODES, AUSTIN & DRUCE; 1969, pp. 146-147, Pl. 23, Figs 11-13b.
Magnilaterella contraria RHODES, AUSTIN & DRUCE; 1969, pp.147-148, Pl. 23, Figs 8a-c, 18a-c.

M element (Pl. 4, Figs 9-11) – about 70 specimens.
Neoprioniodus scitulus (BRANSON & MEHL); 1940, p. 173, Pl. 5, Figs 5-6.
Neoprioniodus peracutus (HINDE); 1900, p. 343, Pl. 10, Fig. 22 (*only*).

Sa element (Pl. 4, Fig. 8) – 4 specimens.
Hibbardella milleri REXROAD; 1958, p. 18, Pl. 2, Figs 13-16.

Sb, Sc element (Pl. 4, Figs 5-7) - 45 specimens.
Ligonodina levis BRANSON & MEHL; 1941, p. 105, Pl. 6, Fig. 10.
Ligonodina tenuis BRANSON & MEHL; 1941, p. 170, Pl. 5, Figs 13-14.
Kladognathus macrodentatus (HIGGINS); 1961, p. 214, Pl. 12, Figs 1-3.

REMARKS: According to PURNELL's description, the P elements of *Kladognathus* occur as two morphotypes, occupying Pa and Pb position, which are morphologically distinct but generally related to DE *Magnilaterella contraria* RHODES, AUSTIN & DRUCE. On the other hand, the statistical analysis (REXROAD & HOROWITZ 1990) indicated that another species of the genus, DE *Magnilaterella clarkei* occurs in the *Kladognathus* apparatus, and this observation is confirmed by material from the Lublin Basin. It seems to be reasonable to consider this differentiation of P elements as the main indicator of species in the genus *Kladognathus*. The investigated material is however too scarce for formal proposition, and therefore the present Author remains with the traditional species taxonomy.

The single specimen of a tertiopedate element of DE *Kladognathus macrodentata* should probably be related to the Sc position in the apparatus, as suggested by PURNELL (1993).

OCCURRENCE: Lublin Carboniferous Basin - the apparatus appeared in the Huczwa and Terebin Fm. (from Lst. complex *A3* to Lst. Band *G*); England - characteristic of the upper Brigantian to Arnsbergian (E_{2c}^{3}).

Genus *Neognathodus* DUNN, 1970

Neognathodus bothrops MERRILL, 1972

(Pl. 9, Figs 10-11)

1972. *Neognathodus bothrops* sp.n.; G.K. MERRILL, pp. 823-824, pl. 1, Figs 8-15.

1975. *Neognathodus bothrops* MERRILL; W.C. SWEET, pp. 203-204, Neognathodus-Pl. 1, Fig. 7.

1984. *Neognathodus bothrops* MERRILL; N.V.GOREVA, Pl. 4, Figs 18-22.

1987. *Neognathodus bothrops* MERRILL; Z.H.WANG & *al.*, p. 130, Pl. 3, Figs 8-10.

1987. *Neognathodus bothrops* MERRILL; I.S. BARSKOV & *al.*, p. 69, Pl. 17, Figs 15-16 *(cum synonymy)*.

MATERIAL: 4 specimens.

REMARKS. This species is extremely rare in the collection from the Lublin Carboniferous Basin. It is represented by adult or even gerontic specimens (Pl. 9, Fig. 11), characterized by a subsymmetric platform with two parapets, transversely ridged in a semi-radial pattern and fused to the carina in the posterior end. The parapets are wider towards the anterior end and they are widest in the anterior one-third. Their symmetry is slightly different from specimens presented by MERRILL (1972), in which the inner parapet is usually broader than the outer one. Comparison with the large Russian collection (BARSKOV & *al.* 1987) shows that the symmetry of parapets is typical only of adult specimens.

The fusion of the parapets with the posterior terminus of the carina is emphasised in MERRILL's original diagnosis and in the description made by BARSKOV & *al.* (1987), as the most characteristic feature, which allows distinction of this species from *Neognathodus bassleri (sensu N. bassleri bassleri)*. HIGGINS (1975) accentuated these feature also in the description of specimens included in *N. bassleri* and similar to *N. bassleri bassleri*. It seems that they may correspond with *N. bothrops*, but the quality of illustrations does not allow verification of this hypothesis. Thus, it could explain the astonishing appearance of the "*bassleri bassleri*" morphotype (which is considered as a descendant of *N. symmetricus*) as early as in the Homoceras Zone (at the beginning of the range of the genus *Neognathodus*) in some British sections (*cf.* HIGGINS 1975, p. 65). Such an early appearance of *N. bothrops* is in agreement with the stratigraphic range of this species reported by BARSKOV & *al.* (1987) and contradicts MERRILL's opinion that *N. bothrops* descended from *N. bassleri bassleri*.

OCCURRENCE: Lublin Carboniferous Basin - upper part of the Dęblin Fm. and lower part of the Lublin Fm. (Lst. Bands *M-O*; Moscow Basin - rare in the uppermost Bashkirian and more characteristic of the lower part of the Moscovian.

Neognathodus symmetricus (LANE, 1967)

(Pl. 9, Figs 3-7)

Selected synonymy:

1967. *Gnathodus bassleri symmetricus* ssp.n.; H.R. LANE, pp. 935-936, Pl. 120, Figs 2, 13-14, 17, and Pl. 121, Figs 6, 9.

1975. *Neognathodus bassleri* (HARRIS & HOLLINGSWORTH); A.C. HIGGINS, pp. 64-65, Pl. 17, Figs 12, 15? (*only*).

1987. *Neognathodus symmetricus* LANE; I.S. BARSKOV & *al.*, p. 73, Pl. 17, Figs 1-6.

1987. *Neognathodus symmetricus* LANE; T. I. NEMIROVSKAYA, Pl. 2, Figs 1-5, 7, 9, 11, 18-19.

1987. *Neognathodus symmetricus* LANE; Z.H. WANG & *al.*, Pl. 3, Figs 6-7.

1989. *Neognathodus symmetricus* LANE; S. SKOMPSKI & *al.*, Pl. 5, Figs 1-2.

1990. *Neognathodus symmetricus* (LANE); R.C. GRAYSON & *al.*, pp. 377-378, Pl. 3, Fig. 23 (*cum synonymy*)

MATERIAL: 66 specimens.

REMARKS. Specimens from the Lublin Carboniferous Basin exactly correspond with the diagnosis presented by LANE (1967). The parapets are parallel to the carina and usually higher than the carina, especially in its posterior part. The carina is noded and its posterior nodes are lower than those at the anterior. The parapets, noded or ridged, are equal in length and symmetricaly located in relation to the carina, which is separated by marked throughs. The parapets join together behind the posterior terminus of the carina.

This species, moderately common in the Lublin Carboniferous Basin, was primarily distinguished by LANE (1967) as a subspecies of *Gnathodus bassleri* (*Gn. bassleri symmetricus)*, but after the revision of LANE & STRAKA (1974) and GRAYSON (1984), it is usually treated as a separate species of the genus *Neognathodus*. However, in some descriptions from the British conodont succession (HIGGINS 1975, 1985) the name *Gnathodus bassleri* is still used in the previous, broader sense. Thus, it includes specimens referred to both the *symmetricus* and *bassleri* subspecies (most of the specimens are similar to the *symmetricus* morphotype). This different concept of *N. bassleri* could cause confusion in stratigraphic analysis, since *N. bassleri (sensu bassleri bassleri)* is considered to be a descendant of *N. symmetricus (sensu bassleri symmetricus*, *cf.* GRAYSON & *al.* 1990) and it became extinct evidently later. In the present paper the taxonomy of the species corresponds with the species concept of GRAYSON (1984), which was followed also in the Russian literature (*see* BARSKOV & *al.* 1987).

OCCURRENCE: Lublin Carboniferous Basin - upper part of the Dęblin Fm. and lower part of the Lublin Fm. (Lst. Bands *M-P*); Dneper-Donetz Basin - Bashkirian except its uppermost part (E_1 to H_5 limestone Horizon, according to KOZITSKAYA & *al.* 1978) or uppermost Bashkirian (according to BARSKOV & *al.* 1987, p. 140, without documentation); Great Britain - probably Chokierian to lower Marsdenian (Homoceras to Reticuloceras R_{2a} Zone).

Genus *Synclydognathus* REXROAD & VARKER, 1992

REMARKS: The elements included in the newly erected (REXROAD & VARKER 1992) multielement genus *Synclydognathus* are relatively numerous in the investigated collection from the Lublin Basin, and compose about 20% of all specimens. Although the generic name is rather new, the presence of discrete elements of this apparatus was reported from numerous countries (*see* review *in:* REXROAD & VARKER 1992), including the Lublin Carboniferous Basin (SKOMPSKI & SOBOĄ-PODGÓRSKA 1980, SKOMPSKI & *al.* 1989). The taxonomy of disjunct spathognathodont and apatognathid elements incorporated into the genus is well established, but multielement classification is still a subject of controversy and comprises one of the most tangled taxonomic enigmas in the late Viséan/early Namurian interval.

The first problem was connected with the morphological similarity of Devonian and Lower Carboniferous forms referred to the genus *Apatognathus*. These elements are not known from the lowest part of the Tournaisian, and it results in the Carboniferous forms always being classified provisionally, with question- or quotation marks. NICOLL (1980) proved that the Devonian apatognathid elements belonged to a separate apparatus, and it was obvious that the classification of the Carboniferous specimens ought to be changed. There were at least 2 ways of reconstructing the apparatus (presented in papers by REXROAD and SWEET), embracing apatognathid forms - the history of investigation was extensively summarized by PURNELL (1992). However, a new concept by REXROAD & VARKER (1992) appeared simultaneously with PURNELL'S paper, and this idea with some reservations, is accepted in the present paper. REXROAD & VARKER (1992) erected a new genus *Synclydognathus*, composed of DE *Spathognathodus scitulus* (as Pa elements), DE *Ozarkodina laevipostica* (as Pb element), and different apatognathids: *A.? cuspidata, A.? petila, A.? gemina, A.? scalena, A.? chaulioda* and *A.? librata* in the S positions of the apparatus. This hypothesis is generally consistent with the earlier find of a fused cluster consisting of *S. scitulus, A. porcatus* and *A. scalenus* (AUSTIN & RHODES 1969), and with suggestions expressed by REXROAD & THOMPSON (1979) regarding the *Apatognathus* apparatus. This classification solved the problem of the most commonly appearing apatognathids, but leaves unclear the taxonomy of the other spathognathodonts, particularly the frequently occurring DE *S. cristulus*. According to REXROAD & THOMPSON (1979) DE *Sp. cristulus* and DE *Sp. scitulus* belong to different lineages, and are included in distant apparatuses. Another opinion was presented by SWEET (1988), who placed particular species of the discussed genus in the Pa position of the *Hindeodus* apparatus (*H. crassidentatus, H. scitulus, H. cristulus*). Although hypothetical, SWEET'S reconstruction is reasonable (taking into account the morphological similarity of the Carboniferous spathognathodonts), it is not documented by bedding plane assemblages or statistical analysis. For this reason in the present description the taxonomy proposed by REXROAD & VARKER (1992) has been applied, as better documented and more precisely formulated. DE *Spathognathodus cristulus* and DE *Sp. minutus* are here included as Pa elements to the apparatuses *Hindeodus cristulus* and *H. minutus* respectively (*see* Pl. 5, Figs 13-15).

Synclydognathus geminus (HINDE)
(Pl. 5, Figs 1-12)

1900. *Prioniodus geminus* sp.n.; G.J. HINDE, p. 344, Pl. 10, Fig. 25.

1967. *Apatognathus*? *librata* sp.n.; W.J. VARKER, p. 134, Pl. 18, Figs 3, 6, 8-9, 12-13.

1992. *"Apatognathus" cuspidatus* VARKER; M.A. PURNELL, pp. 41-42, Pl. 8, Figs 6-9 (*only*), [*cum synonymy*].

1992. *Synclydognathus geminus* (HINDE); C.B. REXROAD & W.J. VARKER, p. 168, Figs 3/1-10.

1992. *Synclydognathus libratus* (VARKER); C.B. REXROAD & W.J. VARKER, p. 168, Figs 3/11-14.

MATERIAL:

Pa elements (Pl. 5, Figs 1-2) – 119 specimens.
Spathognathodus scitulus (HINDE); *see* CLARKE 1960, p. 21, Pl. 3, Figs 12-13.

Pb elements (Pl. 5, Figs 4-5) – 23 specimens.
Ozarkodina laevipostica REXROAD & COLLINSON; 1963, p. 19, Pl. 1, Figs 1-6.
= *Apatognathus minutus* AUSTIN & HUSRI; 1974, p. 51, Pl. 10, Figs 1-2, 5, 9.

M elements (Pl. 5, Figs 3, 8) – 20 specimens.
Apatognathus? *librata* VARKER; 1967, pp. 134-135, Pl. 18, Figs 3, 6, 8-9, 12-13.

S elements (Pl. 5, Figs 6-7, 9-12) – about 120 specimens.
Apatognathus? *chaulioda* VARKER; 1967, pp. 129-131, Pl. 17, Figs 1, 3, 5.
Apatognathus? *gemina* (HINDE); *see* VARKER 1967, p. 133, Pl. 17, Figs 9, 12, 13.
Apatognathus? *petila* VARKER; 1967, pp. 135-136, Pl. 17, Fig. 11; Pl. 18, Figs 7, 10, 11.
Apatognathus? *scalena* VARKER; 1967, pp. 136-137, Pl. 18, Figs 1-2, 4-5.

PLATE 1

1-3 — *Gnathodus girtyi collinsoni* RHODES, AUSTIN & DRUCE; Pa elements, **a** – oral view, **b** – lateral view
1 – borehole Orzechów *IG-22* (depth 1185 m), × 50
2 – borehole Syczyn *IG-4* (depth 1217 m), × 50
3 – borehole Syczyn *IG-4* (depth 1217 m), × 75

4-7 — *Gnathodus girtyi meischneri* AUSTIN & HUSRI; Pa elements, oral view
4 – borehole Syczyn *IG-4* (depth 1197 m), × 65
5 – borehole Orzechów *IG-2* (depth 874 m), × 65
6 – borehole Rejowiec *IG-1* (depth 1379 m), × 65
7 – borehole Hostynne *IG-1* (depth 1295 m), × 65

8-9 — *Gnathodus girtyi girtyi* HASS; Pa elements, oral view
8 – borehole Syczyn *IG-4* (depth 1137 m), × 65
9 – borehole Rejowiec *IG-1* (depth 1313 m), × 50

10 — *Pseudognathodus homopunctatus* (ZIEGLER); Pa element, oral view borehole Syczyn *IG-4* (depth 1217 m), × 50

11-12 — *Gnathodus girtyi intermedius* GLOBENSKY; Pa elements, oral view borehole Hostynne *IG-1* (depth 1269 m), × 50

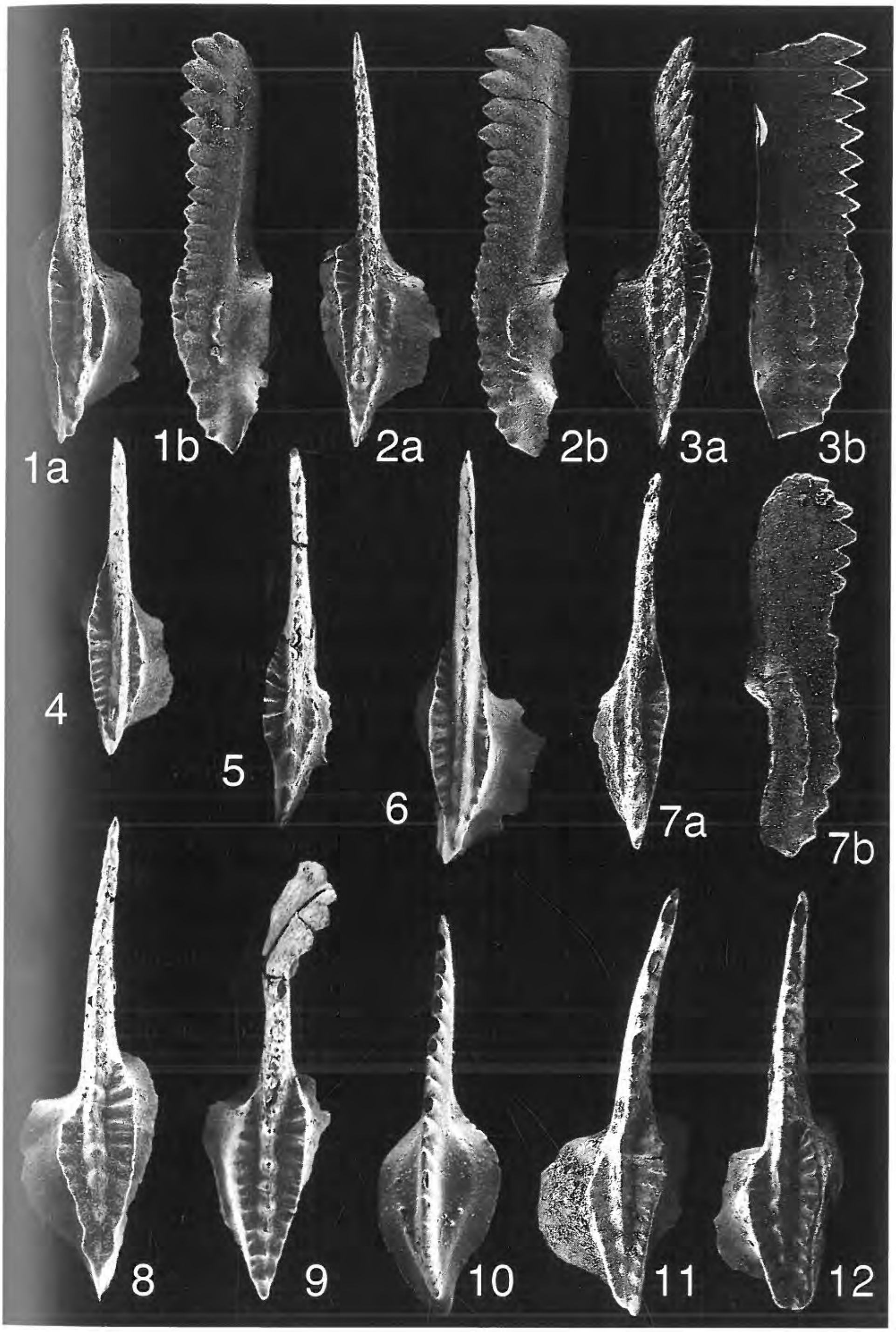

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PLATE 2

1-2 — *Gnathodus girtyi meischneri* AUSTIN & HUSRI; Pa elements, oral view
  1 – borehole Hostynne *IG-1* (depth 1325 m), × 80
  2 – borehole Syczyn *IG-4* (depth 1197 m), × 65

3 — *Pseudognathodus homopunctatus* (ZIEGLER); Pa elements, oral view
borehole Wyhalew *IG-1* (depth 624 m), × 45

4-5 — *Mestognathus bipluti* HIGGINS; Pa elements, oral/inner lateral view
  4 – borehole Włodawa *IG-4* (depth 408 m), × 40
  5 – borehole Sawin *IG-7* (depth 1083 m), × 60

6 — *Cavusgnathus naviculus* (HINDE); Pa element, oral view
borehole Syczyn *IG-4* (depth 1305 m), × 60

7-8 — *Gnathodus girtyi rhodesi* HIGGINS; Pa elements, oral view
  7 – borehole Orzechów *IG-22* (depth 1165 m), × 60
  8 – borehole Michałów *IG-4* (depth 903 m), × 60

9-11 — *Gnathodus bilineatus bilineatus* (ROUNDY); Pa elements, oral view
borehole Telatyn *IG-1* (depth 1185 m), × 80

12 — *Gnathodus girtyi intermedius* GLOBENSKY; Pa element, oral view
borehole Hostynne *IG-1* (depth 1269 m), × 55

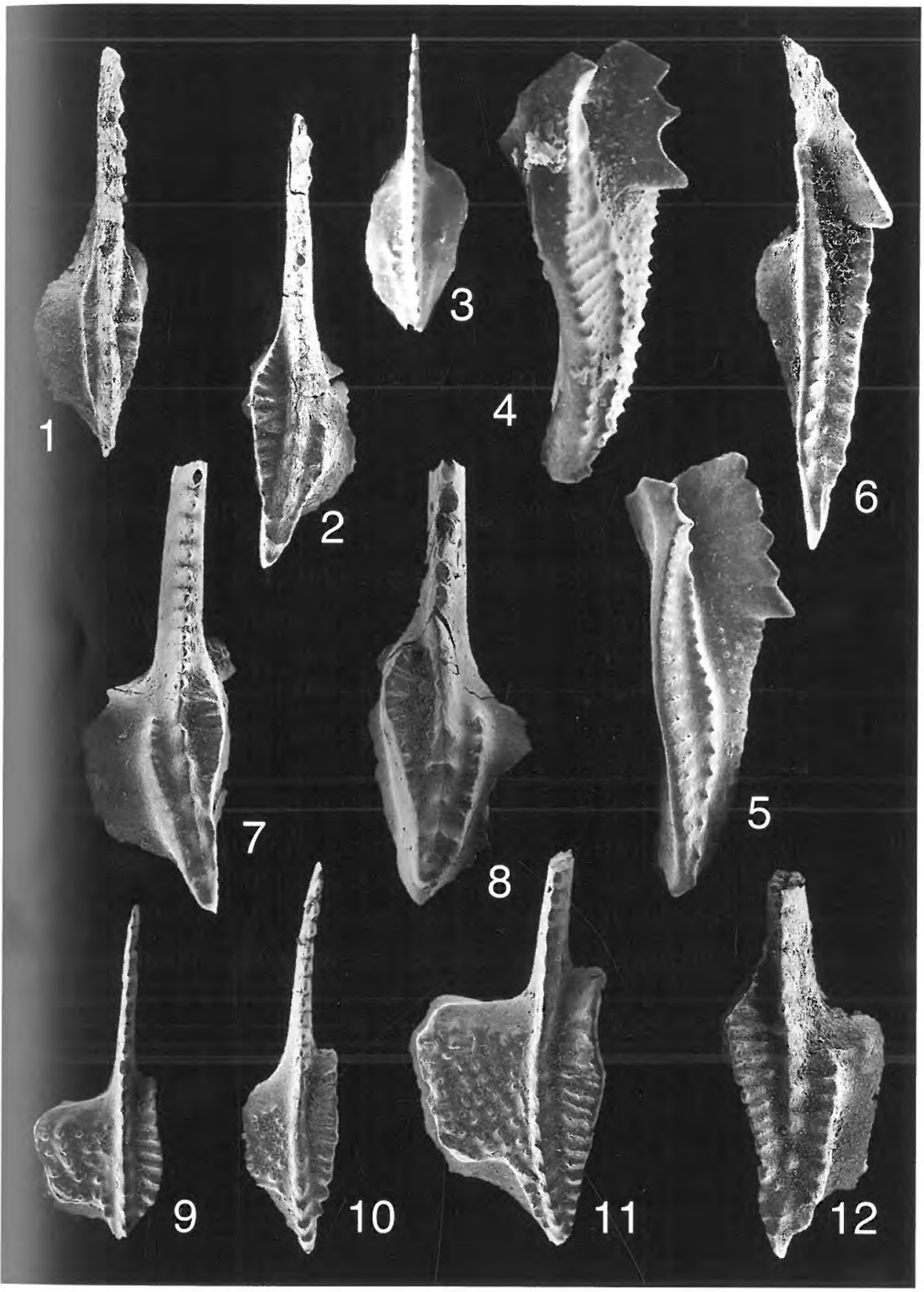
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PLATE 3

1-3 — *Lochriea ziegleri* NEMIROVSKAYA, PERRET & MEISCHNER; Pa elements, oral view
borehole Grabowiec *IG-3* (depth 1414 m), × 60

4-5 — *Lochriea* cf. *cruciformis* (CLARKE); Pa elements, oral view
4 – borehole Syczyn *IG-4* (depth 1218 m), × 60
5 – borehole Syczyn *IG-4* (depth 1209 m), × 60

6-7 — *Lochriea cruciformis* (CLARKE); Pa elements, oral view
6 – borehole Syczyn *IG-4* (depth 1134 m), × 60
7 – borehole Rejowiec *IG-1* (depth 1379 m), × 60

8-9 — *Lochriea nodosa* (BISCHOFF); Pa elements, oral view
8 – borehole Orzechów *IG-22* (depth 1165 m), × 70
9 – borehole Syczyn *IG-4* (depth 1311 m), × 70

10 — *Lochriea mononodosa* RHODES, AUSTIN & DRUCE; Pa element, oral view
borehole Syczyn *IG-4* (depth 1220 m), × 70

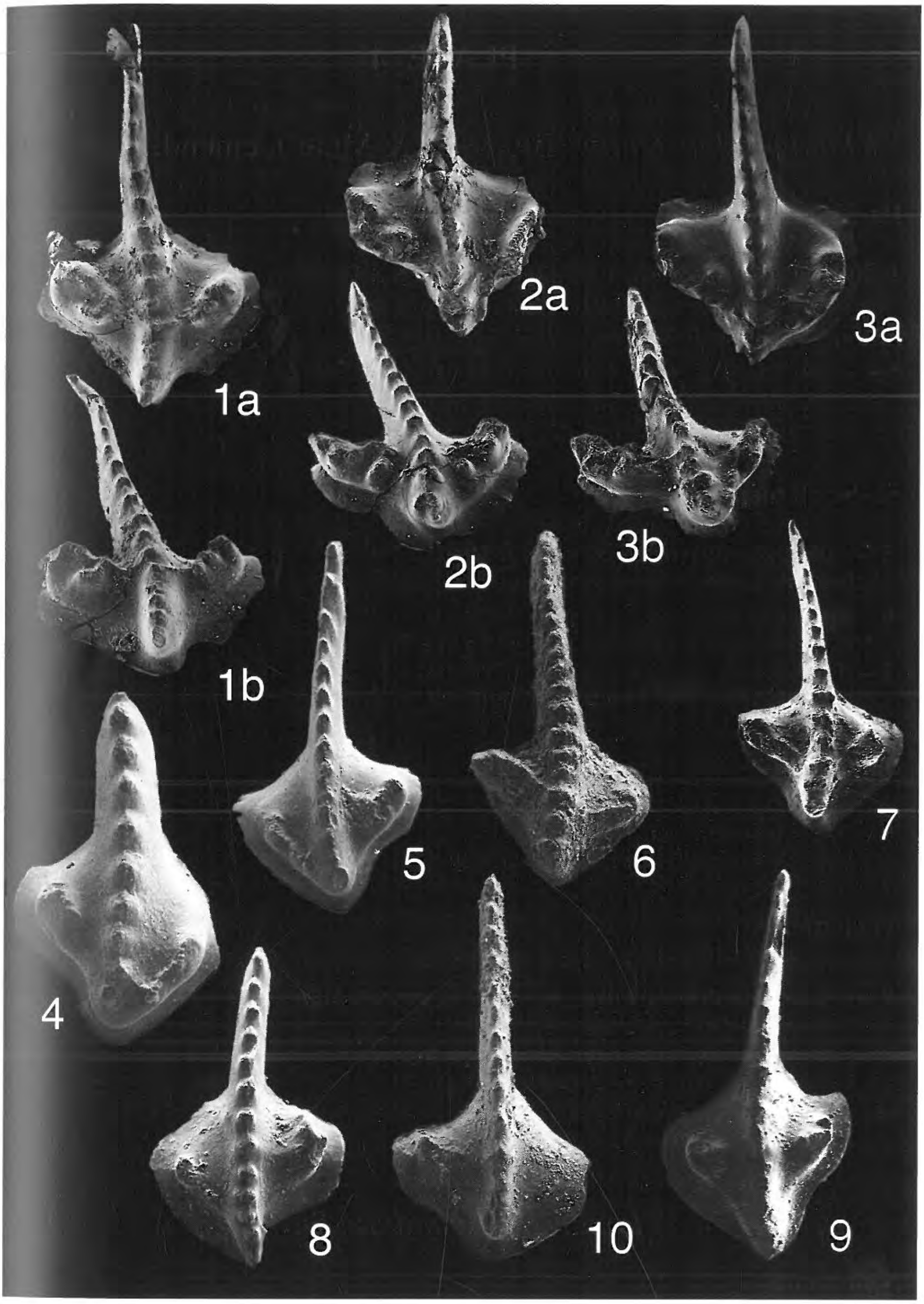
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PLATE 4

Kladognathus tenuis (BRANSON & MEHL), emend. REXROAD

Pa-Pb elements

1-2 — DE *Magnilaterella clarkei* RHODES, AUSTIN & DRUCE
1– borehole Podedwórze *IG-2* (depth 571 m), × 30
2 – borehole Lubartów *IG-3* (depth 1586 m), × 50

3-4 — DE *Magnilaterella contraria* RHODES, AUSTIN & DRUCE
3 – boreholeWyhalew *IG-1* (depth 624 m), × 45
4 – borehole Rudno *IG-1* (depth 740 m), × 45

Sb-Sc elements

5 — DE *Ligonodina tenuis* BRANSON & MEHL
borehole Lubień *IG-1* (depth 715 m), × 70

6 — DE *Ligonodina levis* BRANSON & MEHL
borehole Orzechów *IG-22* (depth 1165 m), × 60

7 — DE *Kladognathus macrodentatus* (HIGGINS)
borehole Telatyn *IG-1* (depth 1313 m), × 60

Sa element

8 — DE *Hibbardella milleri* REXROAD
borehole Rudno *IG-1* (depth 739 m), × 30

M elements

9 — DE *Neoprioniodus scitulus*, juv. spec. (BRANSON & MEHL)
borehole Rudno *IG-1* (depth 740 m), × 50

10 — DE *Neoprioniodus scitulus* (BRANSON & MEHL)
borehole Podedwórze *IG-2* (depth 571 m), × 40

11 — DE *Neoprioniodus peracutus* (HINDE)
borehole Podedwórze *IG-2* (depth 571 m), × 30

Lochriea commutata SCOTT

S elements

12 — DE Neoprioniodus montanaensis (SCOTT)
borehole Podedwórze *IG-2* (depth 571 m), × 30

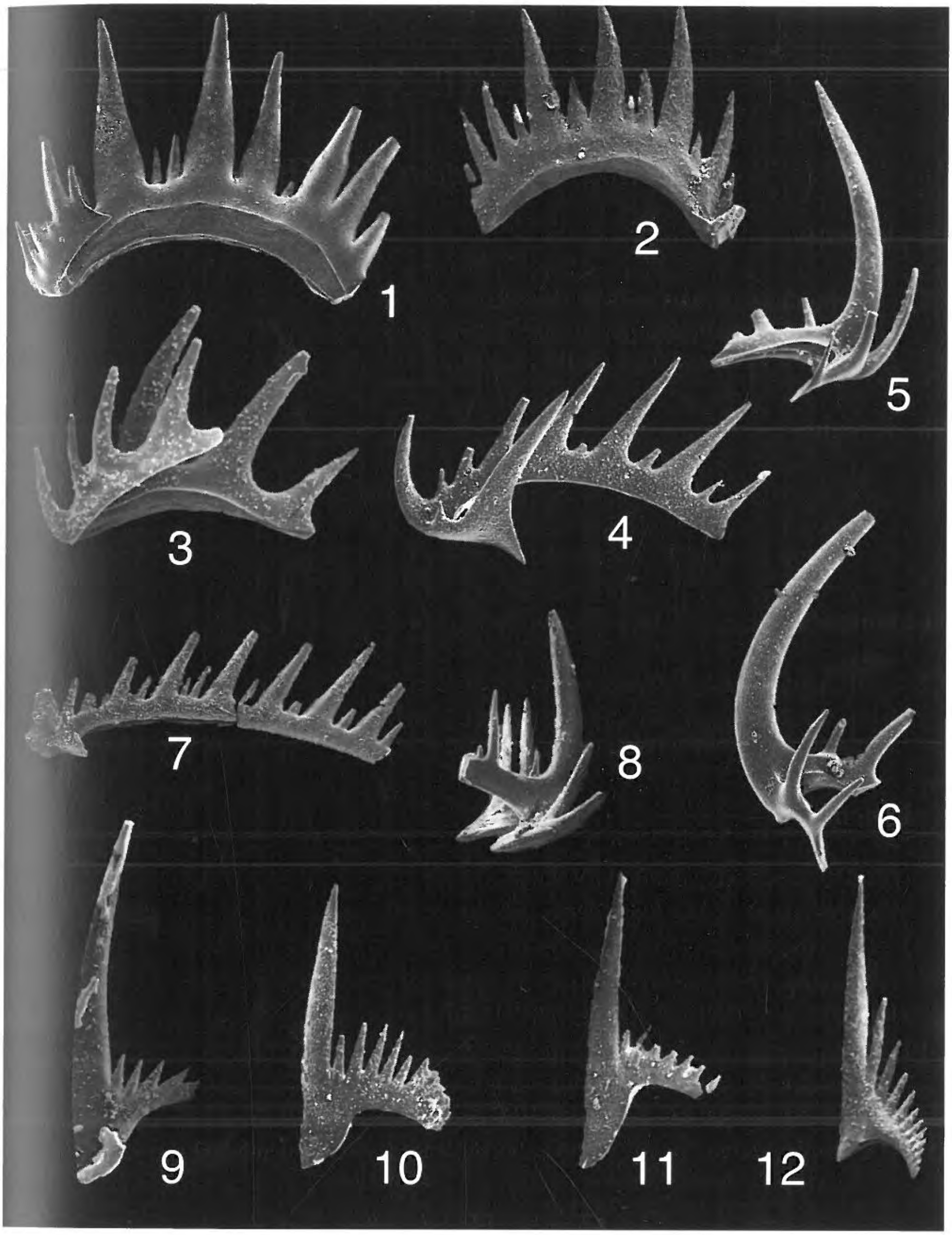
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PLATE 5

Synclydognathus geminus (HINDE)

Pa elements

1-2 — DE *Spathognathodus scitulus* (HINDE)
1 – borehole Podedworze *IG-2* (depth 565 m), × 45
2 – borehole Hostynne *IG-1* (depth 1324 m), × 40

Pb elements

4-5 — DE *Ozarkodina laevipostica* REXROAD & COLLINSON
4 – borehole Telatyn *IG-1* (depth 1287 m), × 30
5 – borehole Rudno *IG-1* (depth 763 m), × 40

M elements

3, 8 — DE *Apatognathus? librata* VARKER
3 – borehole Włodawa *IG-4* (depth 408 m), × 40
8 – borehole Hostynne *IG-1* (depth 1295 m), × 30

S elements

6 — DE *Apatognathus*? *chaulioda* VARKER
6 – borehole Hostynne *IG-1* (depth 1324 m), × 40

7, 12 — DE *Apatognathus*? *scalena* VARKER
7 – borehole Orzechów *IG-2* (depth 892 m), × 30
12 – borehole Orzechów *IG-2* (depth 918 m), × 30

9-10 — DE *Apatognathus*? *gemina* VARKER
9 – borehole Syczyn *IG-4* (depth 1311 m), × 30
10 – borehole Włodawa *IG-4* (depth 385 m), × 35

11 — DE *Apatognathus*? *petila* VARKER; borehole Rudno *IG-1* (depth 763 m), × 35

Genus *Hindeodus*

13-14 — *Hindeodus minutus* (ELLISON); Pa elements
borehole Rudno *IG-1* (depth 740 m), × 30 (Fig. 13), × 50 (Fig. 14)

15 — *Hindeodus cristulus* YOUNQUIST & MILLER; Pa element
borehole Włodawa *IG-4* (depth 381 m), × 100

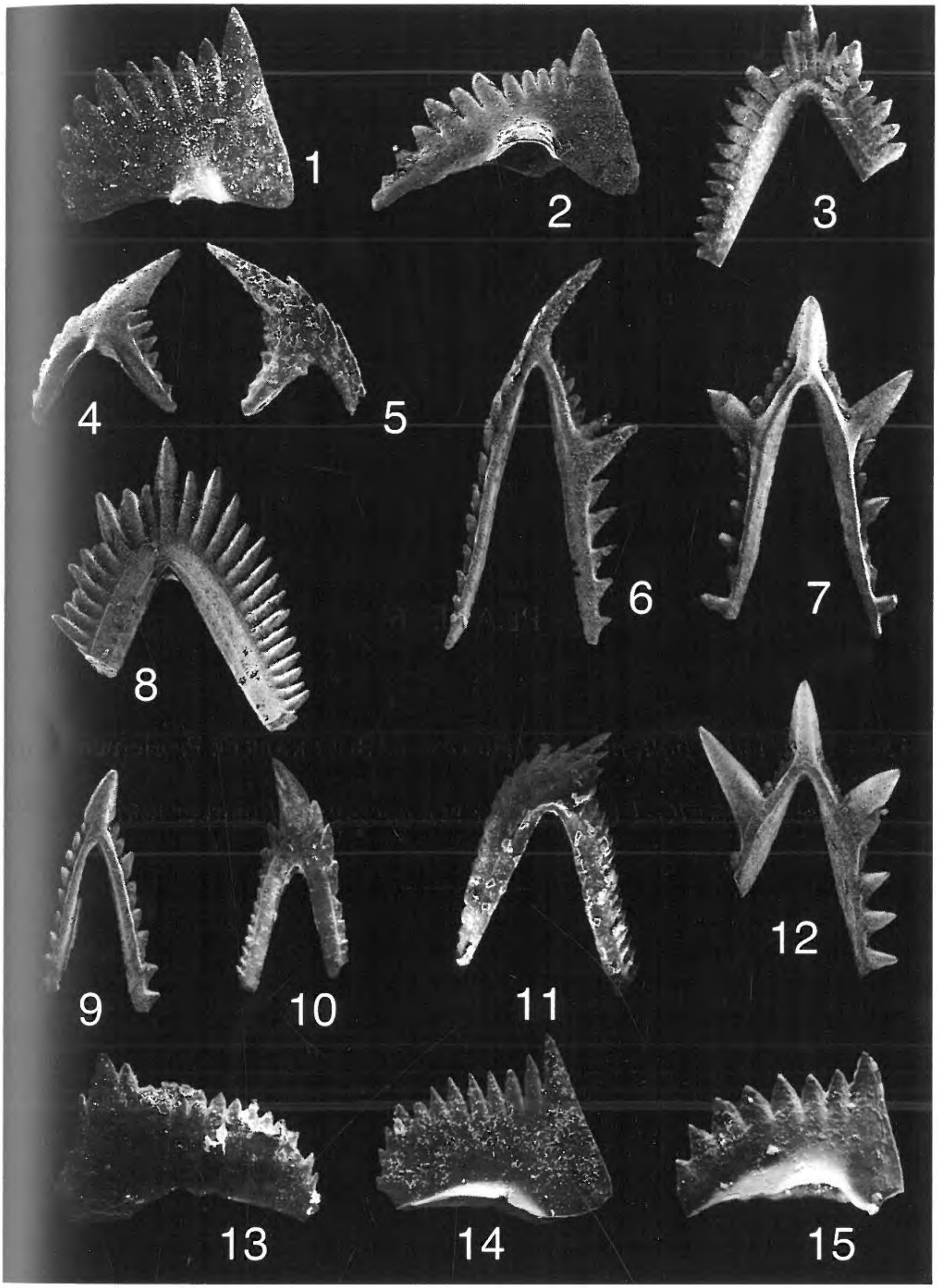
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PLATE 6

1-13 — *Gnathodus bollandensis* (HIGGINS & BOUCKAERT); Pa elements, oral view
borehole Piaski *IG-1* (depth 1131 m), *corrugata I* marker horizon, × 55

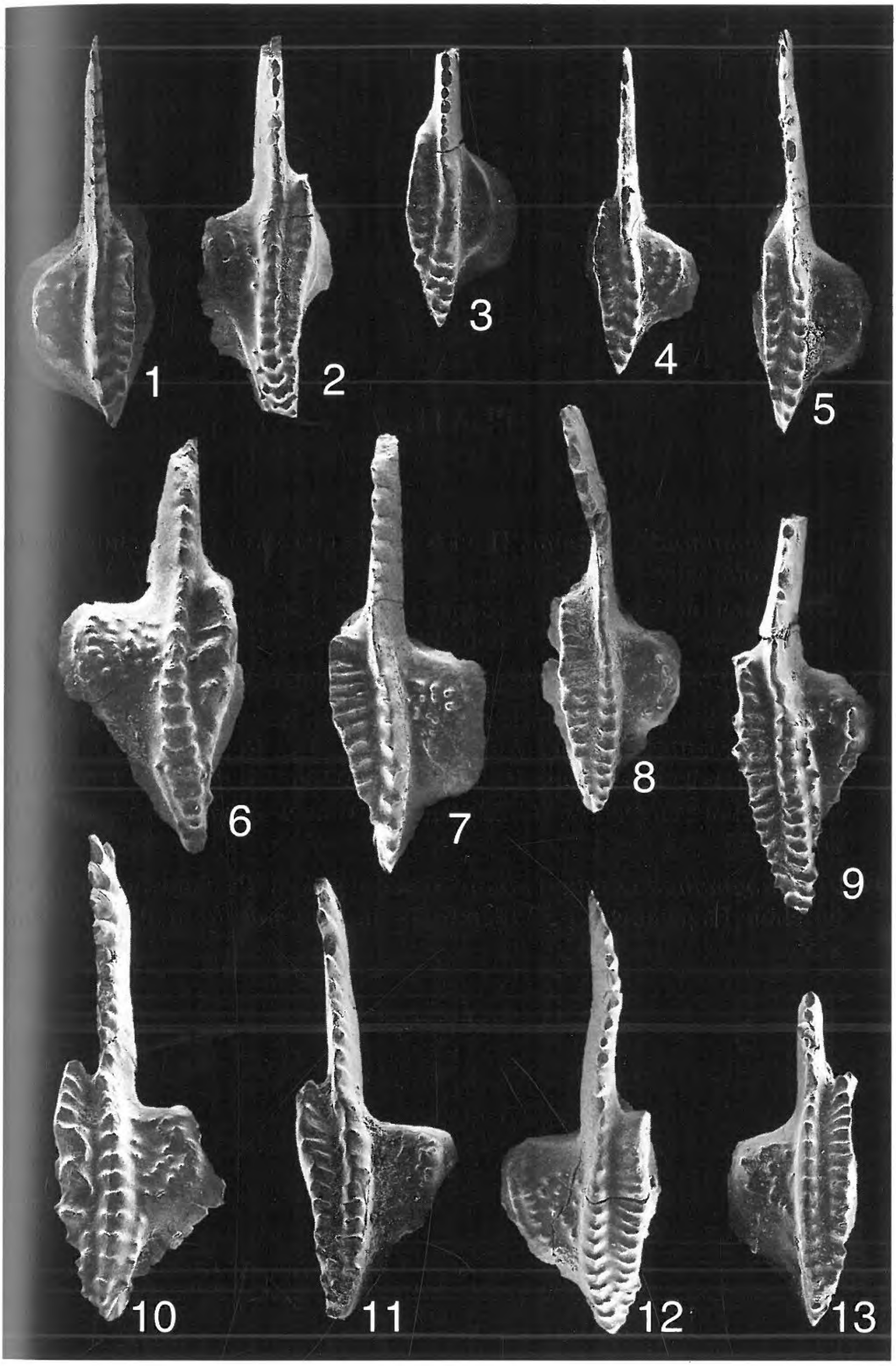
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PLATE 7

1-3 — *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; Pa sinistral elements, oral view
  1-2 – borehole Syczyn *IG-4* (depth 1013 m, Lst. Band *M*), × 75
  3 – borehole Syczyn *IG-4* (depth 1003 m, Lst. Band *N*), × 75

4-8 — *Idiognathoides lanei* NEMIROVSKAYA; Pa elements, oral view
  4 – borehole Lublin *IG-2* (depth 1788 m, Lst. Band *O-P*?), × 50
  5 – borehole Rejowiec *IG-1* (depth 1065 m, Lst. Band *M*), × 60
  6-7 – borehole Grabowiec *IG-1* (depth 1103 m, Lst. Band *O-P*?), × 50
  8 – borehole Orzechów *IG-22* (depth 856 m, *Dunbarella* marker horizon), × 55

9-12 — *Idiognathoides tuberculatus* NEMIROVSKAYA; Pa elements, oral view
borehole Orzechów *IG-22* (depth 864 m, *Dunbarella* marker horizon), × 55

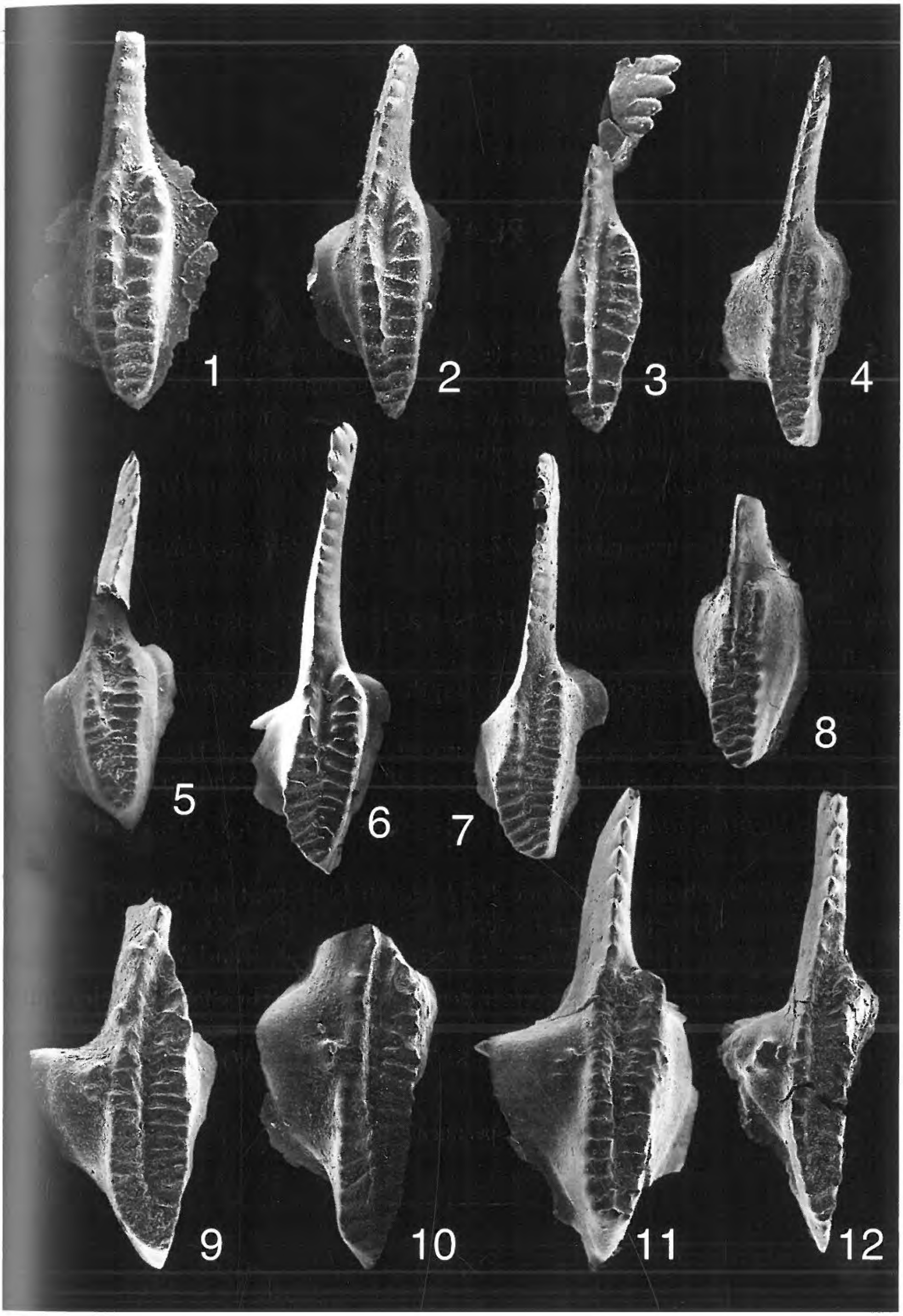
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PLATE 8

1-5 — *Idiognathoides attenuatus* (HARRIS & HOLLINGSWORTH); Pa elements, transition series from young (Fig. 1) to gerontic (Figs 4-5) specimens; note a deepening of the median groove in older specimens

1 – borehole Lublin *IG-2* (depth 1853 m, Lst. Band *N*)

2-3, 5 – borehole Łuków *IG-5* (depth 1982 m, *Dunbarella* marker horizon)

4 – borehole Orzechów *IG-27* (depth 734 m, *Dunbarella* marker horizon)

6-8 — *Idiognathoides sinuatus* HARRIS & HOLLINGSWORTH; Pa dextral elements, oral view

6 – borehole Orzechów *IG-27* (depth 734 m, *Dunbarella* marker horizon)

7 – borehole Tyszowce *IG-1* (depth 887 m, Lst. Band *M*)

8 – borehole Orzechów *IG–27* (depth 819 m, Lst. Band *P*)

9-13 — *Declinognathodus lateralis* (HIGGINS & BOUCKAERT); Pa elements, oral view

9-10, 13 borehole Grabowiec *IG-1* (depth 1131 m, Lst. Band *N*)

11 – borehole Telatyn *IG-1* (depth 731 m, Lst. Band *O*)

12 – borehole Tyszowce *IG–1* (depth 887 m, Lst. Band *M*)

14-15 — *Declinognathodus noduliferus inaequalis* (HIGGINS); Pa elements, oral view

borehole Tyszowce *IG-1* (depth 887 m, Lst. Band *M*)

All specimens × 55

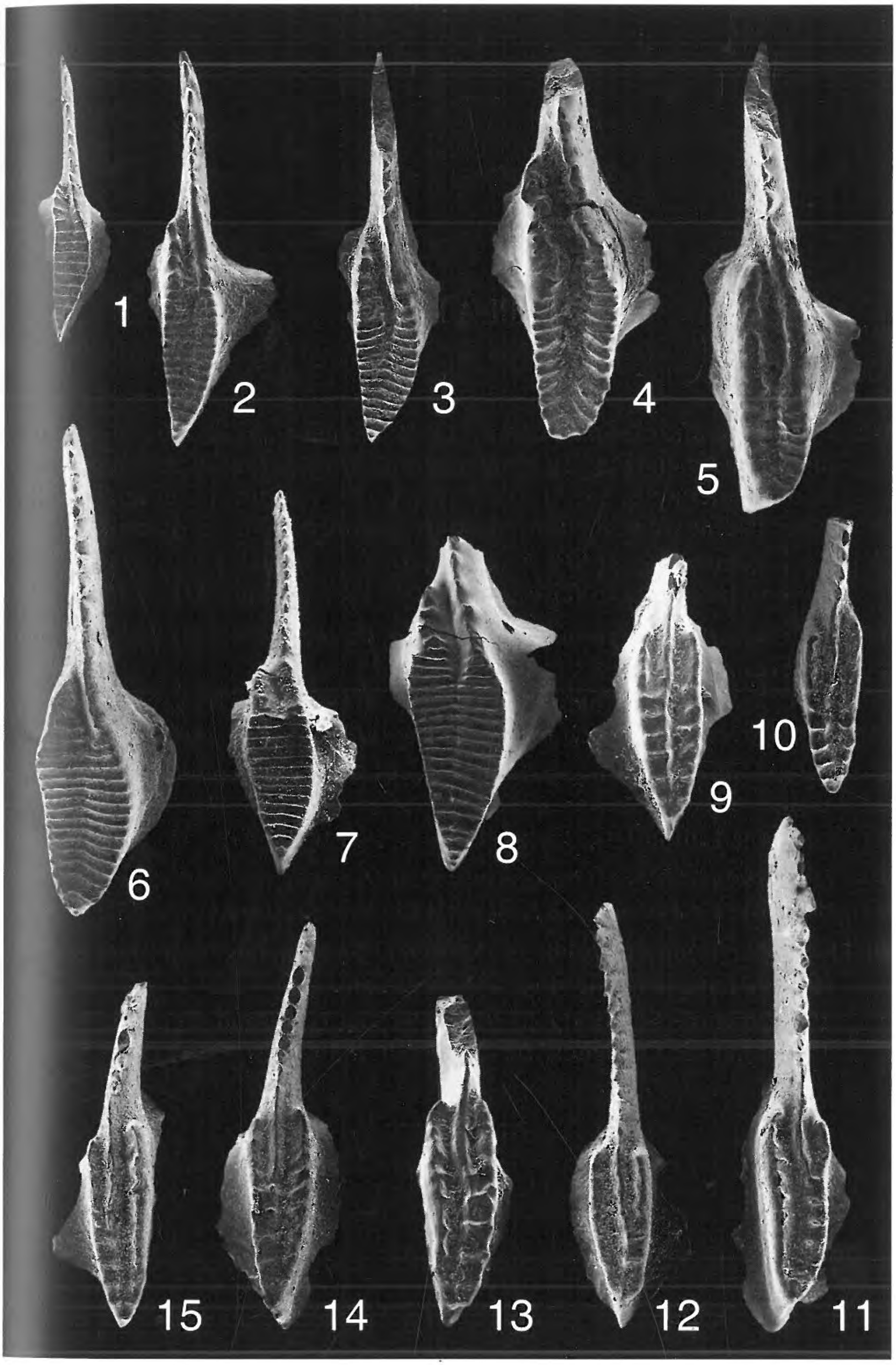
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PLATE 9

1-2 — *Adetognathus lautus* (Gunnell); Pa elements, right- (Fig. 1) and left-sided specimen (Fig. 2), corresponding with *A. lautus* and *A. gigantus* in older literature; 1a, 2a – oral views, 1b – oral/inner lateral view, 2b – outer lateral view; the free blade in specimen (1) is partly broken
1 – borehole Syczyn *IG-4* (depth 1003 m, Lst. Band *N*), × 100
2 – borehole Syczyn *IG-4* (depth 1013 m, Lst. Band *M*), × 100

3-7 — *Neognathodus symmetricus* (Lane); Pa elements, oral and oral/lateral (Figs 4a, 5a) view
3, 5, 7 – borehole £uków *IG-5* (depth 1118 m, Lst. Band *P*), × 55
4, 6 – borehole Orzechów *IG-22* (depth 819 m, Lst. Band *P*), × 55

8 — *Idiognathoides sulcatus* (Higgins & Bouckaert); Pa element, oral view
borehole Lublin *IG-2* (depth 1853 m, Lst. Band *N*), × 55

9 — *Idiognathoides lanei* Nemirovskaya; Pa elements, oral view
borehole Grabowiec *IG-1* (depth 1131 m, Lst. Band *N*), × 75

10-11 — *Neognathodus bothrops* Merrill; Pa elements, oral view of adult (Fig. 10) and herontic (Fig. 11) specimens
10 – borehole Sawin *IG-25* (depth 992 m, Lst. Band *N*), × 55
11 – borehole Orzechów *IG-22* (depth 988 m, Lst. Band *O*), × 55

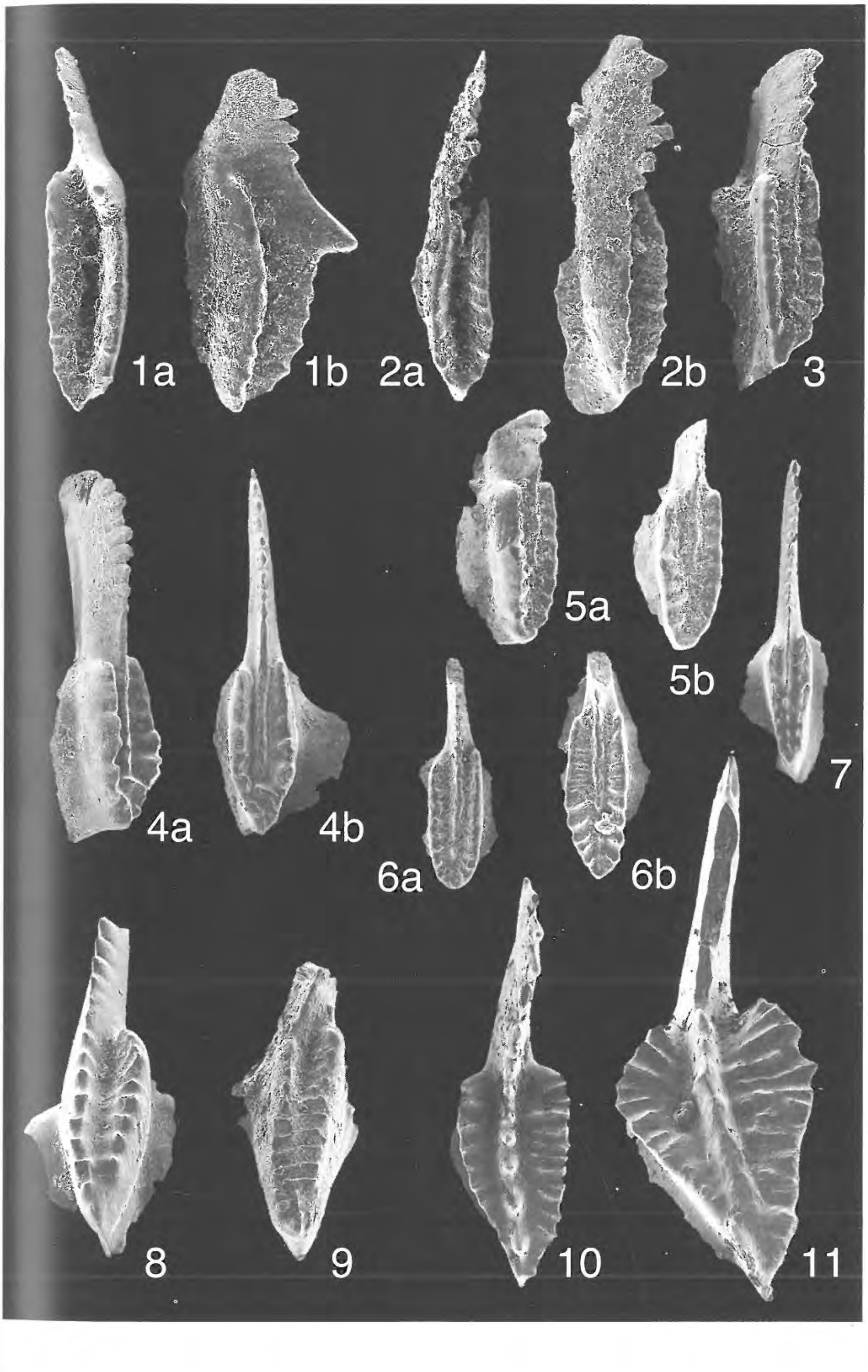
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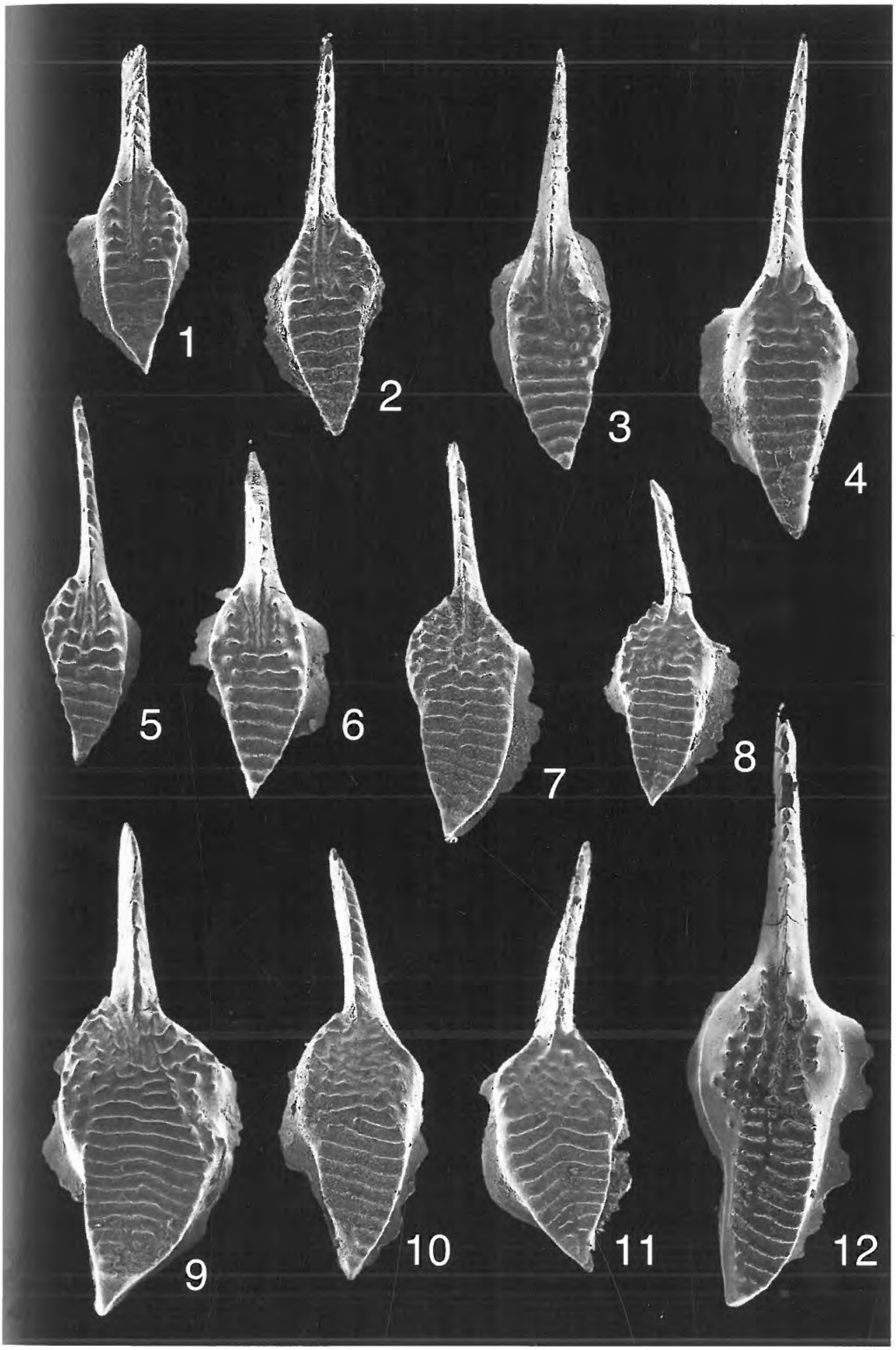
PLATE 10

1-5 — *Idiognathodus sinuosus* ELLISON & GRAVES; Pa elements, oral view
  1, 4 – borehole £uków *IG-5* (depth 1189 m, Lst. Band *N*)
  2 – borehole Lublin *IG-2* (depth 1788 m, Lst. Band *O-P*?)
  3, 5 – borehole Sawin *IG-11* (depth 1003 m, Lst. Band *N*)

6-12 — *Idiognathodus delicatus* GUNNELL; Pa elements, oral view
  6-7 – borehole Tyszowce *IG-1* (depth 887 m, Lst. Band *M*)
  8-10 – borehole Grabowiec *IG-4* (depth 971 m, Lst. Band *M*)
  11 – borehole Orzechów *IG-22* (depth 1014 m, Lst. Band *M*)
  12 – borehole Sawin *IG-11* (depth 1003 m, Lst. Band *N*)

All specimens × 55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REMARKS: In the opinion of the present Author the species *S. libratus* (VARKER) should be included in the species *S. geminus* (HINDE). In distinguishing these two species Rexroad & VARKER (1992) argued that DE *A.*? *gemina* and DE *A.*? *librata* were mutually exclusive and therefore that they belonged to different apparatuses. However, the data from the Lublin Carboniferous Basin indicates that they are present in the same samples and that their local ranges are also similar. This seems to suggest the presence of these two apatognathids in one multielement species and this fact concerns the reconstructed configuration of the *Synclydognathus* apparatus. REXROAD & VARKER (1992) in their diagnosis pointed out that "*...one S element may serve the function of an M element but it is not readily distinguished from other S elements*". The morphology of DE *A.*? *librata* distinctly differs from other apatognathids due to its symmetry, and it seems possible that this alate element could function as an M element. The specific role of DE *A.*? *librata* was stressed also by PURNELL (1992), who placed this element in the Sa position in his apparatus "*Apatognathus*"? *cuspidatus* (VARKER).

OCCURRENCE: Lublin Carboniferous Basin - Huczwa and the lower part of the Terebin Formations (Lst. complex *A1* to Lst. Band *G*); England - *S. libratus* (*sensu*) disappears somewhat later (in the beginning of Pendleian) that *S. geminus* (uppermost Brigantian) [(!) the ranges of these taxa are inversely marked in REXROAD & VARKER 1992, Fig. 2]; in other European occurrences apatognathid elements are extremely sporadic.

CALCAREOUS ALGAE AND MICROPROBLEMATICS

REMARKS ON THE TAXONOMY

The calcareous algae have been found in nearly all limestone bands, except of the interval from the Lst. Band *H* to Lst. Band *K*, situated in the middle part of the paralic sequence (Text-fig. 7). The particular intervals of the sections from the individual boreholes and description of several selected species have been presented in former papers of the Author (SKOMPSKI 1981, 1982, 1986, 1987, 1993, SKOMPSKI & *al.* 1989). In the present paper these data are restated respecting the entire area of the Basin and the complete sequence. In the systematic part only taxa the most problematic from taxonomic point of view are presented: *Anthracoporellopsis*, *Archaeolithophyllum* and *Masloviporidium*. The other taxa are only characterized below in short informal comments.

The absence of algae in the middle part of the investigated succession in natural way divides them into two assemblages. The older one is very rich in respect of number of specimens as well as the taxonomic diversity. Particularly abundant is the group of Dasycladales, in which the paleoberesellids are of great importance. In the northeastern part of the Basin this group is represented by *Kamaena delicata*, *K. awirsi*, *Kamaenella denbighi* and forms similar to the genera *Palaeoberesella* and *Exvotarisella*, which probably are diagenetically changed specimens of *Kamaena* (SKOMPSKI 1986). The investigations in other parts of basin did not furnish additional species. The taxonomic position of the family Palaeoberesellaceae *sensu* SHUYSKY (1987) is still a subject of controversy (*cf*. review of older opinions *in*: SKOMPSKI 1987), especially in the light of concepts presented by BERGER & KAEVER (1992) in their monographic description of fossil and living Dasycladales. They excluded the family Beresellaceae and subordinated tribe Paleoberesselleae from the Dasycladales arguing that "*...septation of the central cavity (central cylinder) by septa or septalike structures are not known in Dasycladales...*". Another opinion has been expressed by DELOFFRE (1987, 1988), who introduced the tribe Beresellaceae, the family Palaeoberesselleae including, into the order Dasycladales, contrary to the earlier opinion of the French group of algologists (BASSOULLET & *al*. 1979). SHUYSKY (1985, 1987) questioned the dasycladacean affinity of the discussed group and proposed the new suborder Palaeosiphonocladales (order Siphonocladales) containing the family Palaeoberesselleae (under the name Palaeoberesellaceae). His argumentation is based on the apparent similarity of the investigated forms to the living Siphonocladales. However, this affiliation of the Paleozoic forms does not resolve the nature of "septation", and this crucial point in his classification is not adequately documented or simply erroneous. The sections, presented by SHUYSKY (1987, Fig. III.37), are not axial but peripheral, and they suggest only seemingly a presence of partitions, analogous to those observed in the living algae (*see* SHUYSKY 1987, Fig.

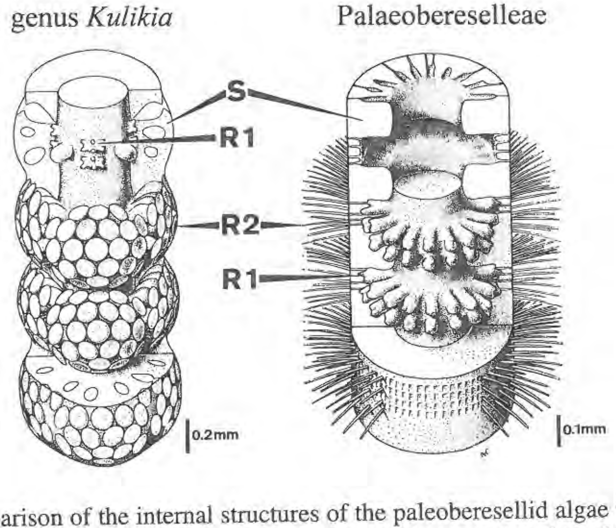
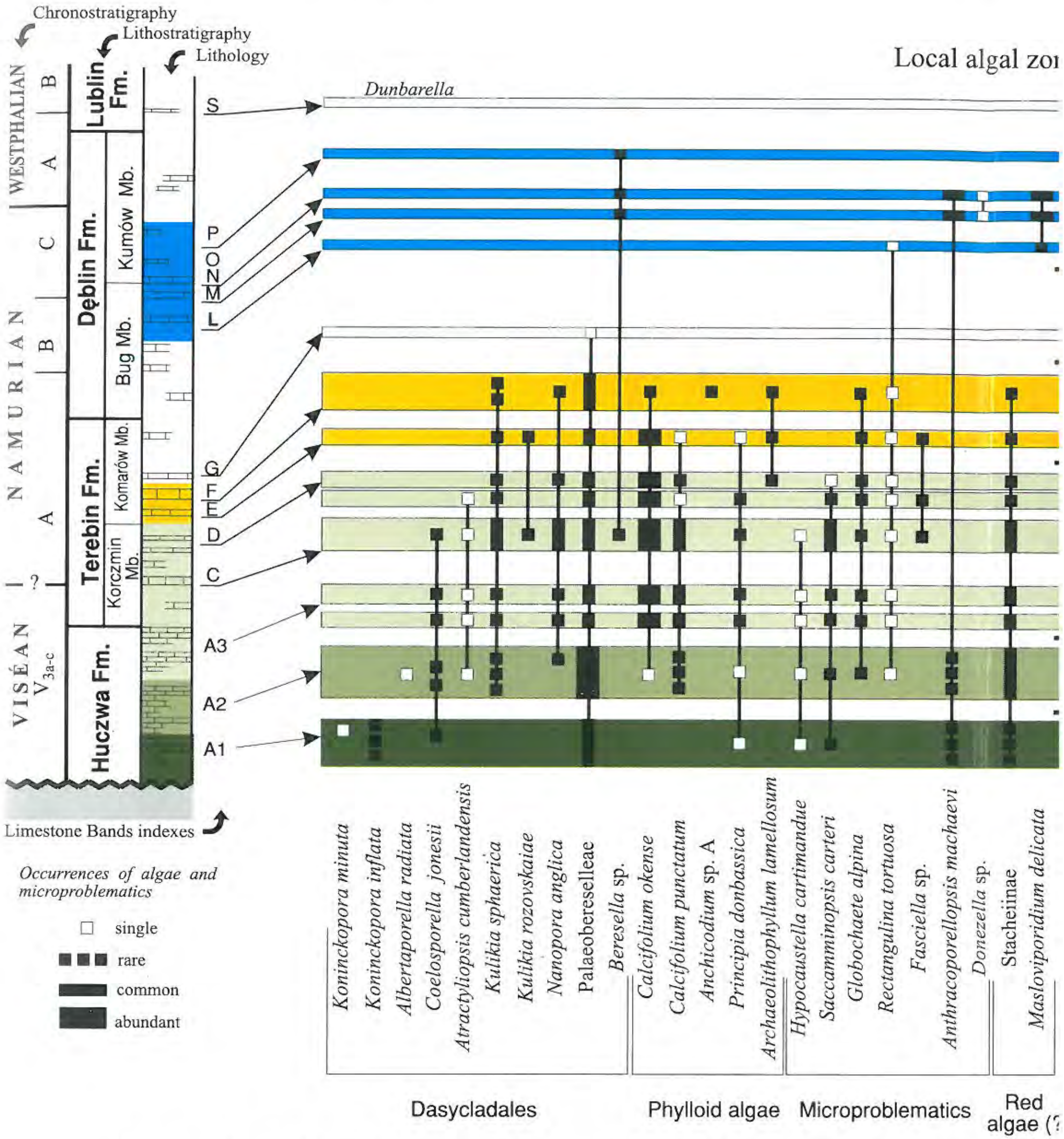


Fig. 8. Comparison of the internal structures of the paleoberesellid algae with typical metaspondyl dasycladacean genus *Kulikia* (GOLUBTSOV); reconstruction of the paleoberesellid algae *after* SKOMPSKI (1987)

S – calcareous coats, **R1** – 1*st* order laterals, **R2** – 2*nd* order laterals

Designed by B. WAKSMUNDZKI, M.Sc.

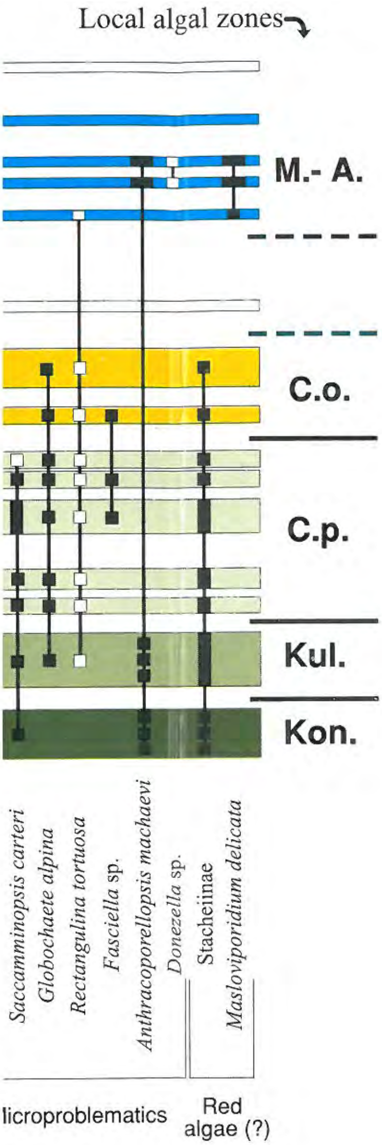


Ranges of algal and microproblematical taxa in the paralic succession of the Lublin Carboniferous Basin

Abbreviations of algal zones: **Kon.** – Koninckopora, **Kul.** – Kulikia sphaerica, **C.p.** – Calcifolium punc
C.o. – Calcifolium okense, **M.-A.** – Masloviporidium-Anthracoporellopsis

Stratigraphic column as in Text-fig. 6

S. SKOMPSKI, FIG. 7



aralic succession

C.p. – Calcifolium punctatum,
hracoporellopsis

III.36). The specimens from the Lublin Basin presented by SKOMPSKI (1987) reveal the presence of more or less regular whorls of laterals. The present Author explained the formation of perpendicular semi-partitions as an effect of specific calcification around the laterals, which is more comparable to annulation process (typical for Dasycladales) than to formation of real septa. A comparison of the morphological details of paleoberesellids with those characteristic of unquestionable dasyclad algae *Kulikia* (Text-fig. 8) shows the correctness of dasycladacean affiliation of the discussed group. However, it should be accepted that the paleoberesellids are a heterogenous group. Most different from the other taxa is the genus *Anthracoporellopsis*, the taxonomic relation of which will be discussed in the systematic part of this work.

The taxonomic position of the genus *Koninckopora* seems to be more problematic. Although this taxon is considered as dasycladacean algae by most of specialists studying the fossil forms, BERGER & KAEVER (1992) doubt accuracy of this classification. The basic difference in relation to other Dasycladales is in the micritic structure of the wall, indicating primary calcitic skeleton of this form. The specimens from the Lublin Basin are extremely rare, poorly preserved, and represent two species: *K. inflata* (DE KONINCK) and *K. minuta* WEYER (Pl. 13, Figs 4-7). They do not afford new arguments for the solution of the above reported controversy, although they represent both commonly found forms of preservation (with, or without, the hyaline acicular layer). Traditionally, the present Author consider this taxon as a member of Dasycladales.

The dasycladacean position of the other taxa typical of older assemblage (Text-fig. 7) is not questioned. Especially ubiquitous are two species of the genus *Kulikia*: *K. sphaerica* and *K. rozovskaiae*. On the contrary, the species *Nanopora anglica* rarely occurred, but usually in a rock forming quantity, interpreted as nearshore shoal accumulations (SKOMPSKI 1993).

The second important group in the older assemblage are the conventionally distinguished phylloid algae. This designation proposed by PRAY & WRAY (1963) is based only on the perfunctory similarity of external morphology of the taxa included. On the other hand, their real taxonomic affiliation is still a subject of extremely controversial opinions (for review *see* BAARS & TORRES 1991), what in some extent justifies the usage of this artificially separated unit. It is possible to include the leaf-like taxa found in the Lublin Basin into the green algae, which show some affinities to the families Udoteaceae (genus *Calcifolium*) and Codiaceae (genus *Anchicodium*), or into the red algae (genera *Archaeolithophyllum* and *Principia*). The taxa representing the family Udoteaceae are characterized by internal medullar filaments which curve outwards and form exterior cortical layer (MU 1991, RIDING 1993). This feature as well as a fan-like form of the thallus, analogous to the living alga *Udotea* are representative of both species of *Calcifolium*, as presented by the present Author formerly (SKOMPSKI 1981) and in this paper (Pl. 16, Figs 5-6). More problematic is taxonomic affiliation of the genus *Anchicodium*, represented here only by single specimens (Pl. 16, Figs 1-3). BAARS & TORRES (1991, *see also* TORRES & BAARS 1992) shook an opinion about the leaf-like form of this alga and they indicated its cylindrical and branched morphology. However, they pointed for a similarity of this taxon to the recent *Codium*, consistently with an intention of the creator of the genus name (JOHNSON 1946). The two recently living families, Codiaceae and Udoteaceae, are characterized by siphonaceous internal structures and they differ only in the presence of specialized gametangia. The fossil material does not enable precise discrimination of these groups. Nevertheless, the genera *Calcifolium* and *Anchicodium* (sensu TORRES & BAARS 1992), together with the genus *Eugonophyllum* (with medullar filaments reported by KIRKLAND & *al*. 1991), or the newly described genus *Calcipatera* (TORRES & *al*. 1992), compose a distinctly separated group of green algae, which was distinguished by SHUYSKY (1987, definition and complete list of the taxa included) as the family Anchicodiaceae.

The remaining two genera reported here as phylloid algae, *Archaeolithophyllum* and *Principia* represent the internal structures characteristic of the red algae ("ancestral corallines"), and, moreover, are phylogenetically connected (*cf*. BRENCKLE & *al*. 1982, VACHARD & *al*. 1991). VACHARD & *al*. (1989) suggested on the base of series of diagenetically changed specimens, that phylloid pseudoalgae *Anchicodium*, *Eugonophyllum*, and *Ivanovia* are only recrystallized forms of *Archaeolithophyllum*, with the microborings made by bacteria, fungi and endolithic algae. In the context of the above presented remarks on the taxonomic position of other phylloid algae, it seems that this idea is weakly documented. However, it does not exclude that the recrystallization and bioerosion often makes difficult a precise recognition of the taxa.

The controversial red algae from the family Stacheiinae are relatively rare but regularly scattered in the lower portion of the section. The investigations in the southern part of the Basin enriched the assemblage recognized in the northeastern area (SKOMPSKI 1986) with the species *Epistacheoides nephroformis* (Pl. 13, Figs 1-3), found in some samples from the borehole Kumów *IG-3*. The rock-forming accumulations of the Stacheiinae, limited to one thin limestone layer in the Włodawa-Łuków region, appeared to be a local phenomenon.

In the upper part of the paralic section the group of problematic red algae is also represented by a taxon with controversial taxonomic affiliation: the species *Masloviporidium delicata* (BERCHENKO) that occurs in the rock-forming amount, and was recognized not only in the thin sections but also in three-dimensional specimens. This allowed to precise the characteristic of this world-wide known, but still enigmatic taxon.

The significant share in the discussed assemblage has a group of microproblematics, containing 7 taxa (Text-fig. 7). Two of them, *Globochaete alpina* and *Saccamminopsis carteri* have been a subject of separate papers (SKOMPSKI 1982, 1993). According to the suggestions of the present Author the former taxon (Pl. 16, Fig. 4) comprises the single-cell and chain-like forms as well as aciniform associations, of which the Carboniferous representants are usually included to the genus *Nostocites* MASLOV (*cf.* discussion *in*: SKOMPSKI 1982, 1986 - with older references, MAMET & PINARD 1985, GROVES 1986, VACHARD & BECKARY 1991). This discrimination seems to be rational from the paleoecological point of view, since the single cell and chain-like forms are characteristic for pelagic environment (BEŁKA & SKOMPSKI 1988, VACHARD *in*: PERRET & *al.* 1994 – nodular limestones preceding Culm sedimentation; BELKA & *al.* 1996 – globochaetids in the pelagic cover of the allodapic limestones, situated in the Culm succession). More complex, aggregated forms are typical of shallow water sediments. However, the incomplete diagnoses of *Nostocites* (MASLOV 1929, 1956) do not give a base for such discrimination of these two genera from the pure taxonomic and formal point of view. The revised diagnosis of *Nostocites*, presented by GROVES (1983, 1986) and its description by VACHARD & BECKARY (1991, *see also* comparison of *Globochaete* and *Nostocites* presented by VACHARD *in* PERRET & *al.* 1994) emphasized sheet-like (tablet-shaped) morphology of the complex specimens. The specimens from the Lublin Basin (*see* SKOMPSKI 1982, Pl. 1, Figs 1-2; *and* Pl. 16, Fig. 4 in this paper) suggest more isometric (spherical) form of the cell associations.

The taxonomic position of the microproblematic *Saccamminopsis* (SOLLAS) is still unsolved. Although the perfectly preserved specimens from the borehole Syczyn *IG-4* (SKOMPSKI 1993) reveal perforated structure of the wall, this feature do not resolve the problem of affiliation to algae or foraminifers. The newly erected genus *Baculella* CONIL & DREESEN (*in*: DREESEN & *al.* 1985) is a synonym of *Saccamminopsis*, what is indicated by identical external morphology and analogously perforated microstructure of the wall (*cf.* MATYJA 1993). The same remark considers the genus *Dreesenulella* VACHARD – the rename of *Baculella* into *Dresenulella* postulated by VACHARD (1991) is inconsiderable and groundless.

From the remaining 5 microproblematical taxa, 4 of them: *Rectangulina tortuosa, Hypocaustella cartimandue, Fasciella* sp., and *Donezella* sp. appear sporadically and the specimens do not stray from those hitherto described and illustrated. In contrast the species

Anthracoporellopsis machaevi occurs in rock-forming amount in the upper portion of paralic succession, and details of the excellently preserved internal moulds surprisingly contradict an algal nature of this form.

STRATIGRAPHIC IMPLICATIONS

An analysis of the distribution of algae and microproblematics through the entire Basin and complete sequence sheds new light on the stratigraphic position of the limestones bands. Generally, the Carboniferous calcareous algae are dominated by long-ranging taxa and cannot be used for precise correlation (MAMET 1991). Fortunately, the genera *Calcifolium* and *Koninckopora* are the exceptions of this only right conclusion. The stratigraphic significance of algae abruptly increases when we compare the sections from analogous paleoenvironmental zones, *e.g.* the Lublin area with Wensleydale region in northern England – the type area of the Yoredale facies, or the Lvov-Volhynian Basin (Text-fig. 11). A possibility of application of algae for identification and correlation of limestone complexes in the Lublin Basin was formerly indicated by the present Author (SKOMPSKI 1981, 1986). The regional and stratigraphic broadening of the scope of investigations beyond the peripheral part of the basin, allowed the more advanced conclusions. The appearance of algal taxa is usually strictly environmentally controlled. However, in the investigated succession the microfacies analysis indicated relatively stabile and insignificantly diverse facies spectrum both in the Viséan as well as in the Namurian carbonate strata. In both lower units, Huczwa Fm. and Terebin Fm. the limestone complexes are more or less dominated by algae, which form comparatively homogeneous assemblages, composed mostly of Dasycladales and phylloid algae, but devoid of typical Solenoporaceae. Constancy of environment during carbonate sedimentation, together with very similar sequence of taxa in analogous areas (*cf.* Text-fig. 11) allows to strengthen the importance of algae as stratigraphic indicators.

To the most important genera in the investigated assemblage belong *Calcifolium* and *Koninckopora*. HALLETT (1970) and MAMET & ROUX (1975) indicated that two species of *Calcifolium, C. punctatum* and *C. okense,* appeared in different basins of the western Paleotethys in constant sequence. *C. punctatum* occurred and became extinct slightly earlier than *C. okense*. Moreover, the extinction of *C. punctatum* is coincident with the boundary between Viséan and Namurian. The more recent data from the Dneper-Donets Basin, Moscow Basin, and the northern Urals as well as from the Pyrenees confirm such a relation these two species of *Calcifolium*, but the extinction of *C. punctatum* is shifted slightly higher to the lowermost Namurian, that is the Serpukhovian (YABLOKOV & *al.* 1975; TCHERMNYKH 1976; BERCHENKO 1983; IVANOVA & BOGUSH 1992; CHUVASHOV & *al.* 1993; MAKHLINA & *al.* 1991, 1993; DELVOLVÉ & *al.* 1994). In the Lublin Basin the most specific point in the succession of *Calcifolium* species is the beginning of the abundant, rock forming appearance of *C. okense* (asterisked in the Text-fig. 10). In one section only (Orzechów *IG-27*) the mass-occurrences of *C. okense* is followed by the appearance of a single specimen in the older layer.

The genus *Koninckopora* does not extend usually beyond the Upper Viséan (MAMET 1991), although IVANOVA & BOGUSH (1992) reported it also from the Lower Serpukhovian. However, in western Europe *Koninckopora* only rarely occurs in the strata younger than Asbian (HALLETT 1970, SOMERVILLE & STRANK 1984 – Great Britain, PAPROTH & *al.* 1983 – Belgium; *see* discussion *in*: VACHARD & BERKHLI 1992). In the Yoredale area the youngest *Koninckopora* was found in the Great Scar Lst. (*cf.* Text-fig. 11).

Another possibility of stratigraphic application of calcareous algae was pointed by VACHARD (1991) and BERKHLI & *al.* (1993). They proposed the phylogenetic relation between the genus *Principia* (ancestor) and the genus *Archaeolithophyllum* (successor). The extinction of *Principia*, similarly to *C. punctatum*, seems to be good indicator of the Viséan/Namurian boundary (data from France, Spain, Morocco, Algeria, Germany). The material from Poland generally confirms this recognition.

Other taxa, frequently found in the investigated succession are typical of the late Viséan/early Namurian interval *(Kulikia*, *Nanopora*, *Coelosporella*, *Saccamminopsis*) or have longer ranges (*Anthracoporellopsis*, Palaeobereselleae, Stachaeiinae, *Masloviporidium*).

The review presented above points for promising significance of the calcareous algae in the late Viséan/early Namurian interval, which from the biostratigraphic point of view is generally low diverse and difficult to correlation (*cf.* discussion *in* SKOMPSKI & *al.* 1995). The following 5 local algal zones are proposed. They have geographically restricted significance and only two Calcifolium zones appear to be more universally distributed and useful in the whole area of the genus occurrences.

Koninckopora Zone

The lower boundary of this taxon-range zone is coincident with the Tournaisian/Viséan boundary (MAMET 1991) and is not observed in the Lublin Carboniferous Basin. The upper boundary is defined as the last occurrence of the index taxon; in the investigated sequence it is coincident with the top of limestone complex *A1*. Rare specimens of *Koninckopora* are associated with paleoberesellids, stacheinids, rare *Anthracoporellopsis* and oldest occurrences of *Coelosporella*.

Kulikia sphaerica Zone

Formally this is consecutive-range zone of the species *Kulikia sphaerica*. The lower boundary is defined as the first occurrence of the species *Kulikia sphaerica* (with unique state of preservation - *cf*. SKOMPSKI 1984), the upper boundary is the beginning of mass-occurrence of *C. okense*. Another possibility is to consider this zone as consecutive-range zone of the species *Calcifolium punctatum*, limited by the upper boundary by mass-occurrence of *C. okense*. However, this taxon is proposed as the index for the younger concurrent-range zone, and therefore the present Author decided to give the name of characteristic and abundant dasycladacean taxon. The zone corresponds with limestone complex *A2* and is easy to recognize due to the abundance of rock-forming paleoberesellids. A distinction of zone is facilitated by the relatively abundant appearance of the dasycladacean genera: *Coelosporella* and *Nanopora*, as well as other associated taxa: *Saccamminopsis* and stacheinids.

Calcifolium punctatum Zone

The lower boundary is defined as the beginning of mass-occurrences of *Calcifolium okense*, the upper boundary is the last (regular) occurrence *of C. punctatum*. The characteristic feature of this concurrent range zone is the presence of both species of *Calcifolium*, from which *C. okense* appears regularly and often in the rock-forming amount. The zone corresponds to the interval including the complex *A3* to the Lst. Band *D*. *Calcifolium punctatum* practically disappeared in the Lst. Band *D*; only single specimen has been found in the Lst. Band *E* (borehole Rejowiec *IG-1*). The associated assemblage is extremely rich, and composed primarily of *Coelosporella*, *Kulikia*, *Nanopora, Principia*, *Saccamminopsis*, *Globochaete*, and stacheinids. In the uppermost part appears the genus *Archaeolithophyllum*.

Calcifolium okense Zone

The lower boundary of this consecutive-range zone is the last (regular) appearance of *C. punctatum*; the upper boundary is the last appearance of *C. okense*. The associated taxa are restricted practically to *Kulikia*, to the lowermost Namurian, that is the Serpukhovian (YABLOKOV & *al.* 1975; TCHERMNYKH 1976; BERCHENKO 1983; IVANOVA & BOGUSH 1992; CHUVASHOV & *al.* 1993; MAKHLINA & *al.* 1991, 1993; DELVOLVÉ & *al.* 1994). In the Lublin Basin the most specific point in the succession of *Calcifolium* species is the beginning of the abundant, rock forming appearance of *C. okense* (asterisked in the Text-fig. 10). In one section only (Orzechów *IG-27*) the mass-occurrences of *C. okense* is followed by the appearance of a single specimen in the older layer.

The genus *Koninckopora* does not extend usually beyond the Upper Viséan (MAMET 1991), although IVANOVA & BOGUSH (1992) reported it also from the Lower Serpukhovian. However, in western Europe *Koninckopora* only rarely occurs in the strata younger than Asbian (HALLETT 1970, SOMERVILLE & STRANK 1984 – Great Britain, PAPROTH & *al.* 1983 – Belgium; *see* discussion *in*: VACHARD & BERKHLI 1992). In the Yoredale area the youngest *Koninckopora* was found in the Great Scar Lst. (*cf.* Text-fig. 11).

Another possibility of stratigraphic application of calcareous algae was pointed by VACHARD (1991) and BERKHLI & *al.* (1993). They proposed the phylogenetic relation between the genus *Principia* (ancestor) and the genus *Archaeolithophyllum* (successor). The extinction of *Principia*, similarly to *C. punctatum*, seems to be good indicator of the Viséan/Namurian boundary (data from France, Spain, Morocco, Algeria, Germany). The material from Poland generally confirms this recognition.

Other taxa, frequently found in the investigated succession are typical of the late Viséan/early Namurian interval (*Kulikia*, *Nanopora*, *Coelosporella*, *Saccamminopsis*) or have longer ranges (*Anthracoporellopsis*, Palaeobereselleae, Stachaeiinae, *Masloviporidium*).

The review presented above points for promising significance of the calcareous algae in the late Viséan/early Namurian interval, which from the biostratigraphic point of view is generally low diverse and difficult to correlation (*cf.* discussion *in* SKOMPSKI & *al.* 1995). The following 5 local algal zones are proposed. They have geographically restricted significance and only two Calcifolium zones appear to be more universally distributed and useful in the whole area of the genus occurrences.

Koninckopora Zone

The lower boundary of this taxon-range zone is coincident with the Tournaisian/Viséan boundary (MAMET 1991) and is not observed in the Lublin Carboniferous Basin. The upper boundary is defined as the last occurrence of the index taxon; in the investigated sequence it is coincident with the top of limestone complex *A1*. Rare specimens of *Koninckopora* are associated with paleoberesellids, stacheinids, rare *Anthracoporellopsis* and oldest occurrences of *Coelosporella*.

Kulikia sphaerica Zone

Formally this is consecutive-range zone of the species *Kulikia sphaerica*. The lower boundary is defined as the first occurrence of the species *Kulikia sphaerica* (with unique state of preservation - *cf*. SKOMPSKI 1984), the upper boundary is the beginning of mass-occurrence of *C. okense*. Another possibility is to consider this zone as consecutive-range zone of the species *Calcifolium punctatum*, limited by the upper boundary by mass-occurrence of *C. okense*. However, this taxon is proposed as the index for the younger concurrent-range zone, and therefore the present Author decided to give the name of characteristic and abundant dasycladacean taxon. The zone corresponds with limestone complex *A2* and is easy to recognize due to the abundance of rock-forming paleoberesellids. A distinction of zone is facilitated by the relatively abundant appearance of the dasycladacean genera: *Coelosporella* and *Nanopora*, as well as other associated taxa: *Saccamminopsis* and stacheinids.

Calcifolium punctatum Zone

The lower boundary is defined as the beginning of mass-occurrences of *Calcifolium okense*, the upper boundary is the last (regular) occurrence *of C. punctatum*. The characteristic feature of this concurrent range zone is the presence of both species of *Calcifolium*, from which *C. okense* appears regularly and often in the rock-forming amount. The zone corresponds to the interval including the complex *A3* to the Lst. Band *D*. *Calcifolium punctatum* practically disappeared in the Lst. Band *D*; only single specimen has been found in the Lst. Band *E* (borehole Rejowiec *IG-1*). The associated assemblage is extremely rich, and composed primarily of *Coelosporella*, *Kulikia*, *Nanopora*, *Principia*, *Saccamminopsis*, *Globochaete*, and stacheinids. In the uppermost part appears the genus *Archaeolithophyllum*.

Calcifolium okense Zone

The lower boundary of this consecutive-range zone is the last (regular) appearance of *C. punctatum*; the upper boundary is the last appearance of *C. okense*. The associated taxa are restricted practically to *Kulikia*, *Nanopora*, *Archaeolithophyllum*, rare *Globochaete*, and stacheinide. The zone corresponds to the Lst. Bands *E-F*.

Masloviporidium–Anthracoporellopsis Zone

The zone has quantitative character and it comprises mass-occurrences of both index taxa, which are associated with rare beresellids and single specimens of donezellids. The association is mostly characteristic of the Lst. Bands *M-N* and is separated from older assemblages by a long interval with thin layers of marly and sandy limestones devoid of algae.

The recognition of algal zonation clarifies the spatial arrangement of paralic cyclothems in the lowermost Huczwa Formation. A proposal of a distinction and correlation of the limestone complexes (Text-fig. 10) in the lower part of succession (below Lst. Band *C*) is mostly implication of the analysis of algae distribution.

The Huczwa Fm. and younger Terebin Fm. are similar to each other in their paralic nature, but the lower unit is dominated by the marine deposits (argillaceous shales and carbonates), the share of which in the upper formation is relatively lower. The second difference is lying in the expressiveness of the cyclicity of deposition, which in the Terebin Fm. is considerably more distinct. This feature causes that correlation of limestone bands (or broadly considered complexes) is more clear and safe in the Terebin Formation and for this reason PORZYCKI (1970, 1979, and recent papers) proposed the limestone bands from this Formation as the correlation marker-horizons. PORZYCKI leaved the correlation of limestone complexes in the lower Formation an open question; he recognized a northward thinning as a result of proportional decrease of thickness of particular cyclothems (PORZYCKI & ZDANOWSKI 1995) or pinching of some of them (*e.g.* PORZYCKI 1988, p. 53). This vague conclusion has been based only on general lithology and it is not confirmed by the biostratigraphical data (MUSIAŁ & TABOR 1988, p. 103), since the macrofauna do not allow the internal subdivision of the discussed interval. According to the above mentioned authors the deposits of Huczwa Fm. correspond to the three units of the Upper Viséan: *Go* α, *Go* β and *Go* γ, but precise investigations of the boundaries between them are impossible. Similar conclusions have been presented by SOBOŃ-PODGÓRSKA (1979, 1988) on the base of foraminifers, which belong to zones *14*, *15* and *16* according to the zonation of MAMET & SKIPP (1970).

An occurrence of algal forms explicitly indicates the stratigraphic onlap of succeeding cyclothems. The oldest cyclothems, characterized by limestones with *Koninckopora*, appear in southern region. The deposits dominated by paleoberesellids began a sedimentation in the middle part of the Lublin Basin (vicinity of Orzechów), while in the northern region the carbonate sedimentation did not fully develop before the acme of *Calcifolium*. The onlap interpreted in the macroscale in the whole Basin is also discernible in the local scale, in several boreholes situated near Orzechów (*see* Text-fig. 10). The varied post-volcanic morphology has been leveled here not before the sedimentation of the complex *A3*.

The complex *A1* generally corresponds to the layers with *Koninckopora*, while the complex *A2* to the layers dominated by paleoberesellids. The base of complex *A3* is coincident with mass-occurrences of *Calcifolium okense*, and the sole of Lst. Band *C* is considered as its upper boundary. The Lst. Bands *A* and *B*, distinguished by PORZYCKI, have not been recognized in this proposal, due to their controversial position in sections and a lack of features, which allowed their precise identification. Particularly, this reservation concerns the Lst. Band *A*, which has been primarily distinguished in the southern part of Basin, as a limestone band associated with specific sandstone bed ("Poritzk sandstone" from the Ukrainian part of the Basin). This bed is unknown in the northern part of the area and therefore identification of the limestone is difficult and even mistaken, what is indicated by a comparison of distribution of the algae with the position of the Lst. Band *A* (*cf*. Text-fig. 10). Evidently more safe is correlation of the Lst. Band *C*, which has constant and significant thickness, and is followed by a thin but persistent coal bed. This conclusion effected also on the lithostratigraphic subdivision of the succession, because the lower boundary of the Terebin Fm. has been defined by PORZYCKI & ŻELICHOWSKI (*in:* PORZYCKI 1979) as the sole of Lst. Band *A*. It seems that the acceptation of the Lst. Band *C* as the lower boundary of the Terebin Formation will be more practical solution.

The distinguished algal zones act pretty well as a correlation tool of the Lublin succession with the analogous sequence from the Lvov-Volhynian Basin, in which the vertical succession of algae was investigated by MUROMTSEVA (1979a, 1979b, 1980, 1982). Some differences between Polish and Ukrainian algal assemblages result mainly from different taxonomic concepts (*e.g*. genus *Masloviporidium* is described as *Cuneiphycus*). From among the more important taxa in the Ukrainian assemblage the genera *Principia* and *Archaeolithophyllum* are lacking. The ranges of taxa presented by MUROMTSEVA (1982) confirm the succession from Poland, except of the genus *Koninckopora* and appearance of *Calcifolium punctatum* and *Nanopora*. Unfortunately the papers of MUROMTSEVA are not or poorly illustrated and some range differences seem to be caused by erroneous recognition of the taxa. For example, *Nanopora* cf. *anglica* WOOD illustrated by MUROMTSEVA (1980, Fig. 2) corresponds rather with corroded fragments of echinoderms, than with algae. Similarly to the Polish section, the genera *Kulikia* and *Coelosporella* preceded the mass-appearance of *C. okense*, what allows to specify the interval analogous to the Kulikia sphaerica Zone. The upper boundary of the C. punctatum Zone is not so precisely located, but a distinct decrease of the specimen number of the index taxon permits to estimate its position. The uppermost assemblage in the Lvov-Volhynian Basin is also very restricted in respect to number of taxa, however, its characteristic feature is a lack of *Anthracoporellopsis*, so abundant in the Polish part of the Basin.

The comparison of the taxon-ranges from the investigated area with those from northern England gives a surprisingly convergent results (Text-fig. 11). Although the assemblage seems to be less abundant, the characteristic vertical succession of *Koninckopora* - *Coelosporella* - *Calcifolium* is identical as in Poland. Both discussed areas, the type area of the Yoredale Facies and the Polish-Ukrainian (Lublin-Lvov) Basin represent very similar paleogeographic situation on the southern shelf of the Laurrusian Continent (most internal part of the shelf, separated from the more external regions by deep intracratonic basin, *cf.* generalized paleogeographic map *in:* Skompski & *al.* 1995). This caused that the algal successions, despite of a very long distance between the basins, are also very similar. Under all these limitations of the algal stratigraphy, the correlation of sections proposed (Text-fig. 11) is extremely detailed and considerably exceeds in a precision anyone achieved by means of other groups of fossils, even the conodonts including.

Systematic account of algae and microproblematics

Calcareous algae

Division Rhodophycophyta(?) Papenfuss, 1946
Family undetermined
Genus *Masloviporidium* Groves & Mamet, 1985
Masloviporidium delicata (Berchenko, 1982)
(Pl. 15, Figs 1-6)

1982. *Donezella delicata* sp.n.; O.I. Berchenko, pp. 51-52, Pl. 11, Figs 2-5.

1983. Genus A species A sp.n.; J.H. Groves, p. 26, Pl. 10, Figs 1-9.

1985. *"Masloviporidium"* sp.B; B. Mamet & S. Pinard, Pl. 2, Figs 11, 16.

1985. *Masloviporidium delicata* (Berchenko); J.H. Groves & B. Mamet, pp. 87-89, Figs 2a-i.

1986. *Masloviporidium delicata* (Berchenko); J. Poncet, pp. 190-191, Pl. 3, Figs 1-3.

1986. *Masloviporidium delicata* (Berchenko); J.H. Groves, pp. 485-486, Figs 7.3-7.5 (*with older synonymy*).

1989. *Cuneiphycus aliquantulus* Johnson; D. Vachard & *al.*, p. 709, Pl. 4, Fig. 4 (*only*).

1989. *Masloviporidium delicata* (Berchenko); S. Skompski & *al.*, Pl. 3, Figs 1-3.

1990. *Masloviporidium delicata* (Berchenko); O.I. Bogush & *al.*, pp. 133-134, Pl. 30, Figs 8-10; Pl. 31, Figs 1-4.

1991. *Cuneiphycus aliquantulus* Johnson; D. Vachard & S. Beckary, Pl. 2, Fig. 1.

1991. *Masloviporidium delicata* (Berchenko); B. Mamet, Pl. 3, Fig. i.

1993. *Masloviporidium delicata* (Berchenko); B.J. Chuvashov & *al.*, Pl. 11, Fig. 12.

1996. *Masloviporidium delicata* (Berchenko); B. Mamet, Pl. 1, Fig. 21.

1996. *Masloviporidium delicata* (Berchenko); A. Sebbar & B. Mamet, Pl. 3, Figs 1-2.

MATERIAL: Tens of specimens in thin sections, several three-dimensional specimens chemically prepared from limestones.

DESCRIPTION: The spongy, sometimes flattened thallus of the species is characterized by regular internal construction composed of concentric walls and perpendicular partitions, forming concentric rows of cells. Height of individual cell 40-100 μm, width 20-60 μm. The contiguous rows of cells were connected by tube-like pores in the horizontal (concentric) walls (Pl. 15, Fig. 5). The horizontal walls are considerably thicker than the vertical ones.

REMARKS: The specimens exactly correspond with the diagnosis and description by GROVES & MAMET (1985). Three-dimensional specimens confirm the presence of primary pores in the concentric walls, what allows to distinguish this form from the genus *Cuneiphycus*, which is characterized by similar morphology but devoid of connections between neighboring rows of cells. It contradicts therefore the synonymy of *Cuneiphycus* and *Masloviporidium* postulated by VACHARD & *al.* (1989).

The relatively good recognition of the internal morphology of *Masloviporidium* does not determine an affiliation of the genus to the higher taxonomic units. The specimens are most similar to the family Stacheiinae LOEBLICH & TAPPAN, 1961, *emend.* PETRYK & MAMET, 1972, and to the newly erected subfamily (tribe) Mametellae CHUVASHOV (*in*: CHUVASHOV & *al.* 1987). Both these groups are usually and traditionally included to the red algae (as in this paper), although their affinity with some groups of sponges, postulated by TERMIER, TERMIER & VACHARD (1975; *cf. also* VACHARD & *al.* 1989) is not excluded.

OCCURRENCE: Lublin Carboniferous Basin - Dęblin Fm. (Lst. Bands *M*, *N*) in rock-forming amount; the species is widely known from North America, Eurasia and Algeria from the uppermost Serpukhovian-lower Bashkirian (MAMET 1991); BOGUSH & *al.* (1990) and CHUVASHOV & *al.* (1993) reported its occurrences also in the lowermost Serpukhovian and even in the Viséan.

Morpho-group: Phylloid algae
Division Rhodophycopyta PAPENFUSS, 1946
Family: Archaeolithophyllaceae CHUVASHOV, 1987

REMARKS: CHUVASHOV (*in* CHUVASHOV & *al.* 1987) included to the newly erected family Archae(o)lithophyllaceae the three genera: *Amorphia* RACZ 1966, *Archaeolithophyllum* JOHNSON 1956, and *Principia* BRENCKLE 1982, which previously have been usually classified in the enigmatic group of "Ancestral Corallines". The latter two genera appear in the investigated sequence (the species *Principia donbassica* KOSSENKO is described *in* SKOMPSKI 1986) in accordance with the supposed phyletic succession (*cf.* VACHARD & *al.* 1991, DELVOLVÉ & *al.* 1994), in which the genus *Principia* was an ancestor of *Archaeolithophyllum* (*cf.* Text-fig. 7) and appeared in the beginning of Namurian.

Genus *Archaeolithophyllum* JOHNSON, 1956
Archaeolithophyllum lamellosum WRAY, 1964
(Pl. 14, Figs 3-6)

1964. *Archaeolithophyllum lamellosum* sp.n.; J.L. WRAY, pp. 8-9, Pl. 2, Figs 1, 3-5, 7.

1974. *Archaeolithophyllum lamellosum* WRAY; D.F. TOOMEY, pp. 178-180, Figs 1, 3d-e.

1980. *Archaeolithophyllum lamellosum* WRAY; E. FLÜGEL & E. FLÜGEL-KAHLER, pp. 157-160, Pl. 8, Fig. 6.

1983. *Archaeolithophyllum lamellosum* WRAY; D.F. TOOMEY, pp. 259-269, Figs 4b-f.

MATERIAL: About 20 specimens in the thin sections.

DESCRIPTION: Thallus consists of flat or undulating, horizontally lying crusts, or it makes coatings of oncoids. The internal structure of thallus is composed of elongated, hexagonal cells, arranged in hemispherical rows. The central portion of thallus (hypothallus) is composed of larger and more regular cells, while the external one (perithallus) is usually recrystallized, what precludes detailed observations. Thickness of perithallus corresponds in average with 1/6 to 1/4 thickness of hypothallus. Thallus thickness: 300-600 μm, length of hypothallic cells: 40-60 μm, width of hypothallic cells: 20-40 μm.

REMARKS: The species *Archaeolithophyllum lamellosum* occurs in the Carboniferous sections relatively rare, in comparison with more common *A. missouriense*. WRAY (1964) considered the measurements and characteristic growth form ("*...the superimposed, multilayered encrusting growth form...*") as the main distinguishing criterion. The specimens from the Lublin Basin slightly exceed the measurements reported by WRAY, but exactly correspond to the specimens described by FLÜGEL & FLÜGEL-KAHLER (1980). In the investigated material the thallus of *Archaeolithophyllum* occur in two forms. Usually it makes flat sheet-like layers, encrusting the basement and covered by *Girvanella* coatings. In other cases it makes coatings of oncoids; thickness of thallus is much smaller, and internal structures is not discernible. The two forms of *Archaeolithophyllum* are often associated with encrusting foraminifers (*Tuberitina, Tetrataxis*) or microproblematics *Aphralysia* and *Wetheredella,* newly interpreted as cyanobacterial biostructures (KAŹMIERCZAK & KEMPE 1990).

According to WRAY (1964, p. 10), *A. lamellosum* has a potential to form the small wave-resistant build-ups. In fact, the most interesting occurrence of this algae in the Lublin Carboniferous Basin forms the 2.5 m thick boundstone, composed of *Archaeolithophyllum* and encrusting foraminifers. However, there are no indicators pointing for growing up of this structure to the wave-base.

OCCURRENCE: Lublin Carboniferous Basin - Komarów Mb. of the Terebin Fm.; 2.5 m thick boundstone in borehole Sawin *IG-7* (depth 933.0 - 935.5 m, Lst. Band *F*); the species is known from the Upper Pennsylvanian to Lower Permian in North America and the Carnic Alps.

Microproblematics

Genus *Anthracoporellopsis* MASLOV, 1956

Anthracoporellopsis machaevi MASLOV, 1956

(Pl. 11, Figs 1-9 and Pl. 12, Figs 1-6)

1956. *Anthracoporellopsis machaevi* sp.n.; V.P. MASLOV, p. 62, Pl. 13, Figs 3-4.

1987. *Anthracoporellopsis machaevi* MASLOV; B. MAMET & *al.*, pp. 23-24, Pl. 10, Figs 7-8, and Pl. 11, Figs 4-5 (*with older synonymy*).

1987. *Anthracoporellopsis machaevi* MASLOV; V.P. SHUYSKY *in*: B.J. CHUVASHOV & *al.*, Pl. 16, Fig. 12.

1988. *Anthracoporellopsis* MASLOV; R. DELOFFRE, Pl. 1, Figs 25-26.

1989. *Anthracoporellopsis machaevi* MASLOV; S. SKOMPSKI & *al.*, Pl. 2, Figs 4-7.

1989. *Anthracoporellopsis machaevi* MASLOV; D. VACHARD & *al.*, pp. 705-706, Pl. 1, Fig. 6.

1990. *Anhracoporellopsis ramosus* sp.n.; R. IVANOVA *in*: O.I. BOGUSH & *al.*, pp. 102-103, Pl. 10, Figs 2-4.

1991. *Anthracoporellopsis machaevi* MASLOV; B. MAMET, Pl. 3, Fig. 1.

1991. *Anthracoporellopsis machaevi* MASLOV; D. VACHARD, p. 269.
1991. *Anthracoporellopsis machaevi* MASLOV; D. VACHARD & S. BECKARY, p. 324, Pl. 2, Fig. 2.
1993. *Anthracoporellopsis machaevi* MASLOV; B.J. CHUVASHOV & *al.*, Pl. 12, Fig. 5.

MATERIAL: More than 50 specimens in thin sections, 20 three-dimensional specimens chemically prepared from the rock.

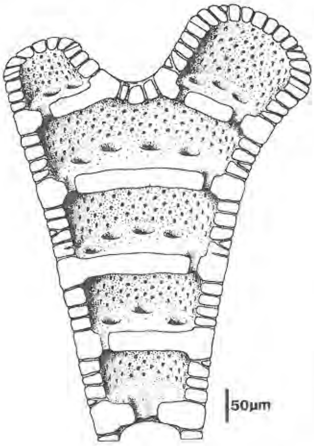


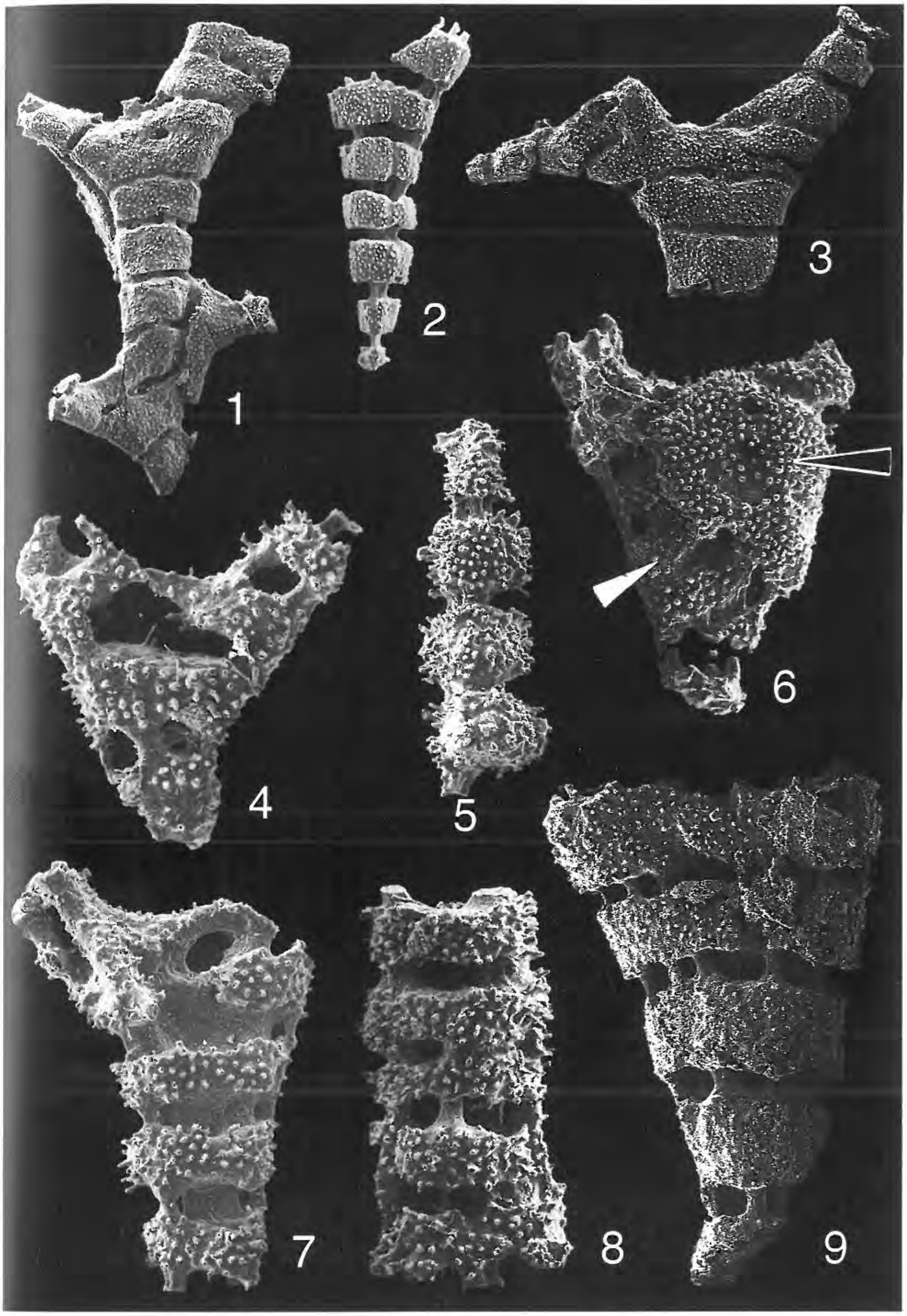
Fig. 9. Reconstruction of the calcareous coat of *Anthracoporellopsis machaevi* (MASLOV) – longitudinal axial section
Designed by B. WAKSMUNDZKI, M.Sc.

DESCRIPTION: The specimens in the thin sections reveal generally cylindrical thallus with changing diameter, rarely ramified. The central cavity is divided by irregular, sometimes symmetrically arranged partitions. Both, the cavity wall and partitions are perforated by straight, sometimes dichotomously branching pores (Pl. 12, Fig. 3). The three-dimensional specimens (recrystallized calcitic internal moulds) indicate that investigated forms are composed of chambers separated by partitions occupying a whole bore of the main cavity (*cf.* reconstruction in Text-fig. 9). The chambers are connected by the system of tube-like channels (Pl. 11, Figs 8-9), which sometimes compose the thick central channel (Pl. 11, Fig. 2). The walls of chamber are perforated by thin pores; the openings in partitions are several times larger than pores. Some specimens suggest double-layered structure of the wall (Pl. 11, Fig. 6).

REMARKS. In the most of descriptions the genus *Anthracoporellopsis* was included to the group of tubular algae with perpendicular partial partitions of the central cavity, traditionally considered as the tribe Palaeoberesellеae (MAMET & ROUX 1974). BERGER & KAEVER (1992), doubt a dasycladacean nature of the paleoberesellids (and particularly *Anthracoporellopsis*), which (according to their opinion) are assembled together in artificial, extremely heterogeneous group with some other taxa, more similar to sponges Sphinctozoa or foraminifers than to algae.

The holotype material of MASLOV (1956) composed of poorly preserved specimens do not present dichotomously branched pores, which appeared to be the basic feature for discrimination of this genus from the very similar *Kamaena* ANTROPOV, 1967. Moreover, the internal structure of the wall and shape of partitions are strongly influenced by neomorphic processes. Both these arguments - unclear diagnosis of species and difficulties in separation of diagenetic effects from the primary features - has led the present Author to the assumption of synonymy of genera *Anthracoporellopsis* and *Kamaena* (see SKOMPSKI 1985, 1986). However, the three-dimensional specimens found later contradict this hypothesis; moreover they deny the algal affiliation of *Anthracoporellopsis*. The basic difference is in the extent of horizontal partitions (*cf.* Text-figs 8 and 9), which in *Anthracoporellopsis* really separate the contiguous chambers and are perforated by relatively large channels. This feature as well as the presence of thin pores in the double-layer wall of the central cavity liken the investigated forms rather to Sphinctozoa than to the algae.

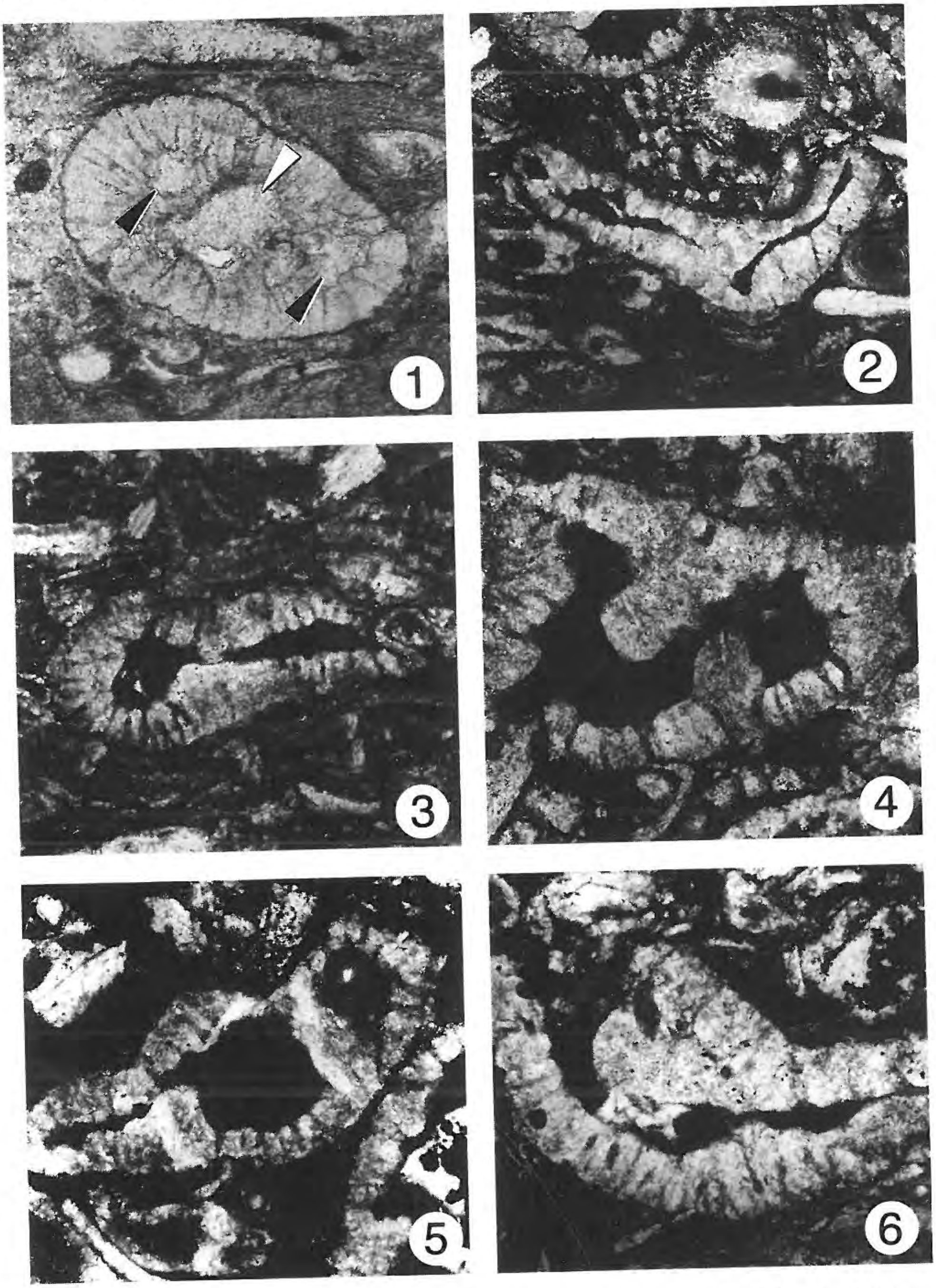
On the other hand, a lack of typical filling tissue, unacquaitance of microstructure of the wall and usually ramifying form (Pl. 11, Figs 1-3 and 7) determine the present Author to reserve in classification of *Anthracoporellopsis* in the midst of sponges. From the taxa originally included to the Palaeoberesellеae the similar (but more regular) morphology of partitions ("cribriform partitions") was reported by BRENCKLE (1985) from the genus



Anthracoporellopsis machaevi MASLOV – three-dimensional, chemically prepared specimens

1-9 — Recrystallized internal molds showing details of chambers and system of inter-chamber connections: 6 – mold of external (*black arrow*) and internal (*white arrow*) layer in the wall; 8-9 – tube-like connections between contiguous chambers

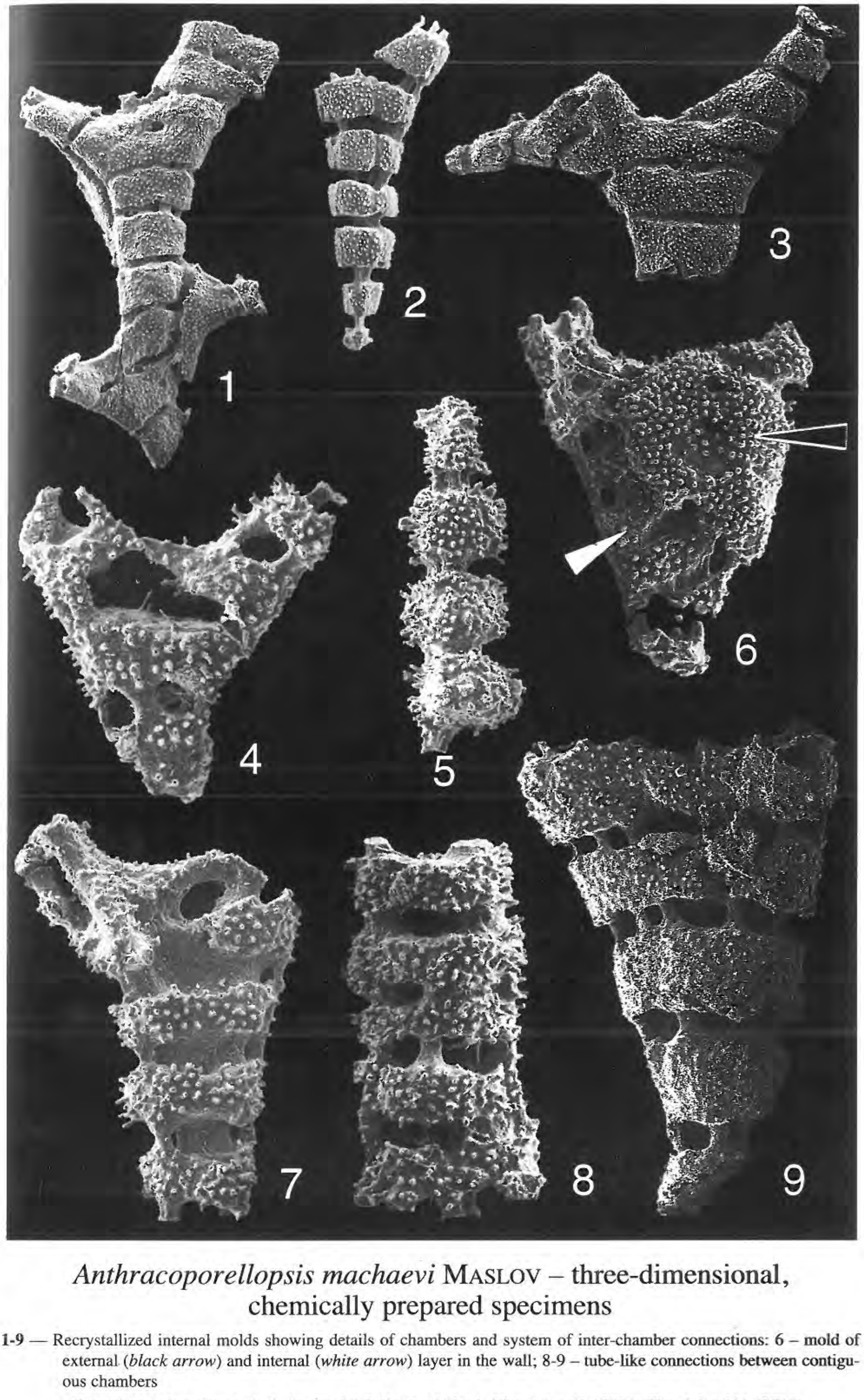
All specimens from borehole Rejowiec *IG-1* (depth 1049 m); Figs 1-3 × 60 (*SEM*); Figs 4-9 × 120 (*SEM*)



Anthracoporellopsis machaevi MASLOV – specimens in thin sections

1 — Section perpendicular to the main axis: indicated are marginal (*black arrows*) and central (*white arrow*) channels connecting two neighboring chambers; borehole Tyszowce *IG-1* (depth 1760 m), × 80

2-6 — Specimens showing irregular morphology of the wall and partitions: dichotomously branching pores are visible in Figs 3-4; borehole Rejowiec *IG-1* (depth 1049 m); Fig. 2 × 70; Fig. 3 × 110; Fig. 4 × 130; Fig. 5 × 40; Fig. 6 × 120



Anthracoporellopsis machaevi MASLOV – three-dimensional, chemically prepared specimens

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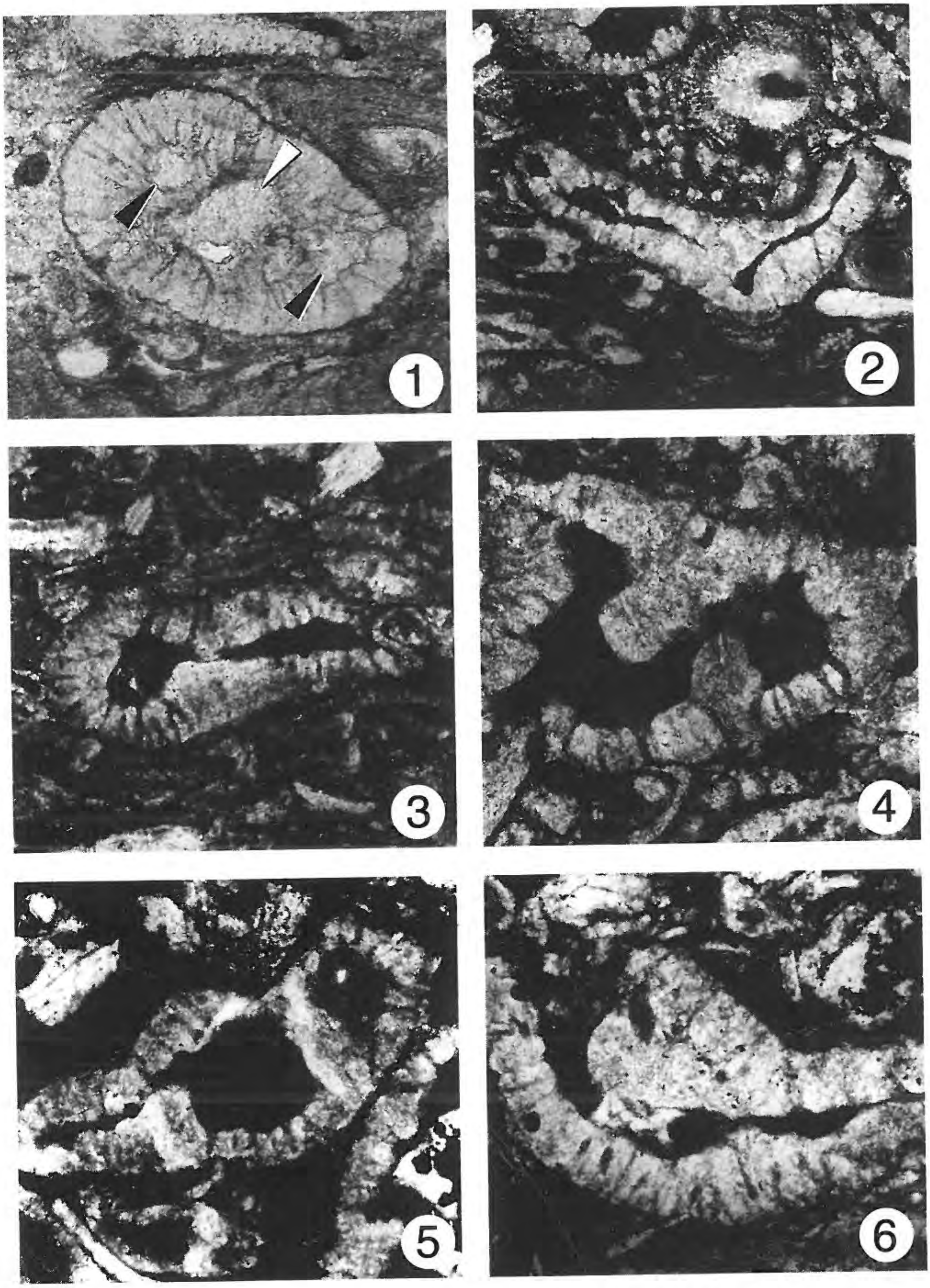

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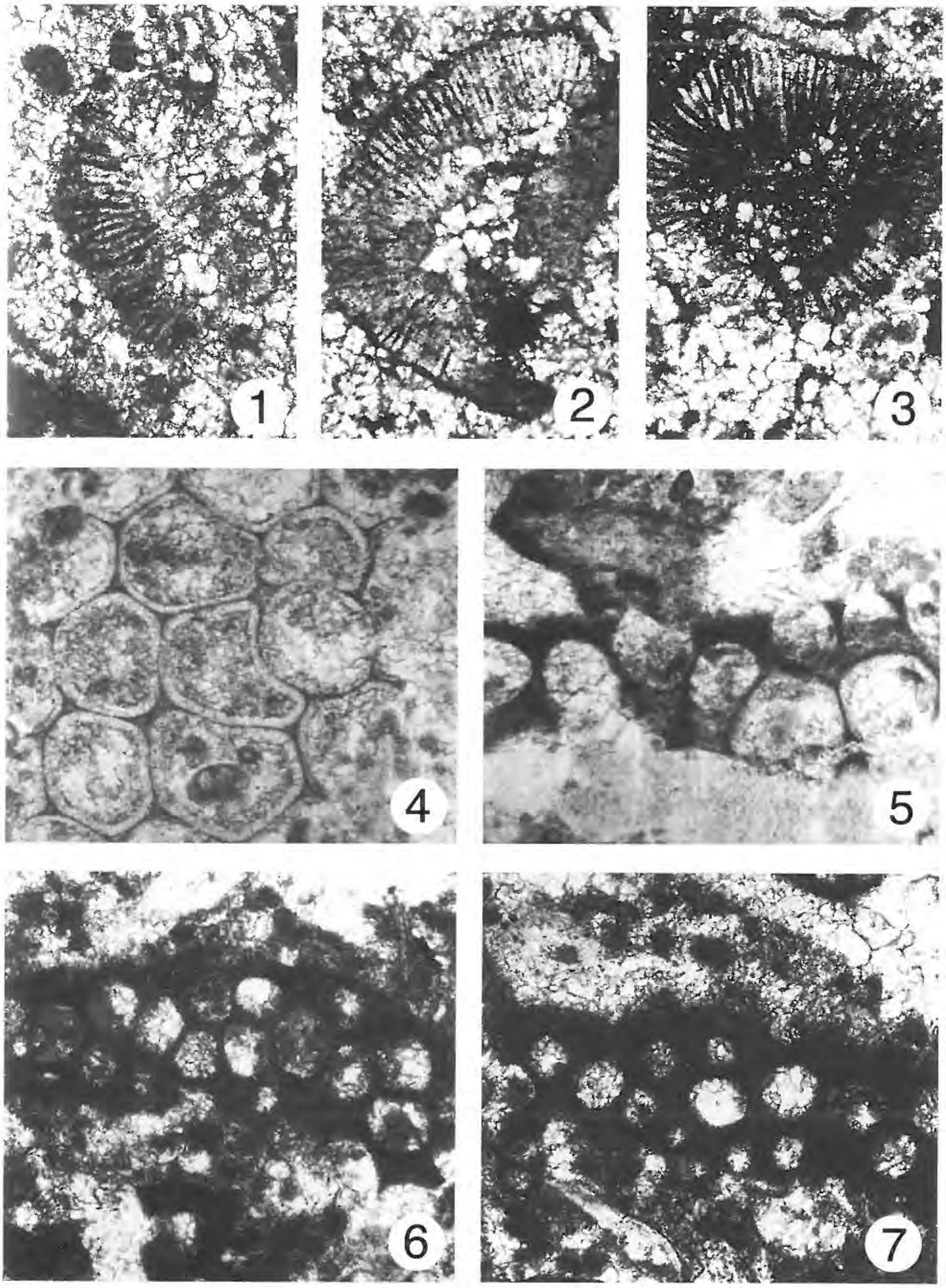
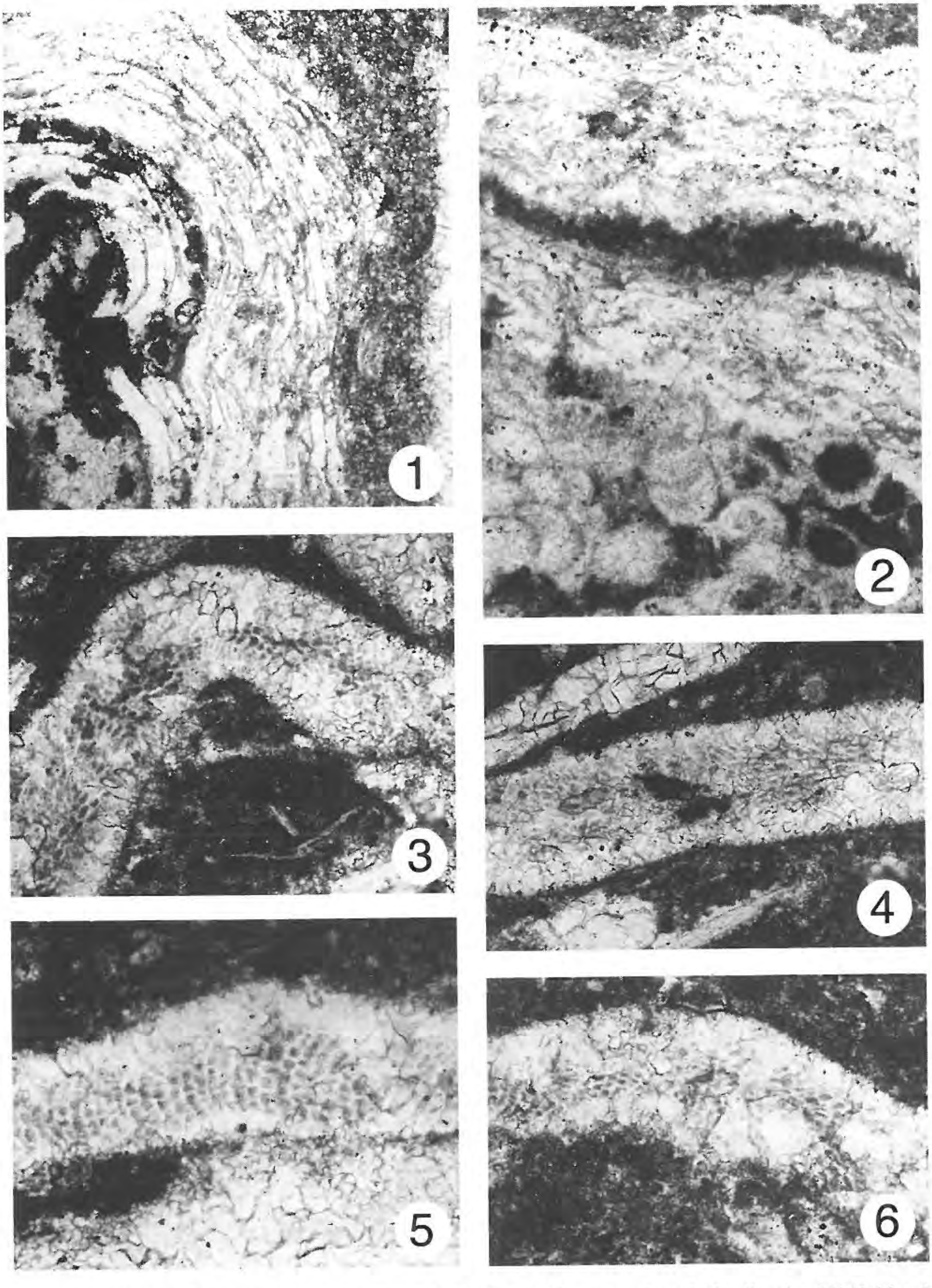


1-3 — *Epistacheoides nephroformis* PETRYK & MAMET – section of perithallium fragments; borehole Kumów *IG-3* (depth 1401 m), × 75

4 — *Koninckopora inflata* (DE KONINCK); borehole Tyszowce *IG-1* (depth 1731 m), × 80

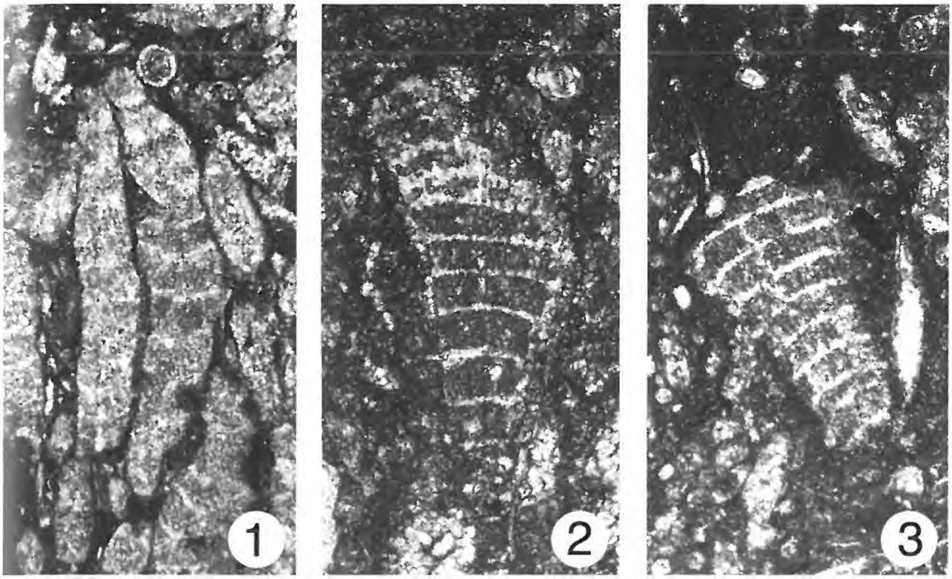
5-7 — *Koninckopora minuta* WEYER; 5 borehole Tyszowce *IG-1* (depth 1731 m), × 120
6-7 — borehole Kumów *IG-3* (depth 1403 m), × 65

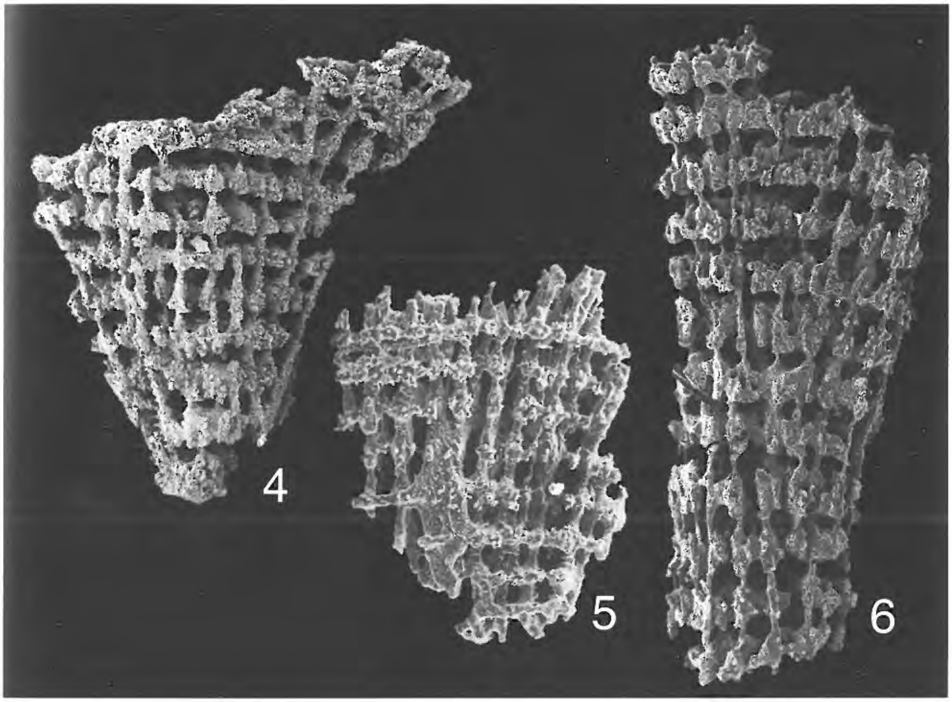


1 — Fragment of encrustation composed of *Fasciella* sp. – borehole Sawin *IG-7* (depth 934 m), × 60

2 — Encrustations composed of *Fasciella* sp., and *Wetheredella* (microproblematicum; cyanobacterial biostructure *according* to KEMPE & KAŹMIERCZAK 1990); borehole Orzechów *IG-2* (depth 886 m), × 60

3-6 — *Archaeolithophyllum lamellosum* WRAY – thin sections show arcuate rows of hypothallic cells and recrystallized marginal perithallus; borehole Sawin *IG-7* (depth 934 m), × 60

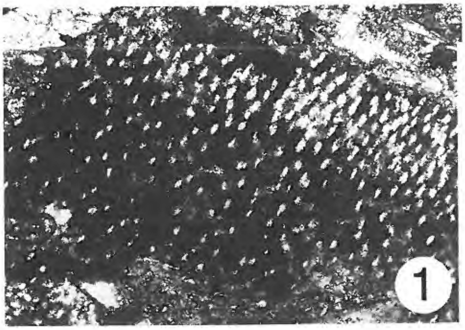


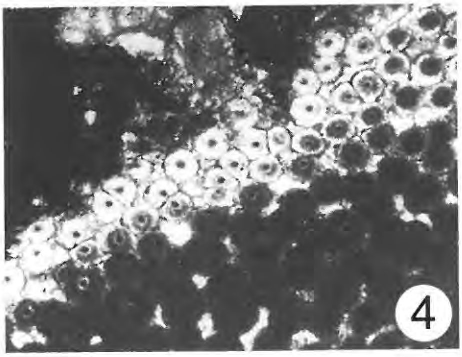


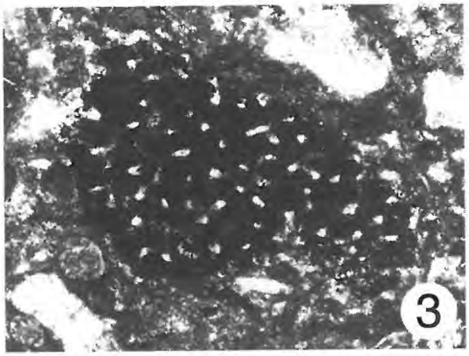
Masloviporidium delicata (BERCHENKO)

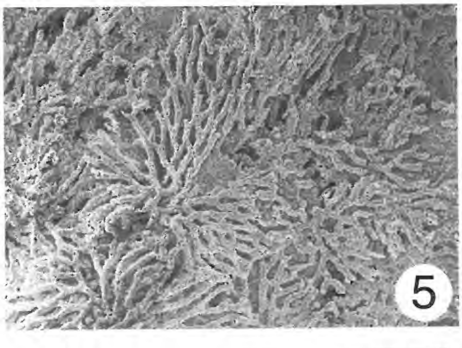
1-3 — Specimens in thin sections – transversal (Fig. 1) and parallel (Figs 2-3) to the surface of the thallus; borehole Syczyn *IG-4* (depth 1013 m), × 50

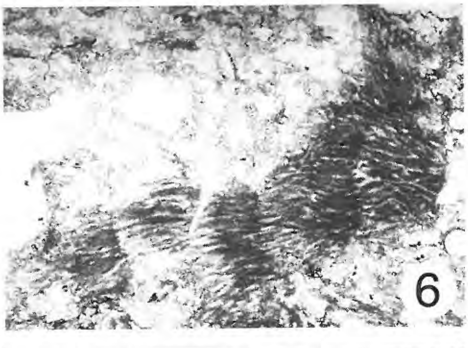
4-6 — Three-dimensional recrystallized specimens, chemically prepared; tube-like connections between contiguous rows of cells (*arrowed*); borehole Grabowiec *IG-4* (depth 971 m), × 70

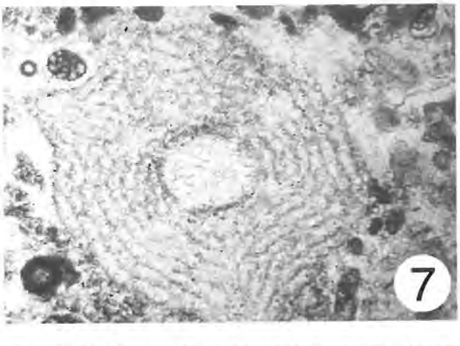












1-3 — *Anchicodium* sp.; Fig. – 1 borehole Telatyn *IG-1* (depth 1182 m); Figs 2, 4 – borehole Hostynne *IG-1* (depth 1202 m), × 75

4 — *Globochaete alpina* (LOMBARD); aciniform association *sensu* SKOMPSKI (1982); borehole Kumów *IG-3* (depth 1328 m), × 100

5-6 — *Calcifolium punctatum* MASLOV; Fig. 5 – molds of internal filament (chemically prepared specimen, SEM, × 50) and thin section (Fig. 6, × 25); borehole Sawin *IG-7* (depth 999 m)

7 — *Fourstonella* sp.; section perpendicular to the axis, borehole Tyszowce *IG-1* (depth 1731 m), × 50

8 — *Fourstonella* sp.; longitudinal axial section, borehole Hostynne *IG-1* (depth 1202 m), × 45

Cribrokamaena. The algal origin of this form is confirmed by the presence of conceptacles. However, the spherical cavities interpreted by the creator of the genus as conceptacles appear in the specimens strongly corroded and possibly they correspond to small borings (*cf*. illustrations of BRENCKLE 1985, Pl. 3, Figs 2 and 11-12).

OCCURRENCE: Lublin Carboniferous Basin – rare specimens in the Viséan Huczwa Fm., abundant in the upper Namurian Dęblin Fm. (Lst. Bands *M* and *N*); cosmopolitan taxon known from the Tournaisian to the Lower Permian.

PROBLEM OF THE VISÉAN/NAMURIAN BOUNDARY

The specific paleogeographic position of the Lublin Carboniferous Basin predistinates this succession to the investigations intending to the correlation of the west- and east-European stratigraphic schemes. The lower part of the sequence, with a continuous transition from the Viséan to the Namurian, is the particularly convenient for this task. In utmost form the problem is illustrated by Polish and Ukrainian stratigraphic schemes for the geologically congeneric basin, divided into two parts by solely political borders. However, the location of the Viséan/Namurian (or Viséan/Serpukhovian) boundary in both these parts is burdened by some inaccuracies.

The lower boundary of the Namurian was defined at the base of the Cravenoceras (=Emstites) leion goniatite Zone, and the first occurrence of this taxon enabled the recognition of this boundary. In the Lublin Basin the goniatites have been found sporadically, and their importance as stratigraphic markers is additionaly lowered by a poor state of preservation. Nevertheless, the presence of *Sudeticeras laevigatum* (RUPRECHT) and *Eumorphoceras pseudobilingue* BISAT allows recognition of the E_1 Zone in the lowermost Namurian (MUSIAŁ & TABOR 1988). The sporadic specimens of these taxa have been found in the lower part of the Terebin Fm. (Komarów Beds in older lithostratigraphic classification), but doubts concerning the taxonomy of the former species (BOJKOWSKI 1979, pp. 51-52) caused that the biostratigraphic diagnosis is relatively certain not earlier than in the interval near the Lst. Band *C*. Above the Lst. Band *F* the number of goniatites is greater and they indicate the E_2 Zone.

The problem of C_V/C_N boundary is also unclear in the foraminifer distribution. The basal Namurian zone "17" (according to the zonation of MAMET & SKIPP 1970) occurs in the Lst. Band *D* (in northern part of the Basin) or in the Lst. Band *B* (in southern and middle part), but differences between the Viséan and Namurian assemblages are very subtle (SOBOŃ-PODGÓRSKA 1979, 1988). SOBOŃ-PODGÓRSKA & TOMAŚ (1995) applied the more recent Belgian zonation (CONIL & *al*. 1977, PAPROTH & *al*. 1983) and they reported the presence of the Viséan *Cf6* and Namurian *Cf7* Zones with characteristic genera *Brenckleina* and *Eosigmoilina*. The detailed analysis presented by CONIL & *al*. (*in*: SKOMPSKI & *al*. 1989) pointed rather late appearance of these taxa in the sections of the Lublin Basin (Lst. Band *F*).

In that case MUSIAŁ (1987), MUSIAŁ & TABOR (1979, 1988) and MUSIAŁ & *al*. (1995) proposed to consider a disappearance of brachiopods from the broadly defined genus *Gigantoproductus* as a practical limitation of the Viséan. However, the comparison of the gigantoproductid ranges in the adjacent European regions indicates that most of these forms became extinct not earlier than in the upper part of the Namurian *A* (*cf*. ŻAKOWA 1984a, 1984b, 1986; DONAKOVA 1993; POLETAEV & LAZAREV 1995).

In practice, in the face of imperfection of the biostratigraphic indicators, the boundary discussed is located usually in the sole of the Lst. Band *A*, inspite of the problems with identification of this complex.

The analysis of algae, microproblematics and conodonts, shows that discussed boundary should be located slightly higher in the section, possibly in the interval between Lst. Bands *C* and *D*. This level is indicated by beginning of the conodont Lochriea cruciformis Zone, which in shallower parts of the Laurussian shelf begins with the Namurian (SKOMPSKI & *al*. 1995). In the

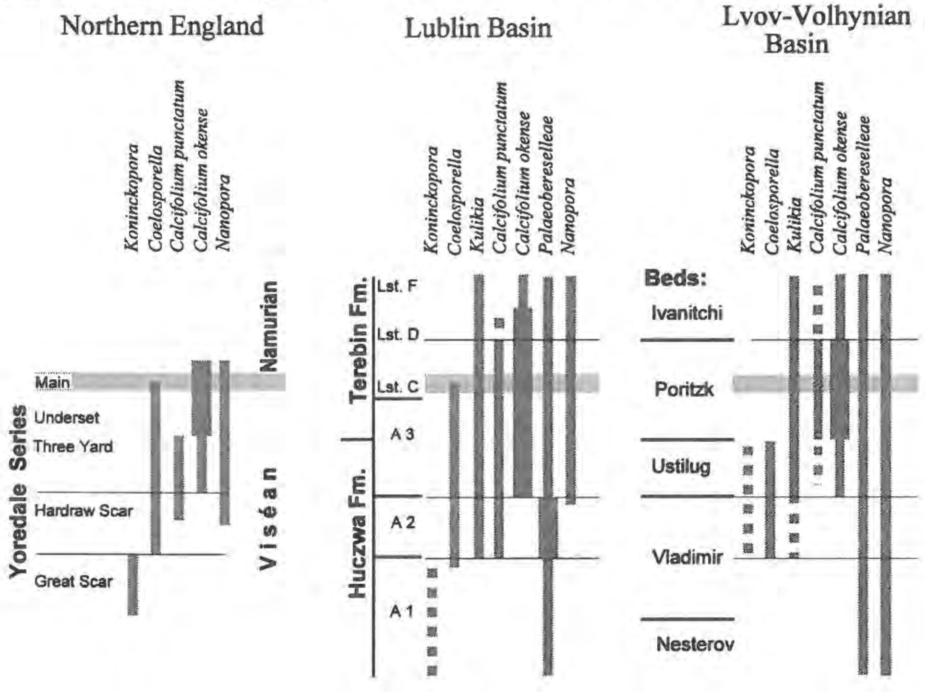
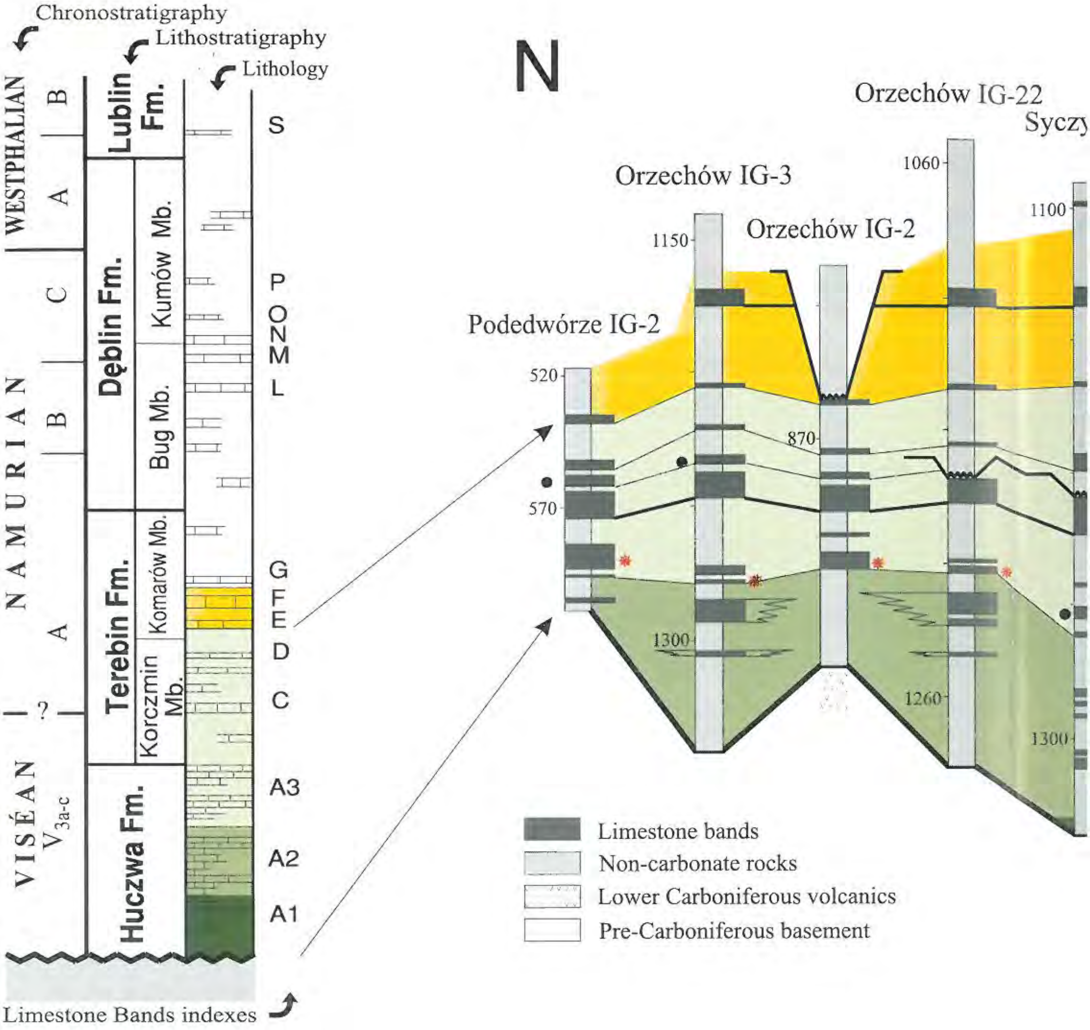


Fig. 11. Correlation of the Late Viséan/Early Namurian successions from northern England, Lublin Basin and Lvov-Volhynian Basin on the basis of selected algal and microproblematic taxa

Lvov-Volhynian Basin *after* MUROMTSEVA (1982); northern England *after* HALLETT (1970), but only selected limestone bands in the Yoredale Series are indicated

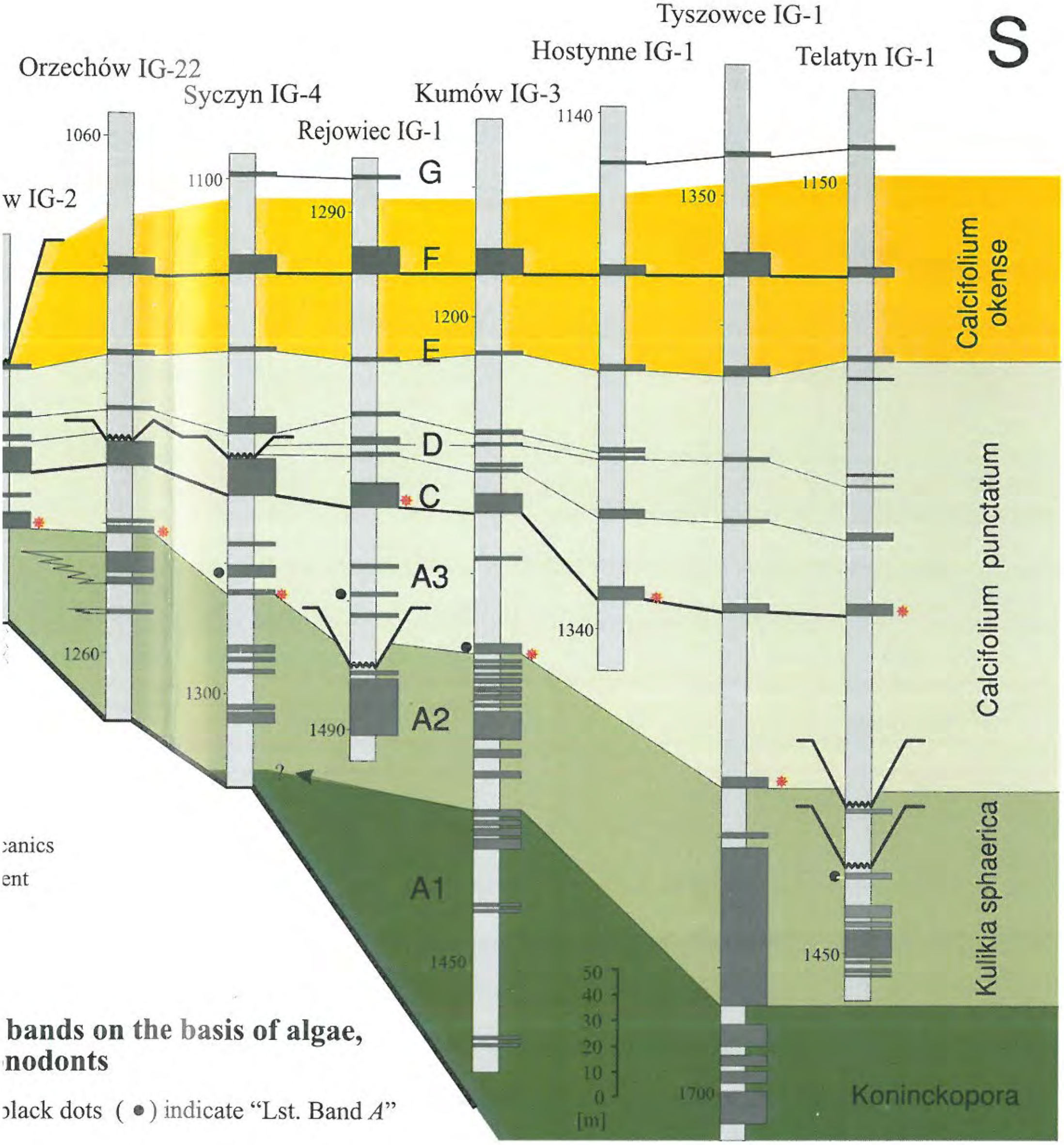


Correlation of limestone complexes and bands on the basi
microproblematics and conodonts

Asterisks (✱) show the beginning of mass-occurrences of *Calcifolium okense*, black dots (●) indicat
according to the hitherto presented reports
Stratigraphic column as in Text-fig. 6

the Warnantian (*cf.* Text-fig. 11). Consequently, the limestone complex A2 corresponding to the upper part of the Vladimir Beds, is interpreted as the lowermost Warnantian, being also confirmed by the stratigraphic diagnosis for Hardraw Scar Lst. in the Yoredale Series (*cf.* HALLETT 1970). The

S. SKOMPSKI, FIG. 10



bands on the basis of algae,
nodonts

black dots (●) indicate “Lst. Band *A*”

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Lst. Band *D* the algal genus *Archaeolithophyllum* also appeared, as hypothetical descendant of the genus *Principia*. According to VACHARD (1991) and BERKHLI & *al*. (1993), this phylogenetic event is roughly coincident with the upper boundary of the Viséan. Another, more equivocal argument, is connected with extinction of *Calcifolium punctatum,* which happened (according to MAMET & ROUX 1975) in the end of Viséan.

The newly proposed location of the C_V/C_N boundary (*see* Text-fig. 11) is also confirmed by correlation of the Polish and Ukrainian parts of the Basin. The Serpukhovian, considered primarily as biostratigraphic equivalent of the Eumorphoceras and Homoceras goniatite zones, corresponds to the Namurian *A*. This stage, originally defined as regional stratigraphic unit in the Moscow Basin, is distinguished in other regions of the East European Platform mainly on the basis of brachiopods and foraminifers. In the Lvov-Volhynian Basin the position of its lower boundary is controversial, but generally connected with the Poritzk Beds. SHULGA (1975), STRUEV & *al*. (1984), and MUROMTSEVA (1979b) settled this boundary in the sole of the Poritzk Beds, although VYRVITCH & *al*. (1978) suggested its position in the top of the Beds. The compromise - in some respect - solution (and best documented) has been proposed by VDOVENKO & POLETAEV (1981). On the base of brachiopods and foraminifers they placed this boundary in the top of the Limestone Bed V_3 in the middle part of the Poritzk Beds. This conclusion was accepted recently by SHULGA & *al*. (1992) and NEMIROVSKAYA (*in*: SKOMPSKI & *al*. 1995). According to the lithological correlation (*cf*. PORZYCKI 1988, 1995) the Lst. Bed V_3 corresponds to the Lst. Band *C* from the Polish part of the Basin. Therefore, its top seems to be the most practical and precisely estimated position of the Viséan/Namurian boundary.

Correlation with the Lvov-Volhynian section is also the key to the more distant correlations with the Moscow and Dneper-Donets Basins. The acme of *Calcifolium okense* begins in the former Basin in the Mikhailov Horizont and persists to the early Serpukhovian. The resulting correspondence of the Ustilug and the lower part of the Poritzk Beds with the Mikhailov and Venev Horizons respectively, is confirmed by the analysis of foraminifers and brachiopods (VDOVENKO & POLETAEV 1981). According to these authors, the lower part of the Poritzk Beds corresponds to the upper part of regional Belgian stage Warnantian (V_{3c} in older literature), while the Ustilug Beds to its lower part (V_{3b}). It seems that the limestone complex *A3*, distinguished in this paper, also represents this part of the Warnantian (*cf*. Text-fig. 11). Consequently, the limestone complex *A2* corresponding to the upper part of the Vladimir Beds, is interpreted as the lowermost Warnantian, being also confirmed by the stratigraphic diagnosis for Hardraw Scar Lst. in the Yoredale Series (*cf*. HALLETT 1970). The position of the lowermost complex *A1* is more unclear. Its Ukrainian equivalents, comprising limestones units V_0 and V_1 (with numerous unstable names – *cf*. PORZYCKI 1988, 1995; *and* Ukrainian authors mentioned above) have been compared by VDOVENKO & POLETAEV (1981) to the Belgian units V_{3a} and V_{2b}. However, the macrofaunistic and foraminiferal data from Poland, summarized in the volume edited by ZDANOWSKI & ŻAKOWA (1995), confirm the biostratigraphically documented age of the discussed strata as not older than V_{3b} (Go α).

MICROFACIES SUCCESSION AND THE LATE VISÉAN/EARLY NAMURIAN CYCLICITY

MODELS OF THE LOWER CARBONIFEROUS CYCLICITY

Exceptionally regular and distinctive cyclicity of sedimentation is a particular feature of the Late Viséan/Early Namurian successions not only in the Lublin Carboniferous Basin but also through the entire shelf of the Laurussia Continent. RAMSBOTTOM (1977) recognized two-order pattern of the cyclic sequences and classified the sedimentary units as mesothems ("major") and cyclothems ("minor"). The minor cyclothems occur in the uppermost part of the Viséan (Asbian, Brigantian stages), and are observable both in the purely carbonate, offshore successions, and in their more proximal equivalents, where the clastic input, deltaic in nature, caused especially diverse lithological composition of cyclothems, with the coal seams and carbonate beds as the end-members. The latter type of sequences, usually named as Yoredale-type cyclothems, is extremely well exemplified by the succession from the Lublin Carboniferous Basin.

In the European part of the Laurussia Continent the cyclicity is well recognized in the two regions, which laid the foundations of the Lower Carboniferous geology: Irish-British-Belgian in the West, and Moscow Basin in the East. Notably, in both these regions the repeating nature of sedimentation was the basis for establishment of the stratigraphic units. In the Moscow Basin these fundamentals have been created in the thirties by sedimentological and paleogeographic investigations of SHVETZOV (thoroughly characterized by TIKHOMIROV 1985, MAKHLINA & *al*. 1993), who constituted stratigraphic standard typified by the predominance of sedimentary events over the pure biostratigraphy. In western Europe the biostratigraphy traditionally dominated, but in the late seventies the cyclicity ideas proposed by RAMSBOTTOM (1973, 1977) decisively influenced on the founding of new Dinantian stages. This stratigraphic aspect is only one example pointing the importance of the determination of cyclicity nature, which conditioned iso- or diachroneity of cyclothem boundaries. The other aspects, *e.g*. hydrocarbon potential of discussed rock interval, are not less important. A dispute of many years standing on the origin of cyclothems investigated mostly in Great Britain and in the Appalachians fruited large number of hypothesis, which can be generalized into three groups: eustatic (Wanless & Shephard 1936), tectonic (Bott & Johnson 1967), and autocyclic sedimentary mechanisms (Moore 1958). The extensive reviews presented recently in numerous papers (*e.g*. Walkden 1987, Leeder 1988, Riegel 1991, Dott 1992, Schwarzacher 1993, Chesnut 1994, Ludwig 1994) led to the obvious conclusions pointing that usually the influence of particular factors is difficult to separate, or the domination of one of them is distinct but limited geographically. The most significant advance in understanding of the origin of the Yoredale-type cyclicity was induced by Leeder & Strudwick (1987). They proposed three models of

Table 3

Comparison of sedimentary models proposed for explanation of the Yoredale-type cyclicity; *based* on proposal *by* Leeder & Strudwick (1987)

	Hypothesis		
	Sedimentary	**Eustatic**	**Tectono-sedimentary**
Mechanism of cycle → formation Part of cyclothem ↓	*Autocyclic processes cause avulsions of delta lobes*	*Eustatic changes cause drowning and progradation of delta lobes*	*Periodic subsidence cause activation of delta progradation*
Top unit	widespread abandonment peats, in distal areas sands coarsening upwards	diachronous boundary with carbonates retreat of delta system, fining-upwards deltaic sequence	widespread abandonment peats and post-abandonment clastics
Middle unit	typical progradational succession	typical progradational succession erosional incision of distributary channels	typical progradational succession
	diachronous boundary	possible paleokarstic surfaces	diachronous boundary
Carbonate unit	constant bathymetry	shallowing in the upper part deepening in the lower part	deepening in the upper part (local shoaling)

cyclothems, typical of sedimentary, eustatic, and tectono-sedimentary mechanisms of sedimentation. A comparison of main diagnostic features in these three models (Table 3) indicates that most evident differences consist in bathymetric trends of limestone layer, in types of lower and upper boundary of carbonates and lithology of the underlying beds. An important feature in eustatic model is development of channel incisions during lowstand of sea level.

In the preliminary test of their theory, LEEDER & STRUDWICK (1987) rejected the eustatic mechanism of the Yoredale-type cyclicity, because of a lack of evident erosional channels in the deltaic intervals and sequences typical of delta retreat. Moreover, relatively well visible evidences of deepening phase in the upper part of some limestone bands, prior to the influx of deltaic clastics, determined these authors to prefer tectono-sedimentary mechanism. This conclusion is seemingly contradictory with observations of the late Dinantian carbonate platforms presented by WALKDEN (1987), who concluded that oscillatory appearance of shallow meteoric cements suggest eustatic changes as principal factor. However, this author did not exclude the secondary role of tectonic factor. Similar reasoning was presented by HORBURY (1989) in an analysis of Asbian Urswick Limestone from southern Lake District; he interpreted major cycles observed in this formation as resulting from rapid platform downfaulting episodes. The minor cycles, distinguished inside major ones and bounded by emergent surfaces, reflected temporary regressions connected probably with glacio-marine changes of sea-level. PICKARD (1994) in the analysis of Brigantian Charlestown Main Cyclothem directly referred to the LEEDER & STRUDWICK's ideas. Surprisingly, the limestone member is here characterized by a shallowing upward trend, what implicates, together with an analysis of subsidence, that the eustacy is the primary control; differential subsidence, terrigene supply and autocyclic progradation are secondary factors which influenced the sedimentary cyclicity. GALLAGHER (1996) also points for glacieustatic changes as most significant cause of cyclicity. In his summary of the late Dinantian carbonate sedimentation in Ireland he reached back to the old arguments punctuating stability of cyclothems across the platforms and their similar number in different regions of British Isles.

The above review of some recently presented investigations in the west European Laurussia shelf demonstrates difficulties in finding of the one universal cause for the late Dinantian cyclicity. In Ireland as well as in Scotland and northern England the fault activity controlled the development of intraplatform basins to such a degree, that separation of tectonic and eustatic effects is perplexing or regionally restricted. In this context the Lublin region seems to be evidently more appropriate area for verification of LEEDER & STRUDWICK's models. The location of the Carboniferous basin on the relatively stabile margin of the East European Craton allows to minimize the tectonic effects (at least in the area of presented here investigations). Numerous, well correlated borehole sections enable the analysis across the large area and in long chronostratigraphic interval. The most suitable interval for realization of above outlined purpose is considered to be the beginning of the Terebin Formation. The entire formation is composed of typical paralic cyclothems, but only in its lower part they exactly correspond to those known as the Yoredale-type cyclothems. The cyclic pattern of sedimentation is less regular in the bottom part of the interval, up to the Lst. Band *C*, and extremely regular in the upper part, up to Lst. Band *G*, what preliminary indicates some changes in sedimentary regime. Moreover, the Lst. Bands *C* and *F*, most firmly correlated beds in this part of the Carboniferous succession, are enough thick to precise record of the sedimentary changes during their deposition. The microfacies analysis of these two bands, on the background of general characteristic of clastic members of cyclothems, is a basis to discuss the causes of cyclic sedimentation.

CARBONATE MEMBERS OF CYCLOTHEMS

Microfacies spectrum

In overall and simplified view the investigated cyclothems are composed of carbonate and clastic members. The informally used here "clastic" members practically consist of all non-carbonate lithological types, namely mudstones and sandstones, as well as claystones and different phytogenic lithologies (carbonaceous shales, coals, and seat-earths). This simplification, offered herein for the clarity of this paper only, seems to be qualified by genetic connections all of these lithotypes.

The carbonate layer was the first Carboniferous rock-sample, which has been pierced in the exploratory borehole, undertaken for verification of the hypothesis offered by SAMSONOWICZ (1932) on the presence of the Carboniferous easterly of the river Bug. However, up to the early 80-ties they have been only macroscopically described as generally monotonous, marly limestone sequences, and the microfacies characteristics of the discussed limestones have been presented in a few papers. KOREJWO (1958), CEBULAK & PORZYCKI (1966), BOJKOWSKI (1978), CEBULAK (1988) confined their descriptions to the specification of main faunal components of limestones. KOWALSKI & *al.* (1982) analyzed 5 borehole sections, and distinguished a few microfacies, detailing the quantity of foraminifers, crinoids, and brachiopods as the main factors for facies discrimination. The present Author (SKOMPSKI 1985, 1988) investigated the greater number of sections, but from a very small area in north-eastern part of the Basin and from only a short stratigraphic interval, restricted more or less to the Upper Viséan (*cf.* Text-fig. 1).

Several microfacies (abbreviated MF in the next chapters) have been distinguished, from which diverse algal, foraminiferal, crinoidal, peloidal, coral, spiculitic, and oncolitic microfacies are most abundant. In addition, the organodetrital MF with average content of all faunistic remnants has been noticed.

In the Ukrainian margin of the Basin, SHULGA & *al.* (1992) detected 8 microfacies ("microstructural-genetic types"), mainly based upon the quantitative relations between the matrix and biodetritic material. From the varied biotic remains only foraminifers, calcareous algae and "blue-green algae" were specifically considered as indices of some MF. Unfortunately, the microfacies spectrum was attributed to all of the limestones beds taken together.

The broadening of the investigated area (in comparison to the earlier Author's paper, SKOMPSKI 1985), over the entire Basin and covering all limestone bands enriched the general MF spectrum, and revealed significant diversity within particular MF types. However, the algal microfacies still remains the most specific and most frequent in the sections. Only some taxa from the rich assemblage make rock-forming accumulations, reasoning a separation of specific submicrofacies (sMF). The most characteristic is *Calcifolium* sMF, in which the index taxon is the only recognizable fossil element, or *Calcifolium*-particles dominate in the sample and are associated with less frequent paleoberesellids, dasycladacean algae, foraminifers, and crinoids. *Calcifolium* is usually found in the form of algal debris (Pl. 19, Fig. 2); the specimens in growth position are extremely rare (Pl. 19, Fig. 1 *and* SKOMPSKI 1981). The small, millimeter-scale size of *Calcifolium* caused that it did not make significant build-ups, and its accumulations probably resembled recent halimedacean meadows or small lagoonal mounds (*see* KOBLUK & KAROLYI 1979, HILLIS 1991). Another characteristic algal-microproblematic sMF are formed by paleoberesellids, association *Nanopora-Saccamminopsis* (Pl. 20), and *Anthracoporellopsis* (Pl. 11, 12). The porous structure of these forms, resulting partly from their dasycladacean nature (SKOMPSKI 1987, 1993) implicated facility of these particles for transportation, selective winnowing and concentration on the nearshore shoals or even upon the low-energy beaches.

The monospecific, "dense" *Masloviporidium* sMF (Pl. 15, Figs 1-6 and Pl. 23, Figs 3-4) is last example of algal-microproblematic MF. It is typical of the Upper Carboniferous Lst. Bands *M-N-O*, which were deposited in restricted, extensive lagoons, distant from the open sea. In contrast to the Early Carboniferous, the marine sedimentation appeared only temporarily in intervals, which were too short for development of real carbonate sedimentary systems with platforms, ramps, etc.

The organodetrital MF is nearly as frequent as algal-microproblematic one, but the idea to distinguish it is different than in remaining cases. According to the scheme used in this paper it is in some sense the "background" MF; the elements, which dominance allowed to categorize specific microfacies end-members, in this MF are equally assembled. Typical of this lithotype are crinoids, foraminifers, different algae, as well as brachiopod-bryozoan debris and gastropods, rare ostracods and sponge spicules. More specific is variety of organodetrital MF enriched with numerous dark intraclasts and pyritized faunistic debris (Pl. 22, Fig. 2). This MF was found only in the bottom part of the Lst. Band *F*. Its characteristics indicate depositional features typical of transgression onto the submerged parts of delta plain covered by peats. The abandoned delta lobe subsided in the absence of clastic input, and the subsequent relative rise of sea level caused the transgression of marine carbonate facies onto the submerged abandonment facies. The peat cover, according to the dynamics of process was eroded or preserved (both these cases are observed along the present-day sea shores), and the abundance of organic matter caused the reducing conditions in the bottom layer of carbonate mud, what produced an effect of early pyritization of faunistic remains. The gray or black clasts in carbonate layer originated from the eroded basement. The thickness of this pyrite-rich variety of organodetrital MF rarely exceeds 60 cm.

The spiculitic MF is rarely found, but its monospecific character distinctly differs it from others. A domination of mainly monoaxial sponge spicules is very clear, and other elements as algae, oncoids, peloids, and rarely crinoidal debris are only accessory. Thickness of lithosomes dominated by this MF in usually not greater than 50 cm. The axial canal of spicules infilled by micrite is visible in numerous specimens (Pl. 18), and this feature indicates (with some reservations) primary siliceous matter of spicules.

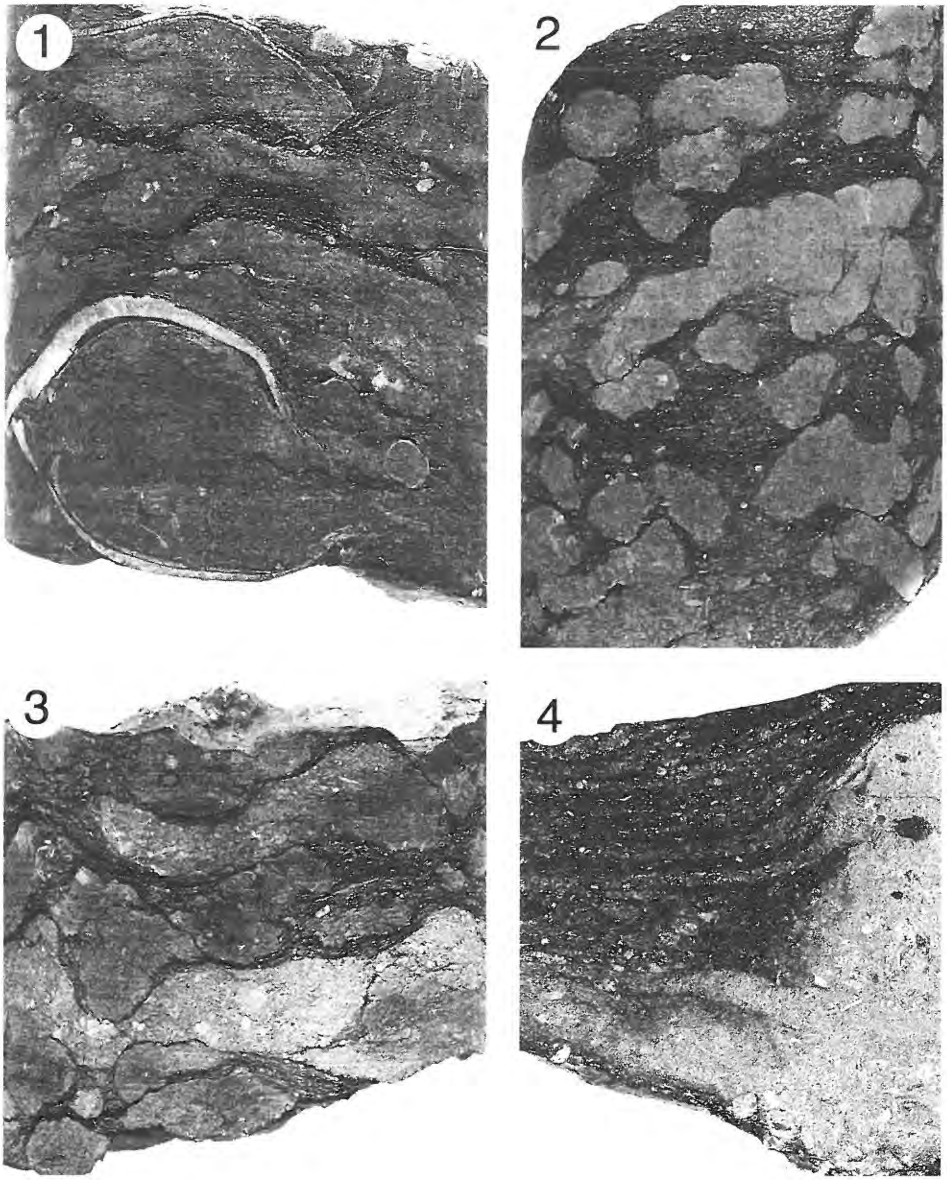
The interpretative value of spicules as bathymetry indicator is rather poor. In most general interpretations the spicules accumulations are characteristic of deep-water basinal sediments. However, the investigations of carbonate ramps and platforms provide every now and again information on shallow water abundance of sponges. JEFFERY & STANTON (1995) reported increasing number of hexactinellid sponge spicules with decreasing depth of Alamogordo Ramp (L. Mississippian). Similarly, in numerous English examples the spicules are associated with shallow water fauna. HORBURY (1989) reported occurrences of spicules together with *Saccamminopsis* and algae in the sub-fair weather wavebase mudstones-packstones of the Urswick Limestone. Identical association is described by PICKARD (1994) from the base of deepening upward Charlestown Main Limestone. In the Lublin Basin this MF is sometimes coupled even with features indicative of the periodically emerged zones of sedimentation, and therefore it is treated as one of the most shallow facies.

The foraminiferal MF appears relatively rare in the succession, but the benthic forams are common elements in nearly all other microfacies.

They represent extremely diverse assemblage (*see* SOBOŃ-PODGÓRSKA 1979, 1988; SKOMPSKI & *al.* 1989, SOBOŃ-PODGÓRSKA & TOMAŚ 1995) with more than 80 species. In the samples classified as foraminiferal MF a number of foraminifer specimens is greater than 50 per sq. cm (up to 120 specimens maximum), and they distinctly dominate over the remaining elements: usually crinoids, less frequent bryozoan-brachiopod and molluscs debris. The benthic mode of life of these invertebrates points for a possible correlation of the taxa distribution with particular ecological niches. However, the statistical factor analysis (SKOMPSKI 1985) and literature services (OSIPOVA & *al.* 1972, MAMET 1977, OSIPOVA & BELSKAYA 1977, BRENCKLE & *al.* 1982) did not reveal any clear relationship. More unequivocal is an interpretation of the total amount of forams, which in the most of Lower Carboniferous carbonate ramps increases with a distance from the shoreline (see MAMET & ARMSTRONG 1977, OSIPOVA & BELSKAYA 1977). On the ground of these observations the foraminiferal MF is considered here to be the most offshore microfacies.

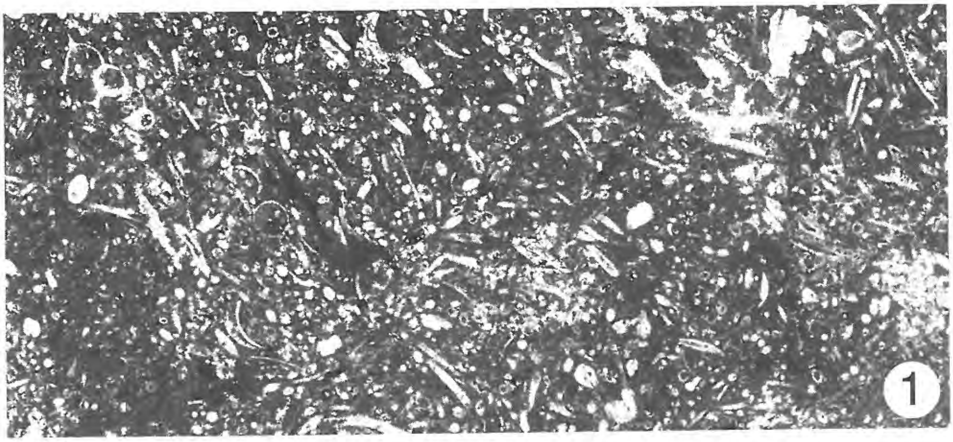
The intervals with crinoidal MF belong to these units which are discernible also macroscopically, in the form of a few meters thick encrinites. The crinoids, similarly to foraminifers, have been found in most of samples, but the crinoidal MF consists only those samples, where crinoids are practically only component (except of rare forams and brachiopod-bryozoan debris). The highly selected contents of this microfacies indicates its secondary nature in relation to *in situ* accumulations. The relatively low specific gravity of porous crinoids makes easier their selection and transport, and as final effect an accumulation of extensive and not very high banks or even mounds. Such an interpretation of crinoidal accumulations, which in the Lublin Basin is considered as an offshore facies, is supported by its close relationship with the foraminiferal MF.

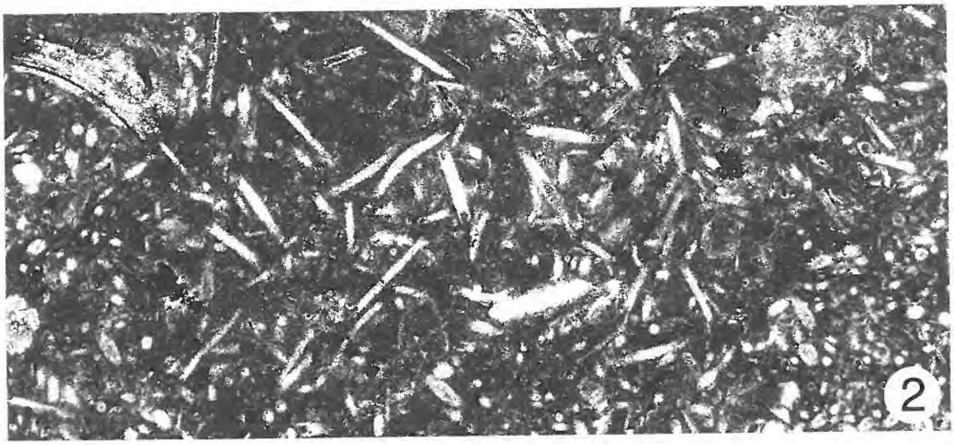
The peloidal microfacies was distinguished as a separate MF type, since it concentrates primary sedimentological and secondary early diagenetic features, connected with the emersion surfaces. Mudstones of this MF are characterized by peloidal microfabrics and general scarcity of micro- and macrofossils, represented mainly by crinoids, rare foraminifers and mollusc debris. Besides peloids, the abundance of different cortoids and small intraclasts is typical of this MF type. The algal-foraminiferal microproblematicum *Saccamminopsis* is a relatively numerous biotic element. The early cementation surfaces, frequently associated with peloidal MF, are characterized (Pls 24-26) by rare burrows or even shallow borings(?), with depth not exceeding 40 mm. Their multistage infillings formed in some cases geopetal structures with internal deposits corresponding to vadose silt. Subsequently, the burrowed intervals were penetrated by possible rhizoidal structures (Pl. 25, Fig. 1a-1b), what is suggested by development of "pellet coats" similar

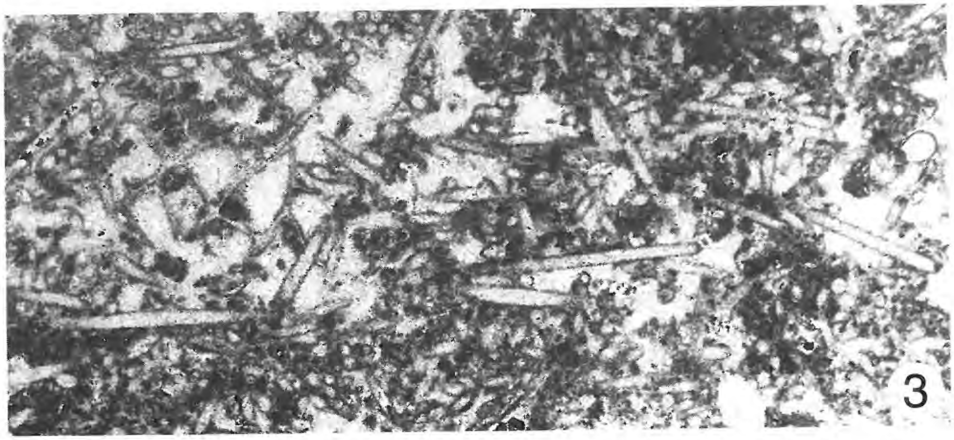


Nodular limestones characteristic of the upper parts of Limestone Bands; some nodules are sheltered by gigantoproductid shells (Fig. 1); the significant level of compaction of marly deposits in comparison to pure carbonates, indicates the early diagenetic origin of nodules (Fig. 4)

Samples from: **1** – borehole Radzyń *IG-10* (depth 768 m), **2** – borehole Orzechów *IG-2* (depth 1179 m), **3** – borehole Syczyn *IG-4* (depth 1215 m), **4** – borehole Orzechów *IG-1* (depth 1275 m); all of nat. size







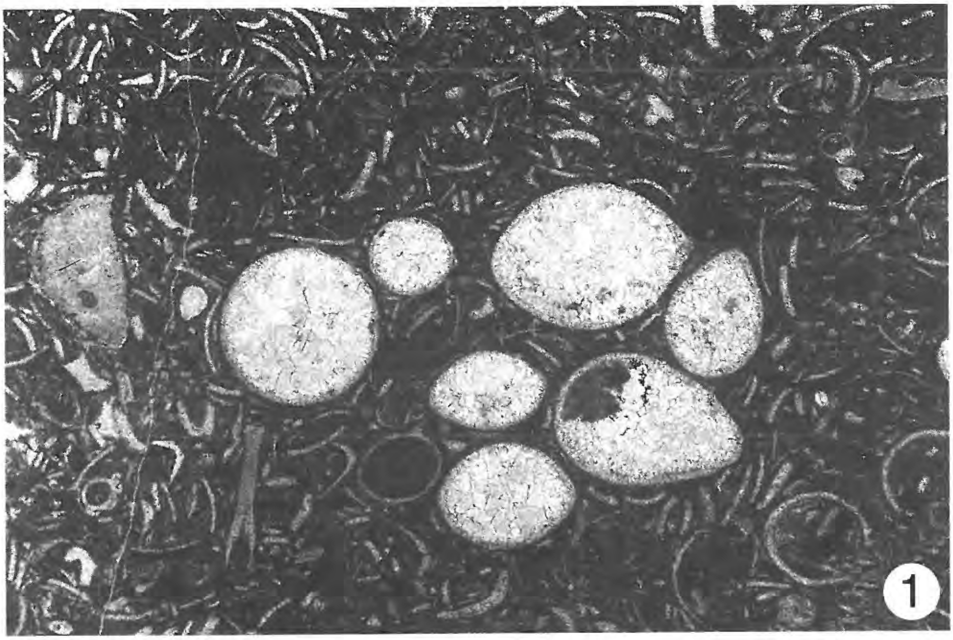
Shallow-water spiculitic microfacies

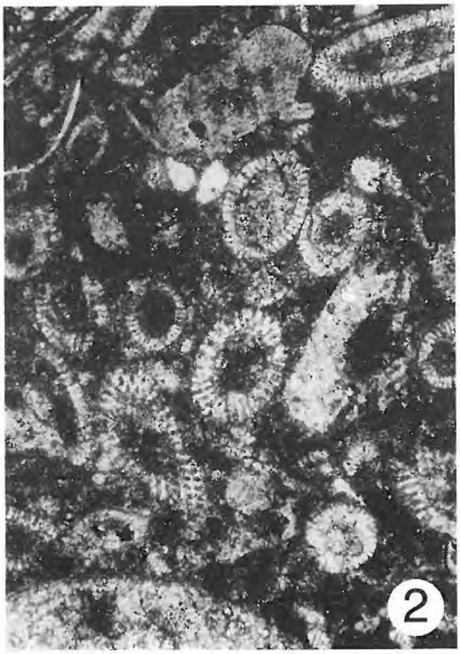
Samples from: **1** – borehole Kumów *IG-3* (depth 1181 m), × 10; **2** – borehole Lubartów *IG-3* (depth 1586 m), × 20; **3** – borehole Parczew *IG-10* (depth 1018 m), × 20

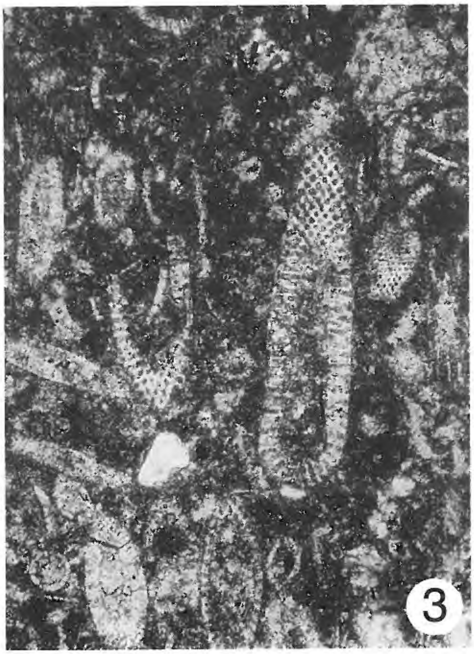
Algal limestones of the *Calcifolium* microfacies

1 — *Calcifolium okense* (SHVETZOV & BIRINA) in growth position; numerous umbrella structures are visible; borehole Krasnystaw *IG-6* (depth 1523 m), × 30

2 — Accumulation of algal debris; borehole Przewłoka *IG-1* (NE marginal part of the Lublin Basin, depth 788 m), × 30







Nearshore or shoal accumulations of light, perforated elements

1 — Monospecific accumulation of *Saccamminopsis* sp.; borehole Kumów *IG-3* (depth 1415 m), × 15

2-3 — Accumulations of *Nanopora anglica* (WOOD), associated with *Saccamminopsis* sp.; borehole Syczyn *IG-4* (depth 1259 m), × 120


1


2

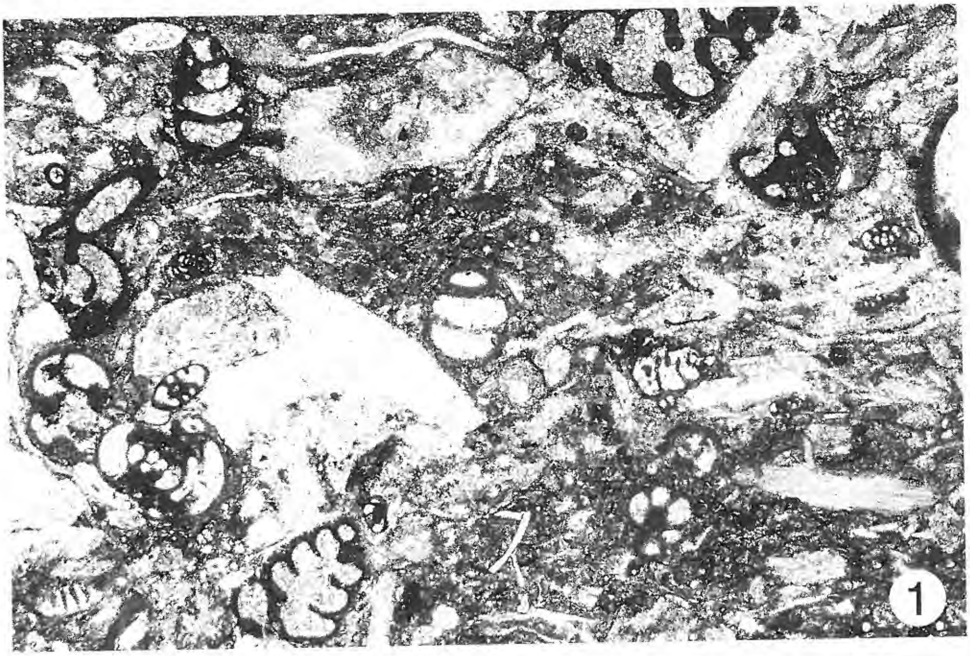

3

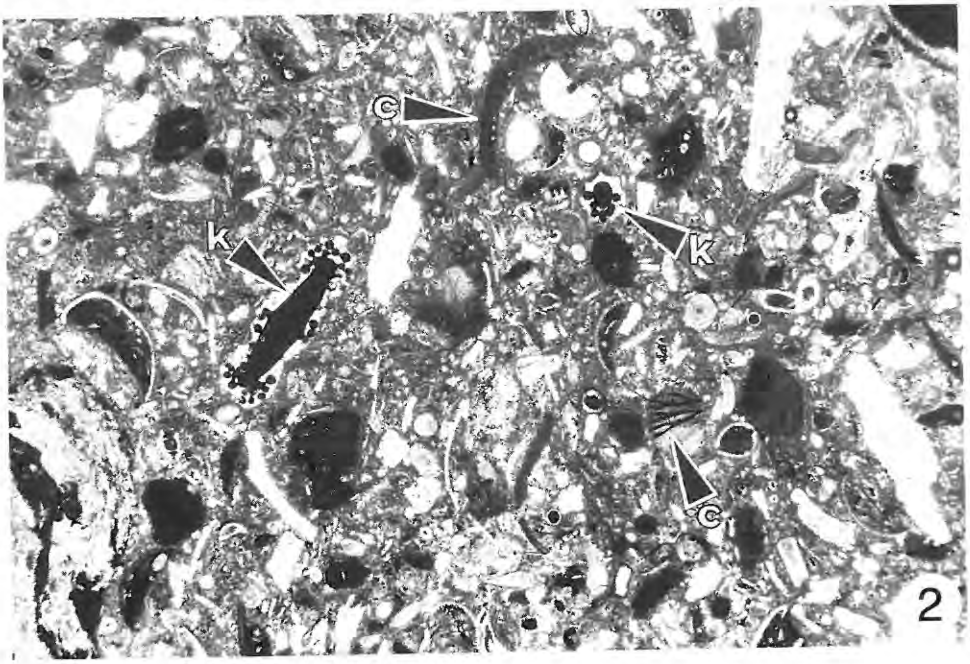

4

1 — Fragment of a phylloid algal buildup, constructed by *Archaeolithophyllum lamellosum* WRAY; borehole Sawin *IG-7* (depth 934 m), × 0.6

2-3 — Details of the build-up (*see* Fig. 1) with numerous geopetal infillings of primary porosity in gastropod, brachiopod and ostracod shells; × 5

4 — Peripheral part of an oncoid composed of *Archaeolithophyllum lamellosum* WRAY and girvanellids; borehole Rejowiec *IG-1* (depth 1169 m), × 5



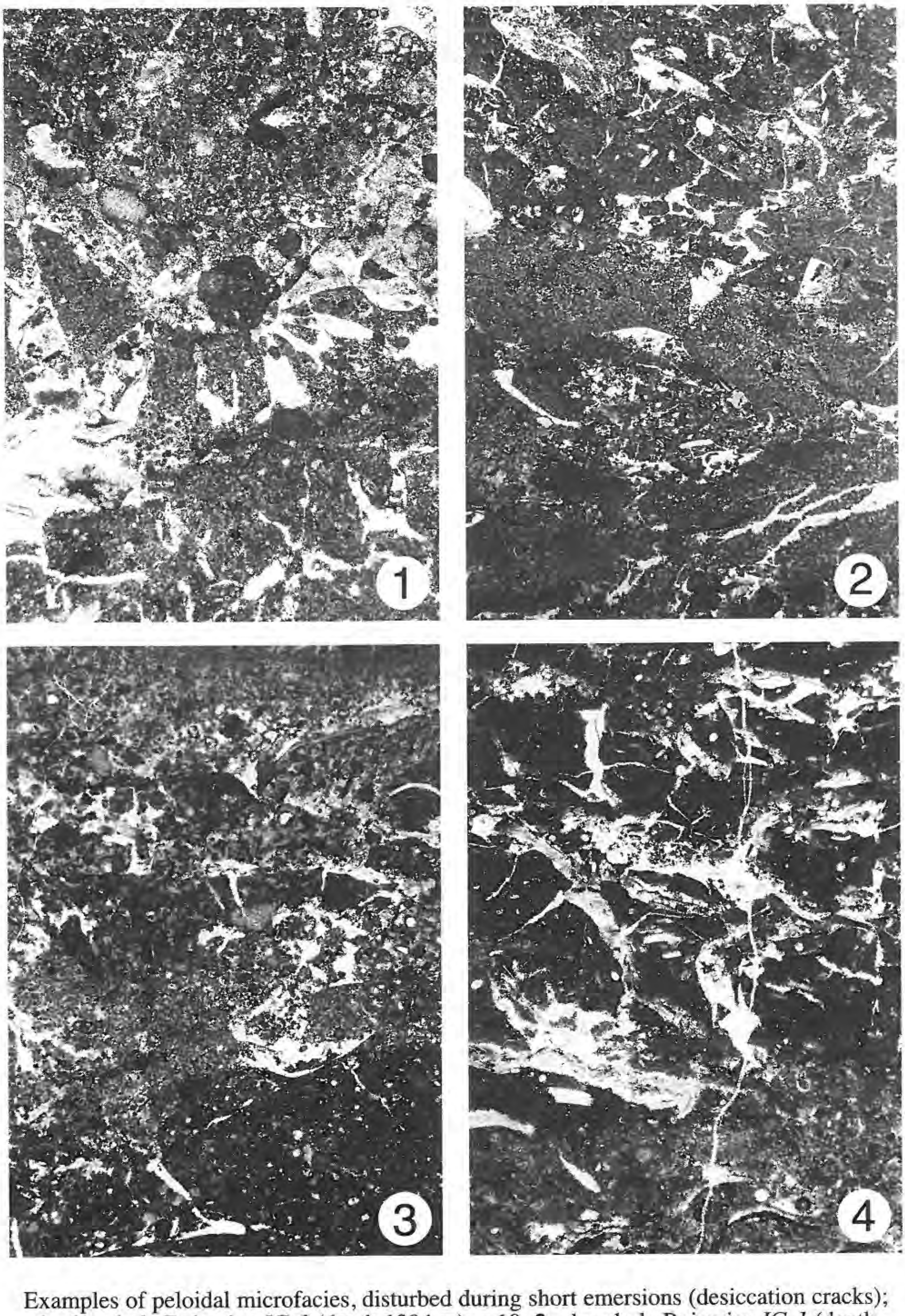


1 — Foraminiferal microfacies; borehole Kumów *IG-3* (depth 1244 m), × 30

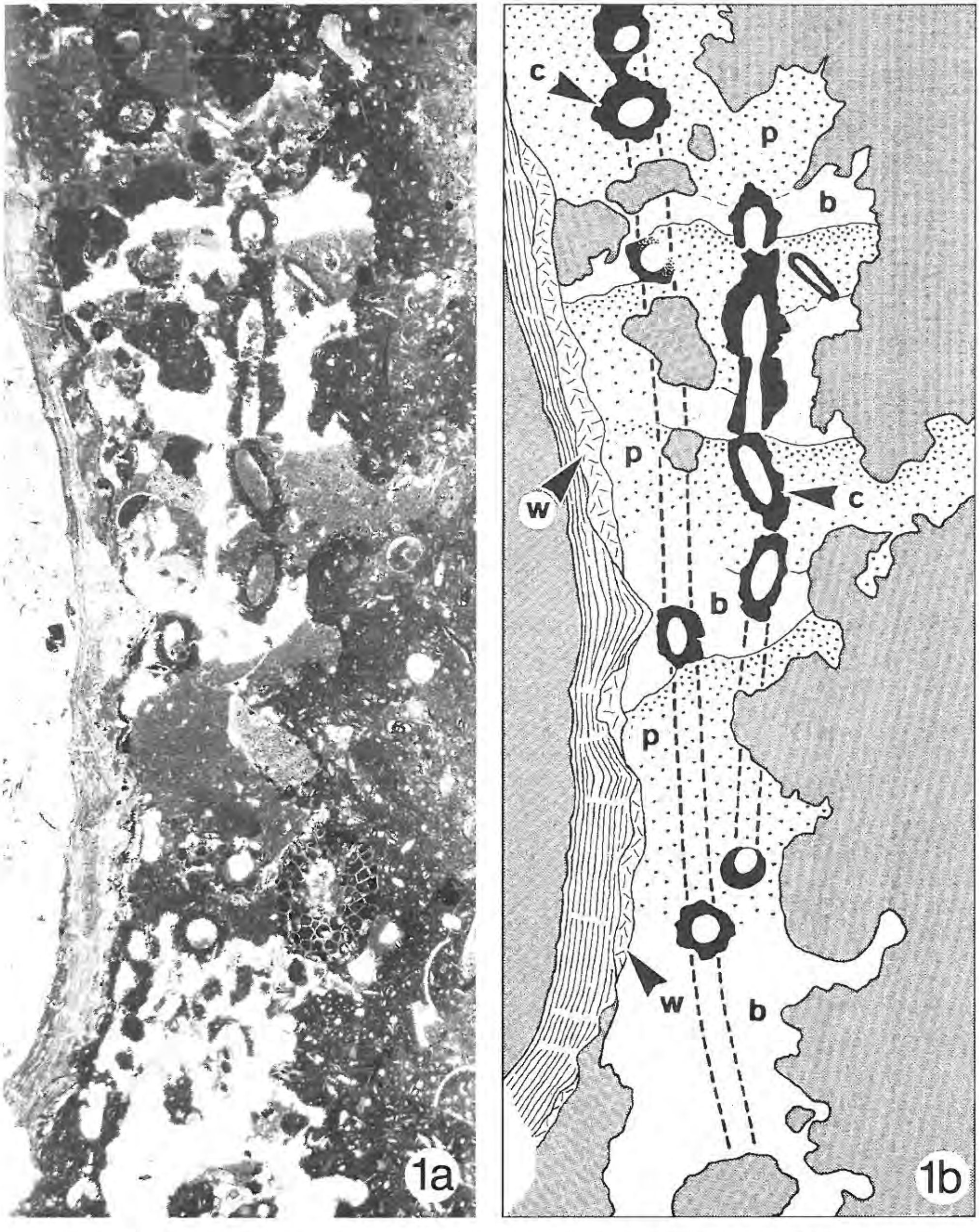
2 — Organodetrital microfacies with black clasts and pyritized algal debris: **K** – *Kulikia sphaerica* (Golubtsov), **C** – *Calcifolium okense* (Shvetzov & Birina); typical microfacies of the bottom part of the Lst. Band *F*; borehole Sawin *IG-7* (depth 935 m), × 25

1-2 — *Zoophycos* bioturbations in the organodetrital wackestones; polished slabs, nat. size; 1 – borehole Michałów *IG-4* (depth 962 m), 2 – borehole Sawin *IG-7* (depth 958 m)

3-4 — *Masloviporidium* microfacies; 3 – borehole Rejowiec *IG-1* (depth 1064 m), × 4; 4 – borehole Syczyn *IG-4* (depth 1013 m), × 10

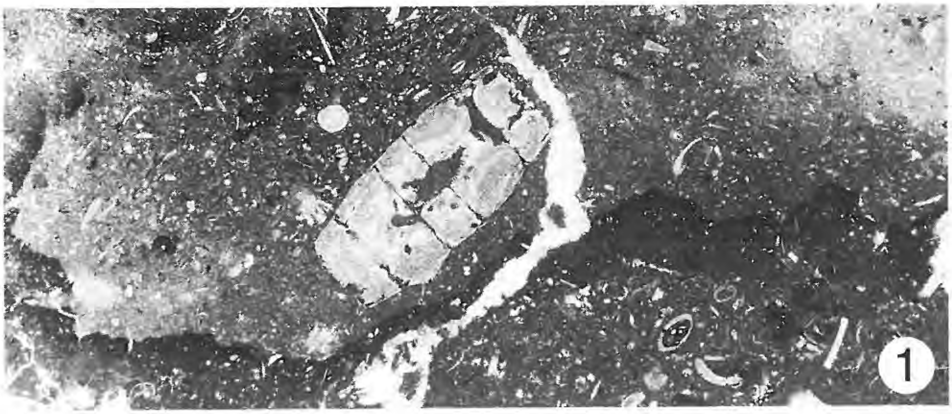


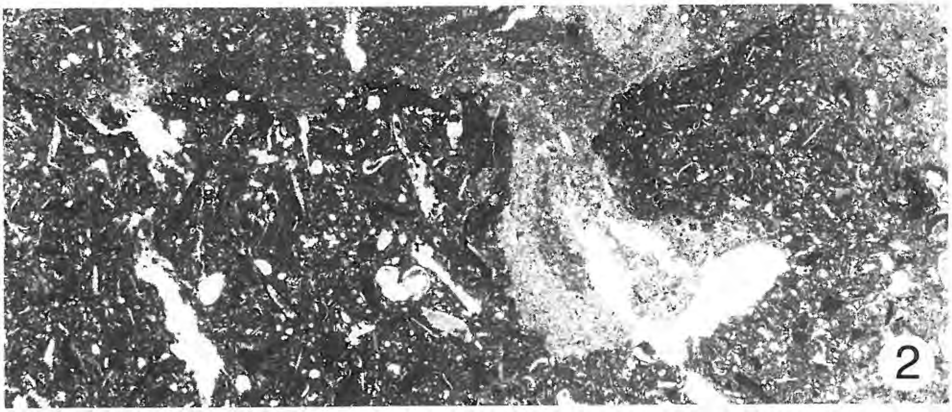
Examples of peloidal microfacies, disturbed during short emersions (desiccation cracks); **1** – borehole Rejowiec *IG-1* (depth 1304 m), × 10; **2** – borehole Rejowiec *IG-1* (depth 1308 m), × 10; **3** – borehole Krasnystaw *IG-6* (depth 1526 m), × 10; **4** – borehole Krasnystaw *IG-6* (depth 1528 m), × 10

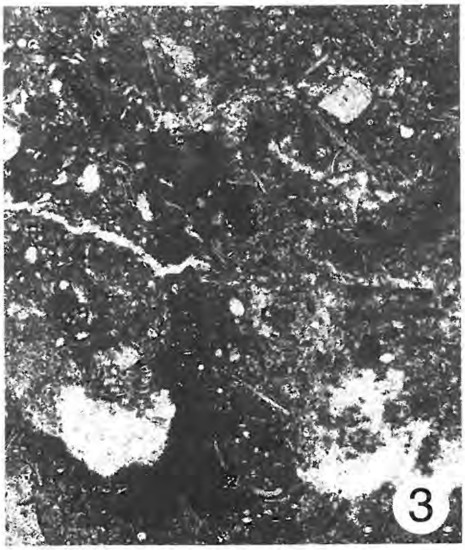


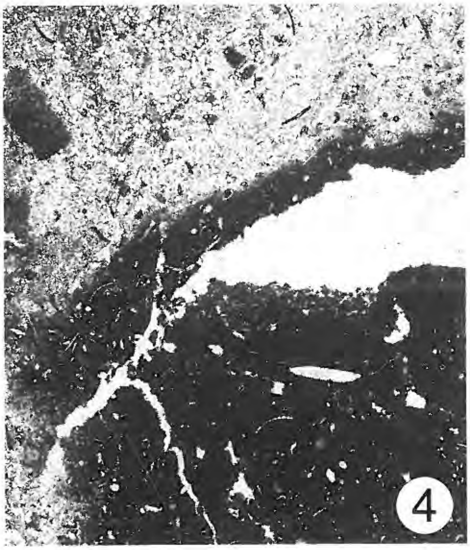
Details of an emersion (or omission) surface in the Lst. Band *C*

Wide burrow (boring ?) along a vertically oriented brachiopod shell, enlarged by karstic solution and bioerosion (**w** - part of the shell, destroyed by algae and encrusting foraminifers); then successively infilled with peloids mixed with biodetritus (**p**), and blocky cement (**b**); finally penetrated by roots with specific peloidal coatings (**c**) around them (*cf.* similar features described by WRIGHT 1983); borehole Parczew *IG-6* (depth 904 m), × 25





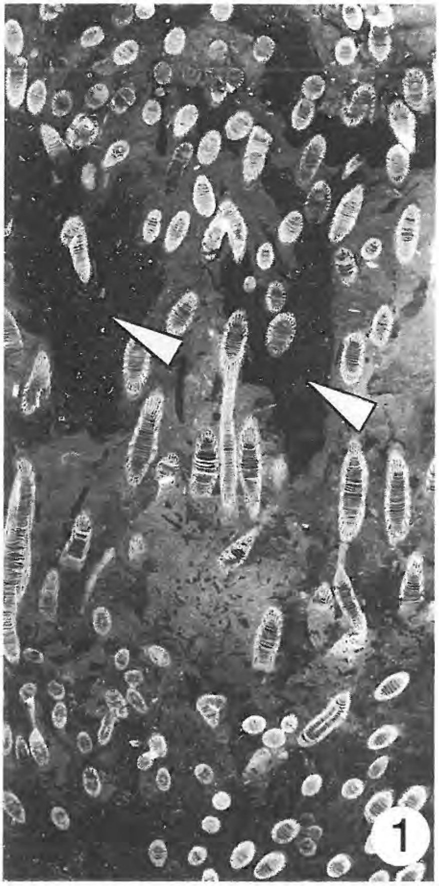


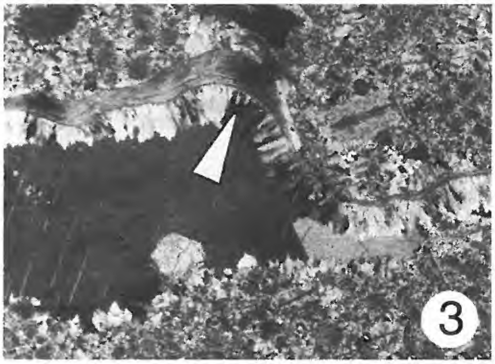


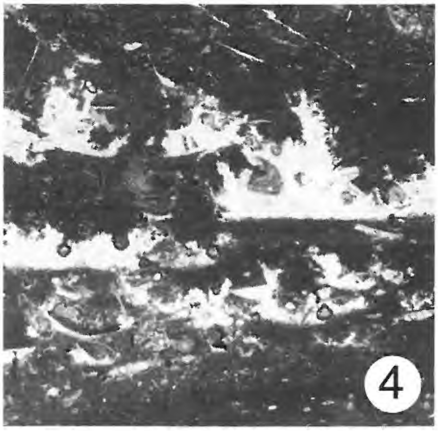
1 — Omission surface with early lithification structures and "circum-granular" cracks around crinoidal particle, borehole Parczew *IG-6* (depth 570 m), × 6

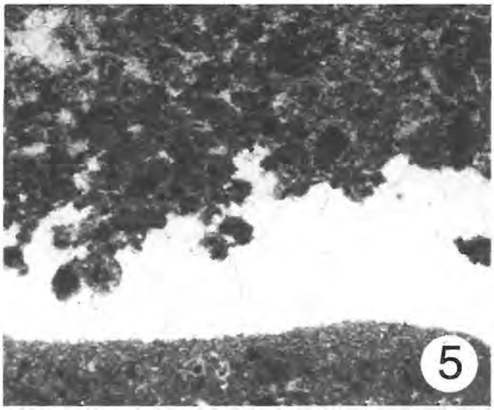
2-3 — Fragment of omission surface with corrosionaly enlarged burrows; 2 – borehole Lubień *IG-1* (depth 737 m), × 5; 3 – borehole Podedwórze *IG-2* (depth 570 m), × 7

4 — Bottom part of burrow, partly infilled with peloids; borehole Parczew *IG-6* (depth 904 m), × 3









Details of the lithostrotionid and microbially cemented bryozoan-crinoidal buildups

1 — Coral framework in biodetrital matrix composed of peloids, rare bryozoans, gastropod and brachiopod detritus; the darker matrix (*arrowed*) is bioturbated and dominated by numerous foraminifers; borehole Orzechów *IG-22* (depth 1113 m), × 0.7; polished slab

2-5 — Peloidal matrix of the bryozoan-crinoidal bioherm; borehole Minkowice *4a* (depth 1325-1340 m); **2** – Spar that fills cavity sheltered by the productid shell and lined with the inclusion-rich radiaxial fibrous cement; thin section, × 8; **3** – Enlarged part of Fig. 2, to show RFC cement lining (*arrowed*); crossed nicols, × 25; **4** – Stromatactoid cavities in the core facies; thin section, × 7; **5** – Peloidal micrite cemented by yellow calcite microspar forming the matrix of biohermal microfacies; thin section, × 25

Details of the contact zones between the coal beds and overlying limestone layers

1 — Lenticular bedding composed of carbonate biodetrital material in coal matrix; borehole Orzechów *IG-22* (depth 1115 m), nat. size

2 — Strongly bioturbated detritus in the carbonate lens from the upper part of the sample illustrated in Fig. 1; thin section, × 8

3 — Sedimentary lamination in the coal bed underlined by linear arrangement of the secondary pyritic mineralization; enlarged part of Fig. 1, thin section in reflected light, × 15

4 — Less dynamic transition between coal bed and *in situ* deposited carbonates; borehole Orzechów *IG-9* (depth 922 m); polished slab, × 2

to those described by WRIGHT (1983) from the Lower Carboniferous paleosols of South Wales (*cf.* JONES & SQUAIR 1989). Other important feature which is connected exclusively with the peloidal MF is the presence of desiccation cracks and rare fenestra (Pl. 24). This microfacies is rarely reported from the Carboniferous successions. Its characteristics partly corresponds to descriptions of lower parts of paleosols horizons (WRIGHT 1983, 1994; DAVIES 1991, VANSTONE 1991). A lack of higher, more typical parts of paleosols could be explained by a post-cementation washing-away. On the other hand, similar mudstones/wackestones were interpreted by HORBURY (1989) as intertidal/supratidal deposits. Although the unequivocal interpretation of the studied intervals from the Lublin Basin is difficult, the characteristic association of sedimentary and diagenetic features suggest that the intervals with the peloidal MF represent shallowest parts in the carbonate successions.

In comparison to the Author's previous papers (SKOMPSKI 1985, 1988) in the present work the oncoid and coral microfacies are excluded from the MF spectrum The coral boundstones are easy discernible macroscopically and they are practically limited to the lowermost limestone complex *A1* only. A thorough analysis of the bioherm microfacies (not only coral but also algal ones) will be presented elsewhere (SKOMPSKI & ŻYWIECKI *in press*). The oncoids occur in the investigated limestone complexes relatively rare, although they are diverse, and do not form significant accumulations. Specifically, all of them represent biogenically formed coatings, while oncoids with micritic fabric of cortex are absent. Most frequently the coatings were formed by *Girvanella* tubes associated with encrusting foraminifers *Hedraites* and *Apterinella*. They correspond to commonly found in the late Paleozoic "Osagia"-type oncoids. In the younger limestone bands appear "Archaeolithophyllum"-type forms the coatings of which consist of index alga with microproblematica *Aphralysia* and *Wetheredella*, similar to those described by HALLET (1970), BELKA (1981), and SOMERVILLE & *al*. (1996). Sporadically the oncoid coatings are composed of the encrusting specimens of *Calcifolium punctatum*. The environmental distribution of the "Osagia" and "Archaeolithophyllum"-type oncoids is relatively well known (*see* TOOMEY 1974, and PERYT 1981), but their environmental interpretation is still not very precise. Generally, both types are typical of the relatively shallow water of slowly subsiding carbonate platform, what allows to postulate a very broad bathymetrical interval. In the discussed layers the oncoids are associated mainly with peloidal MF and algal MF.

Carbonate buildups

An indication of buildup nature of the carbonate lithosomes on the basis of the borehole material is rather difficult. However, a presence of rigid framework and primary cavities, particular matrix, specific faunal contents, succession of microfacies, distinctive cements, *etc*. allow to suggest a biohermal origin, even when the details of spatial facies arrangement are unknown. Such biohermal successions, even very thin, are rather rare in the investigated limestone bands, except of the lowermost part of the Huczwa Formation. This is not surprising as a general paucity of the shallow water buildups in the Early Carboniferous is well recognized (*see* WEST 1988, WEBB 1994, BRIDGES & *al*. 1995, SOMERVILLE & *al*. 1996). However, the Lublin examples are worth of mention due to their paleogeographic and paleobiological significance. They represent at least three different types of buildups, including also rigid-framework constructions.

In the lowermost part of the Huczwa Formation, usually in the first carbonate complex, there occur reefal successions dominated by lithostrotionid corals (Pl. 27, Fig. 1). Their observed thickness rarely exceeds 3-4 m, but exceptionally, in the north-eastern part of the Basin, it reaches more than 10 m (*cf*. KHOA 1977). In the lowermost limestone complex of the Huczwa Formation the proportion of coral facies reaches in some sections 50% of thickness (SKOMPSKI 1985). The abundance of colony corals in this unit seems to be connected with diverse morphology of the bottom during first phase of the Carboniferous transgression. The intensive Tournaisian or early Viséan volcanism, preceding the late Viséan transgression and especially well recognized in the north-eastern part of the area (CEBULAK 1988, GROCHOLSKI & RYKA 1995) created the hilly, but not very high landscape. During the initial transgression the rocky margins of volcanic islands, projecting above the sea level, were the best place for development of reefs, and clay material transported from the land was detained in a relatively narrow zone of the perilithoral. In the effect of succeeding marine incursions the morphology of the bottom became levelled and transport of argillaceous material in the form of prodeltaic sediments has been performed without disturbances. Consequently, the conditions for growth of colony corals became evidently worse. The process of bottom levelling is well illustrated in the investigated cross-section (Text-fig. 10) by the lower parts of successions in the boreholes Orzechów *IG-3*, Orzechów *IG-22*, and Orzechów *IG-2*. The last sequence represents post-volcanic swell, while the first two sections are characterized by abundance of reef limestones in the lowermost carbonate complex.

Shallow water buildups were also found in the lower half of a 5 m thick Lst. Band *F* in the borehole Sawin *IG-7* (NE margin of Basin). The framework of this bioherm is constructed by *Archaeolithophyllum lamellosum* (Pl. 21, Fig. 1) associated with the microproblematical form *Wetheredella* (*see* Pl. 14, Figs 1-2; alga ?, foraminifer ?, cyanobacterial biostructures *according to* KAŹMIERCZAK & KEMPE 1990). The fragments of *Archaeolithophyllum* thalli are encrusted with another algal problematicum *Fasciella*, as well as foraminifers *Tetrataxis* and *Tuberitina*. Relatively frequent is debris of *Calcifolium okense*, small brachiopods and gastropods (Pl. 21, Figs 3-4). The primary vugs (umbrella-type structures below algal thalli and geopetal cavities inside the brachiopod shells) are infilled with blocky calcite. The biohermal part is covered by strongly bioturbated (*Zoophycos*) wackestones with foraminifers, ostracods, gastropods and crinoids.

Independently of the precise taxonomic position of *Archaeolithophyllum*, which is still a subject of discussion, the taxon is included to the morphological group of phylloid algae, which played an important role as main framebuilders in the Upper Carboniferous and Permian buildups (*see* WRAY 1977, WEST 1988, MAMET 1991). Their Lower Carboniferous (Upper Viséan - lowermost Namurian) occurrences are characterized by a small size and specific association with different encrusting forms, such as *Aphralysia*, *Wetheredella*, and foraminifers (BELKA 1981, ROUX 1985). SOMERVILLE & *al*. (1996) interpreted an appearance of *Archaeolithophyllum* in the topmost part of the Viséan deep water Ardagh and Cregg buildups as an effect of rapid shallowing event, which stimulated the growth of rigid, wave resistant structures. The material from the Lublin Basin does not reveal indices of such function of the discussed buildup, but it may be caused by a small size of this structure and a limited access in borehole section. Anyhow, the appearance of this form documents the earliest stages of the late Paleozoic bioherms.

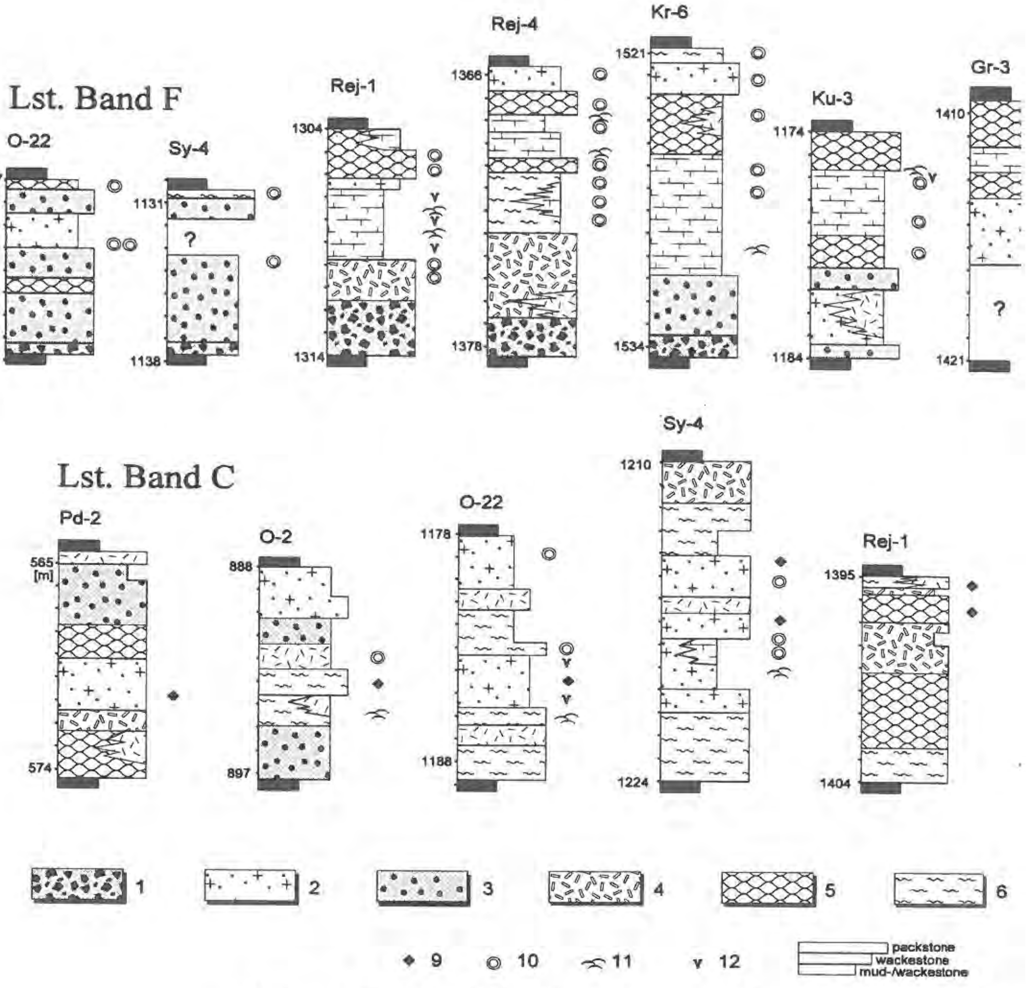
Another type of buildups has recently been recognized (SKOMPSKI & ŻYWIECKI *in press*) in the Lower Namurian carbonates from the borehole Minkowice *4a*, situated near Lublin, in the central part of the Basin. The provisional investigations indicate the biohermal architecture of several meters high buildup and an interfingering of the core and the flank facies. The crinoid and fenestrate bryozoan particles are dominant, while brachiopods, foraminifers and rare ostracods are secondary biotic components in the core part of the bioherm. The matrix is mostly composed of microbially produced peloids. The core microfacies (Pl. 27, Figs 2-5) with numerous non-skeletal microbialite structures generally resembles those described from the Upper Dinantian of Belgium and the British Isles (*see* for review BRIDGES & *al*. 1995, SOMERVILLE & *al*. 1996, PICKARD 1996). The interfingering flank and top facies are the densely packed crinoidal packstones.

According to the classification proposed by BRIDGES & *al*. (1995) this bioherm corresponds to the Type *2* or Type *3* of Early Carboniferous mounds, which usually are located below the photic zone, on the boundary between carbonate shelves and deeper intraplatform basins. If the more detailed investigations confirm, the Minkowice mound will be the first sign indicating the south-western margin of the shallow carbonate platform. Such a position of this margin is anticipated by more general interpretation of the tectonic structures (*e.g*. ŻELICHOWSKI 1972, POŻARYSKI & *al*. 1992) and presented in a schematic form on the cross section by the Author (SKOMPSKI 1995a).

The demonstrated examples of carbonate buildups, although singular, reflect most significant features of the Viséan - Namurian evolution of build constructions, briefly summarized by SOMERVILLE & *al*. (1996). Besides the generally known characteristics, as increasing proportion of algae and encrusting foraminifers and microproblematics, as well as a presence of the Waulsortian-like mud-mounds (here: Minkowice mound), the importance of corals in the Viséan bioherms is pointed. Their role in the Carboniferous environments has until recently been underestimated, despite of very numerous reports on the reef-corals in paleontological literature (in Poland *e.g*. FEDOROWSKI 1971, KHOA 1977). The presented data suggest that one of the most important controls of their development was rough topography of the basin floor, the factor still poorly documented in the Carboniferous sedimentary areas.

Succession of microfacies

The presented assemblage of microfacies is differentiated in respect of bathymetry and dynamics of sedimentary environment, but it does not reveal distinct trends in paleogeographic distribution of facies. Generally, the studied microfacies are typical of internal parts of epeiric platforms with negligible topography and wind-wave activity. In the more protected areas the algal and, to a lesser extent, spiculitic microfacies developed, while the more open regions were dominated by foraminiferal, crinoidal, and organodetrital microfacies. Local or temporary shoalings, situated far away from the shore, have been distinguished by peloidal MF. A lack of typical eulittoral, intertidal facies in carbonate members has been caused by the prevalence of argillaceous sedimentation in the nearshore areas. A comparison with distribution of the Lower Carboniferous facies in the Moscow Basin points that the real shoreline could be located several tens of kilometers further than the present-day north-eastern boundary of the Carboniferous deposits. In the opposite direction, the epeiric platform has been terminated on the line more or less coincident with the NE margin of the Radom-Lublin Trough, *i.e*. the line of the Devonian subcrops of the Kock horst-anticline (*see* Text-fig. 1). The proportion of carbonate sediments in the Carboniferous succession is distinctly lower southeasterly of this margin (*see* PORZYCKI 1988, PORZYCKI & ZDANOWSKI 1995), although single data

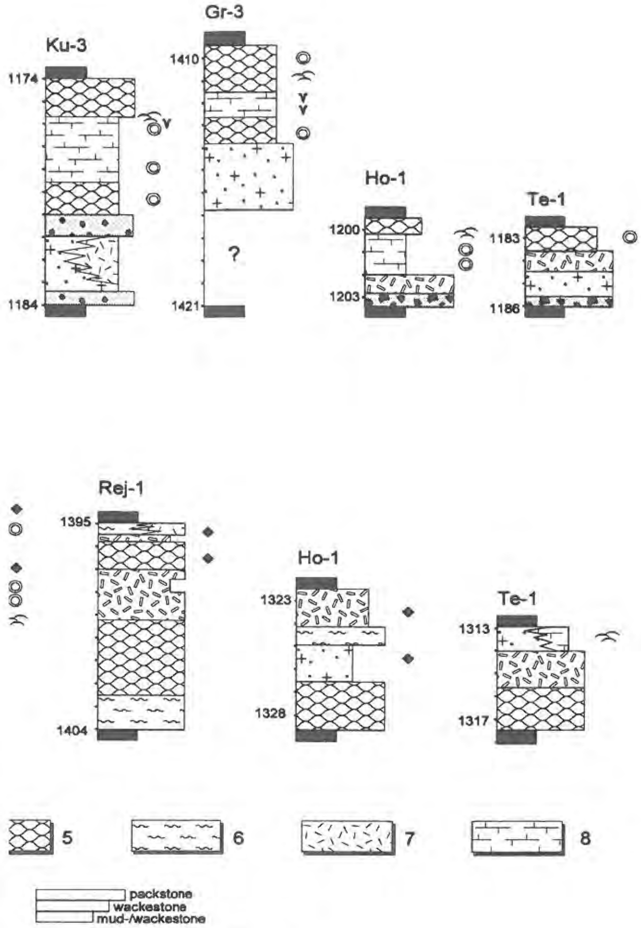


Microfacies (MF) distribution in the Limestone Bands *C* an

1 – Organodetrital MF with dark intraclasts and pyritized fossil debris, **2** – organodetrital MF, **3** – fc
5 – algal (*Calcifolium*) MF, **6** – algal (mixed assemblage) MF, **7** – spiculitic MF, **8** – peloid N
11 – primary porosity (umbrella str., fenestral str., *etc.*), **12** – desiccation c

Fig. 13. Comparison of microfacies proportion in the Limestone Bands *C* and *F*; the microfacies symbols the same as in Text-fig. 12

S. SKOMPSKI, FIG. 12



nestone Bands *C* and *F*

rganodetrital MF, **3** – foraminiferal MF, **4** – crinoidal MF,
iculitic MF, **8** – peloid MF, **9** – intraclasts, **10** – oncoids,
, *etc.*), **12** – desiccation cracks

F;

from this region (boreholes Lubartów *IG-3*, Lublin *IG-2*) did not exhibit sharp microfacies difference in carbonates. An occurrence of the biohermal structure in the vicinity of Lublin, which discloses features typical of the marginal mounds, becomes an important indicator of this boundary.

Evidently more informative is vertical succession in particular limestone bands. A distribution of microfacies in Lst. Bands *C* and *F* (Text-fig. 12), developed as relatively thick, most extensive and well correlated horizons, reveals the significant differences, although the spectrum of microfacies in both complexes is generally similar. Thickness of both bands shows identical regularity – it is greater in the central region between Syczyn and Krasnystaw, while in the marginal parts it is generally of a half of the maximum. In the north it is caused by slower subsidence in the marginal part of the basin. In the south the total thickness of lithostratigraphic units is larger, but in particular cyclothems the proportion of deltaic clastics as well as prodeltaic argillaceous sediments to the carbonates is radically greater, accordingly to the stratigraphic model of the Yoredale cyclothem proposed by JOHNSON (1961). It implicates that the sections from the central region are most representative for the investigations of developmental trends in the limestones. In both complexes the algal facies dominate (Text-fig. 13), while crinoidal and spiculitic ones appear in similar but generally small proportion. The relations of other microfacies are different in the both analyzed complexes. Most specific difference is a presence of organodetrital MF with intraclasts and pyritized components in the bottom part of Lst. Band *F*. Another characteristic feature of this complex is greater share of foraminiferal and peloidal MF, that is two end-members in MF spectrum considering their environmental interpretation. All these features induced that the microfacies pattern in the Lst. Band *F* is more clear and unequivocal than in the Lst. Band *C*.

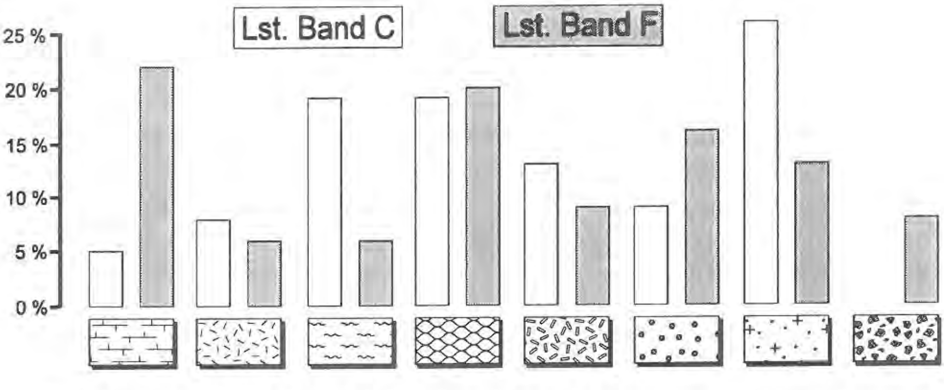


Fig. 13. Comparison of microfacies proportion in the Limestone Bands *C* and *F*; the microfacies symbols the same as in Text-fig. 12

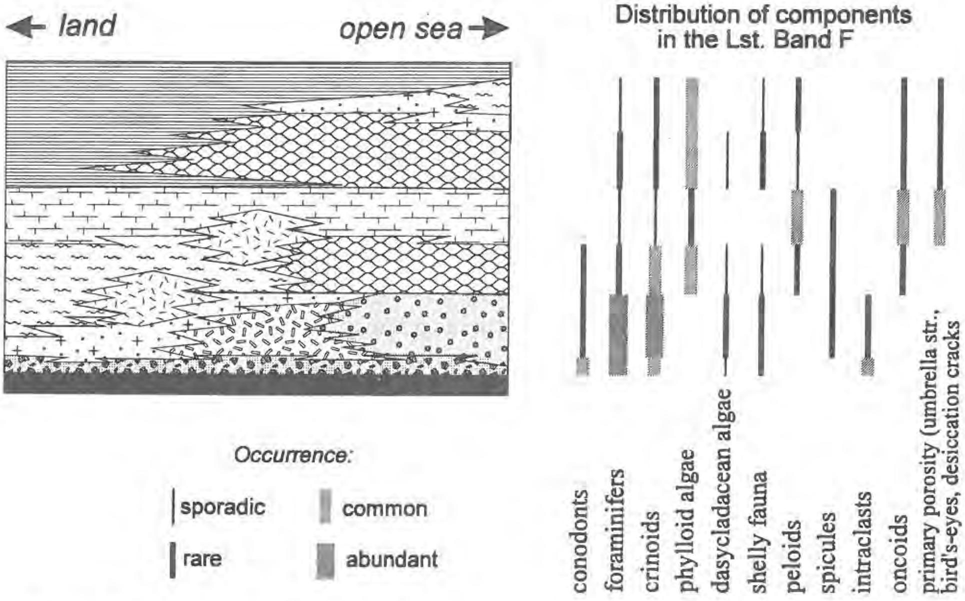


Fig. 14. Scheme of microfacies succession in the Limestone Band *F*; the microfacies symbols the same as in Text-fig. 12

The statistical MARKOV's analysis of vertical succession in the Lst. Band *C* in the northern part of the region (SKOMPSKI 1988) exhibited a lack of unidirectional tendency in development of microfacies and indicated only weak relationship in the groups of shallower facies (peloid-spiculitic-oncolitic) and open marine facies (crinoidal-foraminiferal-organodetrital). The extension of the observation field over the greater area confirms this analysis. Although the fluctuations of microfacies are frequent in the Lst. Band *C*, there is no clear tendency in these changes. Contrary to this case the microfacies succession in the Lst. Band *F* is clearly readable both in, the central and peripheral regions. The sequence exactly illustrates a two-stage regressive succession (Text-fig. 14). The initial rapid transgression results in deposition of open marine facies: foraminiferal, crinoidal, and organodetrital with minimal contribution of algae, mainly ubiquitous Dasycladales. The agradational growth of carbonates led to the shallowing of the basin and occurring of the peloid microfacies with a whole assemblage of associated features. Probably at this time the more restricted lagoons appeared, dominated by phylloid algae and oncoids, typified by scarcity of crinoids, foraminifers and shelly fauna except of bivalves. A control of this lagoonal environment is typical of the final retreat of the carbonate facies, which are overlain by argillites. This shallowing upward trend in the Lst. Band *F* is clearly visible in microfacies succession without involving of the statistical methods, and it is also expressed by the frequency of conodonts. In the bottom parts of the investigated limestone band the conodonts are moderately frequent, while in the upper half of the layer they are completely absent.

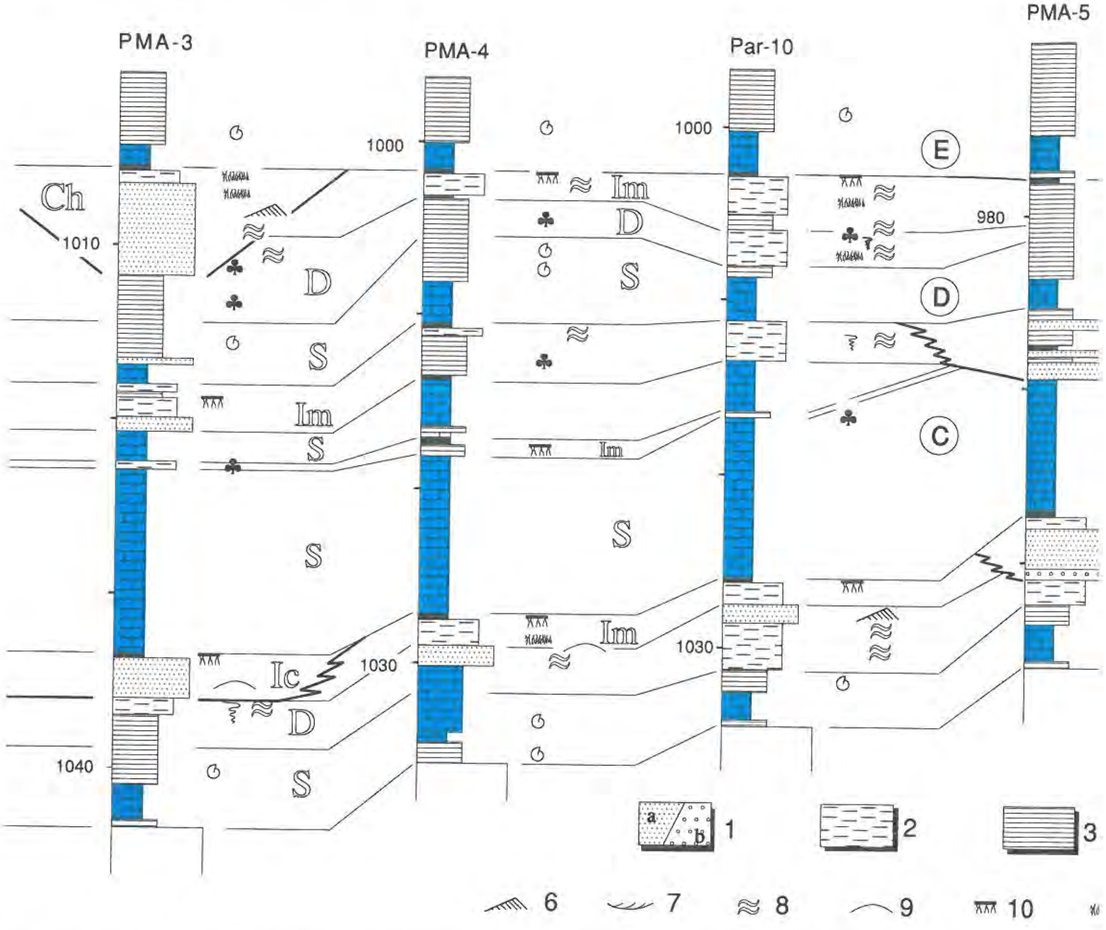
CLASTIC MEMBERS OF CYCLOTHEMS

Although the Viséan and Lower Namurian succession in the Lublin area is well known from numerous and regularly distributed boreholes, the sedimentological description of clastic deposits are very general or only local. The stratigraphic and correlative aspect of cyclicity predominates in these interpretations over the reconstruction of sedimentary environments and depositional processes. Surprisingly, the relatively detailed sedimentological description is presented in the early reports on the Lublin Carboniferous, by SCHWARZBACH (1944, 1949) and by KOREJWO (1958), who distinguished in the borehole Strzyżów *IG-1* respectively 26 and 30 cyclothems and concluded their deltaic origin. The similar, and general conclusions were presented by ŻELICHOWSKI (1964, 1972, 1983, 1987), who included to the investigations the entire basin and estimated the main transport directions. Petrography and mineralogy of the Carboniferous rocks were studied by RATAJCZAK (1974). Some interpretations concerning selected areas or intervals were also given in short abstracts (*e.g.* LASKOWSKI 1980, MAZAK 1988). The most complete information was given by PORZYCKI (1979, 1985, 1987, 1988; CEBULAK & PORZYCKI 1966, PORZYCKI & ZDANOWSKI 1995), who analyzed the structure of cyclothems and characterized petrography of their members. However, also there the data were presented in a generalized form, in relation to the whole formations, and sedimentological conclusions were limited, as in other papers, to confirmation of deltaic nature of cyclothemic succession. Quite recently, the precise sedimentological interpretations of a few sections from Orzechów region and southernmost part of the Basin were presented by SZWEMIN (1992) and WIŚNIEWSKA (1993). The both athoresses distinguished numerous lithofacies connected with prodelta, delta front, mouth bars and different parts of the delta plain. The boreholes analyzed by SZWEMIN (1992) in the Orzechów region allowed her to estimate also the more general paleogeographic changes.

The data presented herein are taken from three different regions, characterized by changing minuteness of details. In the northernmost Parczew region (Text-fig. 15) the sections were situated very close around the central borehole Parczew *IG-10*, in a distance of several hundred meters, while in the more central Orzechów area (Text-fig. 17) the boreholes, localized in nearly regular network, are distant each other up to several kilometres. The southernmost cross-section (Text-fig. 16) includes three boreholes situated in a distance of about 10 km, but in the area of the greatest thickness of paralic succession. These three examples illustrate in a small and large scale the main sedimentary trends, which unequivocally point for determinative influence of the deltaic environment on the formation of succession. Despite of great distance between these fields, the investigated sections are well correlated, and they represent similar time-interval, although different paleogeographic position in the basin caused differences in thickness.

The clastic complexes, delimited by the carbonate layers, are characterized usually by the coarsening upwards sequences, both large and small scale, mostly composed of muddy and silty material, with relatively low content of fine- and medium-grained sandstones. Thickness of large scale sequences is usually greater than 15 m and reaches in some cases 40 m. These sequences appeared directly after sedimentation of the carbonate members, and consist a transition from relatively thin gray claystone member with flat lamination and gradually disappearing marine fauna to bioturbated mudstones with wavy and lenticular bedding. The small-scale slump structures and deformation, caused by unstable density stratification, are relatively frequent. The thick sandstone interbeds reveal small-scale cross stratification, with rarely found escape traces and bioturbations. Consequently, the content of dispersed plant debris increases upward. These parts of sequences are interpreted as transition from prodeltaic (or even offshore) sedimentation to the delta front and mouth bars. The sandstone interlayers represent single episodes of mouth bar progradation. The gradational contacts of recurrent lithofacies typified these monotonous and relatively thick intervals. A lack of three-dimensional data on geometry of lithosomes makes difficult a precise distinction between the particular subfacies in the succession. Therefore, the boundary between shelf - prodeltaic (denoted on the presented schemes as **S**) and delta front (**D**) - mouth bar facies on the presented schemes (Text-figs 15-17) is conventionally identified as a boundary between claystone and mudstone dominated intervals.

The topmost members of sequences are more diverse and characterized by an increasing influence of vegetation. They represented generally two types of delta plain environment: vast, interdistributary areas with progressively developing swamps (**Im**), and the areas periodically inundated during flood incursions (**Ic**). The former environment is characterized by muddy and clayey sediments with frequent seat-earths and carbonaceous shales or even thin coal layers at the top. For the latter, the small-scale cycles (1-3 m) are typical, with nearly black, bituminous and non-laminated claystones (rarely mudstones) in the lower part, covered by fine-grained sandstones lacking internal structures. These several times repeating



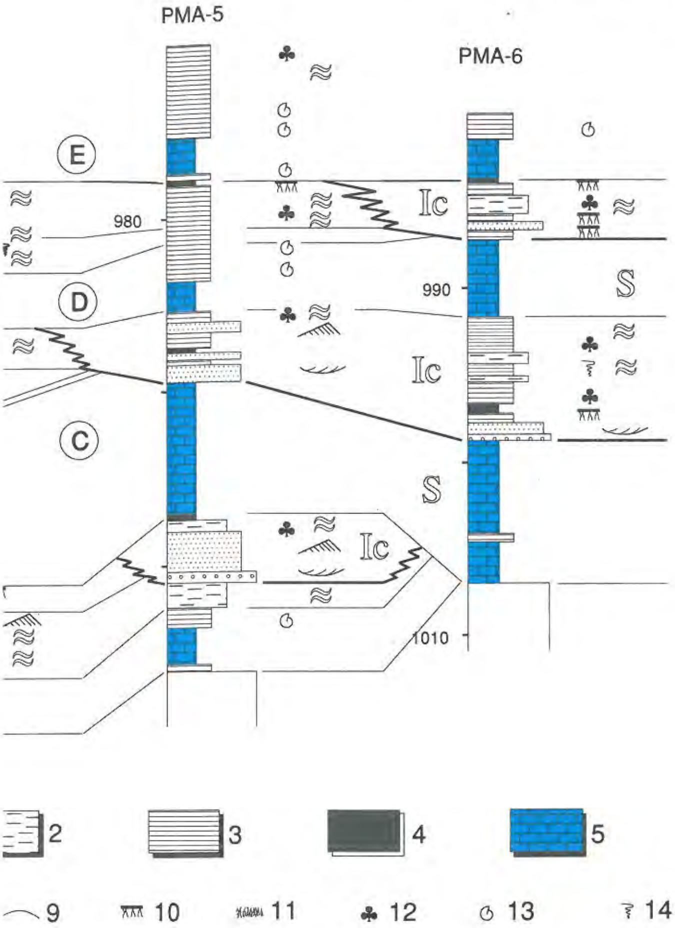
Interpretation of the sedimentary environment in the sections located around the bor
north-eastern part of the Lublin Basin (*see* rectangled area in Text-fig. 1); the in
the Viséan/Namurian transition series (Lst. Bands C, D, E – lettered in circles); the
meters distant each other

LITHOLOGY and FOSSILS: **1** – sandstone facies (**a** – fine-grained, **b** – coarse-grained), **2** – mudsto
5 – carbonates, **6** – small-scale stratification, **7** – trough-cross stratification, **8** – flaser bedding, **9** – l
underlain by seat-earths, **11** – seat-earths, **12** – floristic remains, **13** – marine fauna in non-carb

SEDIMENTARY ENVIRONMENTS: **S** – shelf/prodeltaic carbonate/argillaceous intervals, **D** – delta fr
areas, with progressively developing swamps, **Ic** – areas periodically inundated during flood inc
Ch – distributary channels

mostly sharp, extremely well visible because of the lithological contrast (Pl. 28, Figs 1-2). The presented specimens show that carbonate units gen-

S. SKOMPSKI, FIG. 15

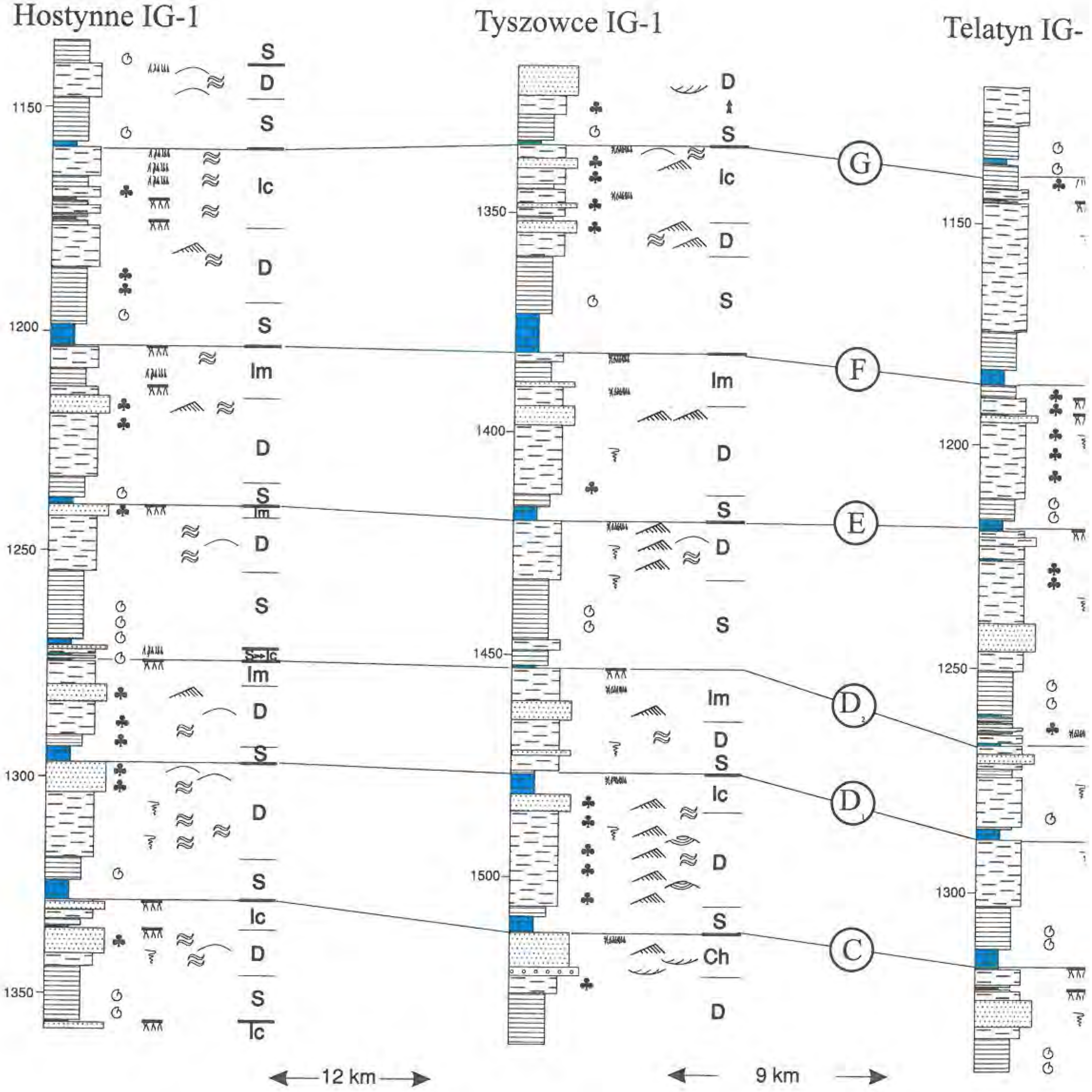


ated around the borehole Parczew *IG-10* (Par-10), Text-fig. 1); the investigated interval represents ered in circles); the boreholes are several hundred her

se-grained), **2** – mudstones, **3** – claystones, **4** – coal layers, **8** – flaser bedding, **9** – lenticular bedding, **10** – coal layers arine fauna in non-carbonate beds, **14** – bioturbations

s intervals, **D** – delta front/mouth bars, **Im** – interdistributary ndated during flood incursions, crevasse-splay deposits,

contrast
nits gen-

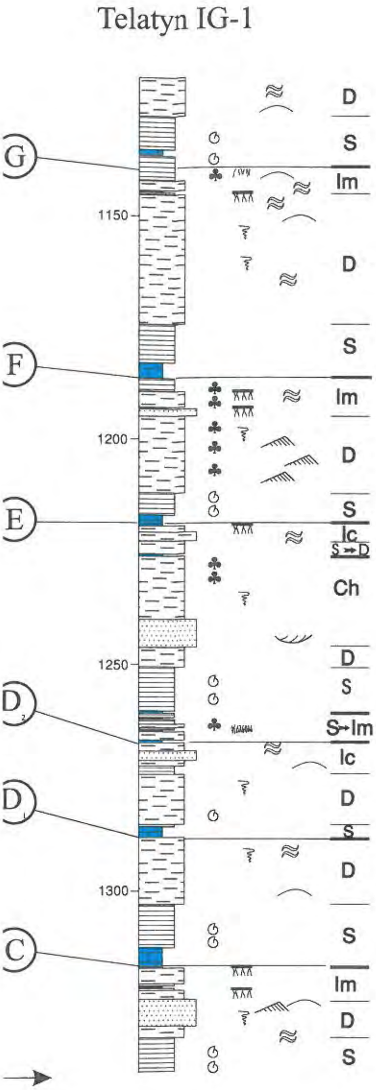


Interpretation of sedimentary environment in the sections located in the souther
of the Lublin Basin; the investigated interval represents approximately the Pend

Symbols the same as in Text-fig. 15; interpretation of Tyszowce *IG-1* log partly *after* WIŚNIEWSK

mostly sharp, extremely well visible because of the lithological contrast (Pl. 28, Figs 1-2). The presented specimens show that carbonate units gen-

S. SKOMPSKI, FIG. 16



ated in the southernmost part
oximately the Pendleian Series

partly *after* WIŚNIEWSKA (1993)

contrast
nits gen-

sequences most probably represent crevasse splay sediments, and occupied evidently smaller areas than swamps.

Sporadically the large-scale coarsening upward sequences are terminated by thin sandstone bodies or small-scale fining-upward cycles. The erosional boundary in their bottom, associated with clay pebbles and cross bedding, show that these sequences correspond to the infillings of minor fluvial or distributary channels.

The coarse-grained thick sandstone members are relatively rare in the succession and they are exclusively typical of the large-scale fining-upward sequences. They are characterized by erosive, sharp bottom contacts, sometimes underlined by the presence of lag deposits, composed of mudstone, limestone or sideritic pebbles. Thickness of those sequences ranges from 10 to 20 m. The trough cross stratified coarse-grained sandstones, typical of the lower part of each sequence, in its upper part are replaced by fine-grained sandstones or mudstones with small-scale cross stratification and wavy and lenticular bedding. The topmost part is composed of rooted flood plain clays and thin coal layers. The described succession represents typical distributary channel deposits, covered by thin layers of delta plain sediments. A depth of incision of these channels was usually delimited by position of resistant carbonate layer, but in a very few cases also thick carbonate bed was eroded (*e.g.* Lst. Band *F* in boreholes Orzechów *IG-2*, *IG-27*; Text-fig. 17).

The investigated cyclothems are usually terminated by deposits more or less connected with vegetation. Most numerous are seat-earths developed in clayey, muddy or (rarely) sandy bottom; their thickness reaches sometimes more than 1 m. In most cases they are covered by thin layers of coals or carbonaceous shales. The coal beds are rather thin (usually 10-20 cm, maximum 60-80 cm thick), but they are traceable over a long distance, sometimes greater than several tens of kilometres. The coal bed lying in the bottom of Lst. Band *C* is the best example of such stable coal horizons. The appearance of extensive coal layers indicates that the formation of peat members was connected not only with interdistributary areas in the phase of delta progradation but also with the abandonment phase, characterized usually by persistence of facies over the large territory.

The contacts between lithological units in most cases are gradual (claystone - mudstone) or sharp (claystone - sandstone - coals), but only incidentally they are erosional. This last feature is practically observed only in the bottom of distributary channel facies. The lower boundary of clastic intervals is usually gradual and commonly between the limestone bed and claystone/mudstone cover the transitional marly layer has been developed. Contrary this the lower boundary of the limestone layer is mostly sharp, extremely well visible because of the lithological contrast (Pl. 28, Figs 1-2). The presented specimens show that carbonate units generally overlie coal beds (or seat-earths) and the transitional zone, where these two lithologies are interlayered does not exceed several centimeters. Appearance of coal flasers in the lowermost parts of limestone bed can be explained by allochthonous nature of uppermost parts of coal bed. The sedimentary structures were imitated by arrangement of pyritic grains formed during early stages of diagenesis (Pl. 28, Fig. 3). On the other hand, the carbonate detrital material was also transported onto the coal layers, in the form of ripples ("lenticular bedding"; *see* Pl. 28, Figs 1, 3).

The coal-bed-marine-unit sequence (as called by HECKEL 1995) is frequently found in the paralic succession (*cf.* ELLIOTT 1975, XU HUI-LONG & *al.* 1987, RIEGEL 1991, MAKHLINA & *al.* 1993), but the conditions of "survival" of coal layers still needs explanation. RIEGEL (1991) in his review of the coal-cyclothem models stressed that "even minute changes in hydraulic conditions are accompanied by extensive erosion" and during transgression the peat bodies should be disintegrated. This problem of nonerosional succession he explained by a "back-door mechanism" of transgression onto the abandonment delta-plain. However, there are also opposite observations, which indicate that thick peat cover could be enough to prevent erosion (CECIL & *al.* 1993). The thickness of the peat bodies in the Lublin area (estimated as 10 times greater than thickness of coal layers) in most cases was probably too low to prevent erosion, and therefore the mechanism proposed by RIEGEL (1991) seems to be, in some respect, necessary for explanation of the coal/carbonates succession in the investigated sections. It is obvious that this mechanism could function only locally and in other cases an erosion intensively destroyed the peat layers.

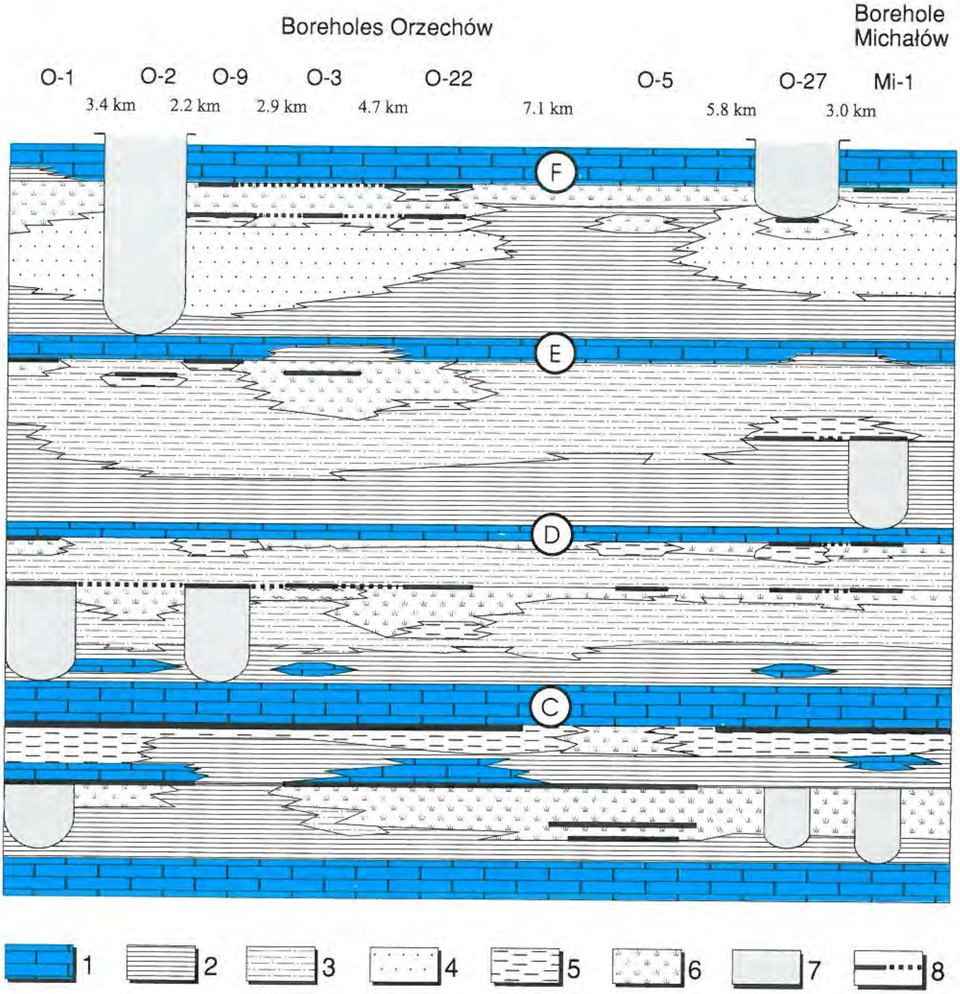
Although the presented data, limited to the three exemplary fields, allow to distinguish typical deltaic facies and successions, an analysis of the paleogeographic extent of particular delta lobes is rather difficult on the basis of this material. The data from the central Orzechów region seem to be most valuable for such reconstruction, and SZWEMIN (1992) tried to estimate there the position of sequential lobes. She demonstrated that the terminal parts of older intervals are characterized by predominance of delta plain facies association, in comparison to the younger ones, in which mouth bars had significant contribution. The appearance of more distal facies in younger intervals indicates generally transgressive regime during successive sedimentary episodes, what is in agreement with conclusions based on the analysis of carbonate members of cyclothems.

CAUSES OF CYCLICITY

The successions observed in the analyzed cyclothems are typical of deltaic induced sedimentation. The maximum thickness of deltaic cyclothem

Facies distribution in the Orzechów area

partly *after* SZWEMIN (1992)



The diagram illustrates central part of the investigated area, *see* Text-fig. 1; lettered C, D, E, F in circles are the Limestone Bands indexes

1 – Shelf carbonates, **2** – prodeltaic claystones, **3** – delta front mudstones, **4** – mouth bars, delta front sand bodies, **5** – interdistributary areas with crevasse-splay deposits, **6** – interdistributary areas with occasional phytogenic sedimentation, **7** – distributary channels, **8** – coal and carbonaceous shales was observed in proximal areas in the southern part of basin, where the carbonate units were relatively thin (*see* Text-fig. 10). In the more central region (boreholes Krasnystaw-Rejowiec) the carbonate facies on the delta foreland reached maximum thickness (*see* Text-fig. 12). The sedimentological features, *e.g.* relatively frequent distributaries, thin muddy-sand bodies at their mouth, spatial architecture of lobes, allow to recognize the investigated forms as the river-dominated lobate type deltas. The fining-upward sequences, which infilled incisions cut by distributaries, are relatively frequent, considering the distance between the boreholes. This feature proves the erosional events during the formation of cyclothems and unequivocally implies the eustatic nature of cyclicity. This conclusion is distinctly enriched by the results of microfacies analysis of limestone bands, in the context of LEEDER & STRUDWICK's models. Lst. Band *F* reveals the shallowing upward trend and succession of offshore and lagoonal facies, up to the replacement of carbonate facies by argillaceous prodelta, what indicates the eustatic mechanism of sedimentary changes, accordingly to the discussed models. The chaotic microfacies succession in the Lst. Band *C*, observed also in the underlying carbonate bands, is more typical of the autocyclic sedimentary mechanism. A significant argument for this conclusion is also irregularity of cyclothemic succession below Lst. Band *C*. Consequently, the transition between these two mechanisms should be recorded in the investigated interval. Practically it is coincident with the top of Lst. Band *C*, what is manifested by distinctly greater regularity of cyclothems above this band, than in the unit below. The microfacies analysis of limestone bands lying between Lst. Bands *C* and *F* did not bring better and more precise arguments; the bands are thin and composed of marly limestones, dominated by poorly interpreted organodetrital and mixed algal facies.

The appearance of the glacial cause of the eustatic sea level changes near the boundary between Viséan and Namurian fits very well with the records of Gondwanan glaciation. They are reported from the El Paso Formation in the latest Viséan of Argentina (CROWELL & FRAKES 1970, CROWELL 1978, VEEVERS & POWELL 1987, GONZALEZ 1990).

In the most general sense the change of sedimentary mechanism reflects distinguishing of the Huczwa and Terebin formations in the lithostratigraphic scheme. More detailed examination of this problem is hindered by different identification of some limestone by the present Author and in papers of PORZYCKI (*e.g.* 1979, 1988). Difficulties in the identification of stratigraphic position of Lst. Band *A*, indicative for the boundary between those formations, caused that in the present Author opinion the Lst. Band *C* would be a more practical boundary of these formations. This band is evidently better recognized, easily identified and connected with important change in sedimentary mechanism.

The investigated cyclothems display some differences compared with "ideal", theoretical successions from the models of LEEDER & STRUDWICK (1987). The carbonate bands are not terminated by emerged karstic surfaces as it is proposed in the model. It seems that this feature would be more expected in the pure carbonate sequences than in the mixed carbonate-clastic succession. An overlying of carbonate member by argillaceous deposits is more natural than emersion of carbonate layers on the seashores dominated by fluviatile deltas. Another difference is connected with deepening upward bathymetrical tendency, expected in the models in the bottom part of the carbonate member, so that the whole layer presents symmetrical succession (*cf.* Table 3). Meanwhile the microfacies sequence in the observed Lst. Band *F* is univocally asymmetrical, with bathymetrical maximum in the beginning of sedimentation. Some explanations of this trend are probably connected with specific role of the coal layer, which in many cases has been underlying the limestone unit. The peat bed, approximately 10 times thicker than the coal bed, has been growing up distinctly faster than other sediments, and its growth kept pace with rise of sea level. Final submergence of the peat layer terminated its growth and started the process of compaction. Overlapping of compaction effect and the rise of sea level reinforced the primary asymmetry of T-R curve, if we assume the glacial cause of eustasy, which is the most probable hypothesis in this stratigraphic interval. This indicates, that the beginning of sea level rise was earlier than appearance of carbonate deposition, although the boundary of cyclothem is traditionally located in the bottom of limestone. A lag time connected with submergence of peat and a break in sedimentation, corresponding with fast rise of sea level, was a next portion on the time-axis. Thus, the sedimentation of limestones appeared at the highstand, when the rate of sea level has been gradually lowering and the formation of shallowing upward sequence could start.

DURATION OF CYCLOTHEMS

A hypothesis of the eustatic controls of the observed cyclicity can be also verified by a determination of duration of cyclical events. The classic Yoredale cyclothems in England appeared in the Asbian and Brigantian, when the precision of radiometric data is still insufficient. It caused very different estimations of cyclothem duration. SCHWARZACHER (1989) suggested that 1-1.5 m.y. cycles may be equivalent to the Yoredale cycles. WALKDEN (1987) more precisely pointed for 500 k.y. as most probable duration of the Brigantian cycles. LEEDER (1988) calculated for the Asbian/Brigantian cyclical events 190-240 k.y. to 319-405 k.y. In the discussed interval in the Lublin Basin the Lst. Band *C* marks the end of Viséan, while the Lst. Band *G* points a beginning of the world-wide *Gnathodus bollandensis* Zone, precisely related to the E_2 goniatite zone. The analyzed interval represents the Pendleian stage in the British classification scheme, but the scarcity of radiometric data in the Namurian makes difficult an estimation of exact age of this stage. However there is information on the age of the two stages, Pendleian and Arnsbergian, taken together. Although particular data for this interval distinctly differ in the recent papers, its duration is nearly the same in all descriptions. HARLAND & *al.* (1990) has been dated the Viséan/Namurian boundary as 333 Ma, and the end of Arnsbergian as 328 Ma. According to WAGNER & WINKLER PRINS (1994a, 1994b), both these boundaries are clearly younger, respectively 325 Ma and 320 Ma. This most widely quoted time scale is based mostly on the investigations of LIPPOLT & *al.* (1985) and other works of Czech and German authors, summarized by DVOŘAK (1994). Still younger data have recently been presented by RILEY & *al.* (1994), who calculated 314.4 ± 4.6 Ma as SHRIMP data for the beginning of the Arnsbergian (E_{2a3} marine bands in Stonehead Back section), and who counted C_V/C_N boundary as 317 Ma.

On the base of all quoted above data a duration of the Pendleian is approximated as 2.5 m.y., and this value is in accordance with HARLAND's and WAGNER & WINKLER PRINS' data, as it is assumed that the Pendleian and Arnsbergian represented equal time interval. In the most complete southern sections of the Lublin Basin it is possible to distinguish 5 cyclothems in the discussed interval, and simple calculation gives about 500 k.y. for each cyclothem. This value is similar to the frequently quoted value 400-450 k.y., calculated for 4th order cyclicity, especially for the Pennsylvanian eustatically controlled cyclothems (BUSCH & ROLLINS 1984, HECKEL 1986, KLEIN 1990, SCHWARZACHER 1993, CHESNUT 1994, DVORJANIN & *al.* 1996), as well as for the Asbian and Brigantian British "minor" cycles (WALKDEN 1987). It should be noticed that order classification of cyclothems used here refers to the hierarchy proposed by VAIL & *al.* (1977, *cf. also* ELRICK & READ 1991). According to BUSCH & ROLLINS (1994) the Yoredale cyclothems should be classified as 5th order ones. The calculated value approximately falls within the total MILANKOVIĆ periodic band. It seems to be linked to 400 k.y. orbital eccentricity period and confirms the glacieustatic hypothesis of the Carboniferous cyclical frequency (*see* CROWELL 1978, HECKEL 1986, VEEVERS & POWELL 1987, HORBURY 1989). However, the recognition of shorter cyclothems expected accordingly to the investigations of the Pleistocene glacial rhythms still remains an open and unsolved question (*cf.* SCHWARZACHER 1993).

SYNCHRONEITY OF DEPOSITIONAL CYCLES

The analyzed cyclothems correspond to the "catch-up" type of eustatically controlled cycles, according to the terminology proposed by

SOREGHAN & DICKINSON (1994). In the first phase of their development the sedimentation lagged behind creation of accommodation space, but later, especially in highstand the sedimentation rate was greater than relative sea level rise. The succession of cyclothems reveals subtle transgressive trend, visible in distribution of the succeeding delta lobes (SZWEMIN 1992), as well as in the microfacies characteristics of limestones. The Lst. Band *F* represents predominance of more offshore microfacies in comparison to the Lst. Band *C*. The significant and stable thickness and broad extent of this layer over the entire Basin points that during its sedimentation an onlap of the sea onto the land was greatest in the early Namurian. In higher part of the cyclic succession this tendency has been reversed and in relatively short time the carbonate layers totally disappeared (argillaceous *corrugata I* correlation horizon, *see* Text-fig. 6).

It has been found that this pattern of succeeding cyclothems corresponds to the mesothem concept of RAMSBOTTOM (1977), but more accurate comparison with other regions of the Laurussian shelf reveals some discrepancies between bio- and eustatostratigraphy. In Great Britain the first Namurian mesothem *N1* is an equivalent of the Pendleian and beginning of Arnsbergian, what generally fits with stratigraphic conclusions from the Lublin Basin. In the Moscow Basin the Pendleian stage should be correlated with the Tarusian, the Steshevian and the lower half of the Protvian stages, according to the appearance *Gn. bollandensis* (ALEKSEEV & KONONOVA 1993). In the middle of this interval a significant retreat of sea occurred and first Serpukhovian cyclothem was terminated in the upper part of the Steshevian (ALEKSEEV & *al.* 1996). In the Donetz Basin the interval corresponding with the Pendleian (Sa, Sb, Sc "assemblage" zones) is characterized by three mesothems (POLETAEV & *al.* 1990). It should be stressed that in the context of above presented data, the early Namurian depositional sequences are not synchronous. Their world-wide synchroneity postulated by ROSS & ROSS (1988) is thought to be misinterpretation, caused partly by wrong biostratigraphic correlation (Pendleian was considered as equivalent of the Tarusian stage only). The discrepancies described above indicate significant role of the tectonic factor, dominating over the eustatic effect, and especially clearly readable in the quickly subsiding Donetz Basin. Similar predominance of the tectonic component has been recorded also by LEEDER & STRUDWICK (1987) from the Yoredale succession in Great Britain. Their conclusion is more intelligible, since these cyclothems have been deposited mostly in the end of Viséan, just before the beginning of the more significant eustatic changes, recorded also in the investigated succession of the Lublin Basin.

FINAL REMARKS

STRATIGRAPHIC CONCLUSIONS

The two groups studied, the calcareous algae and microproblematics, contribute significant data to the stratigraphic knowledge of the Lublin Carboniferous. They allow recognition of internal stratigraphic relation in paralic complex, and correlation between regions in similar paleogeographic position. The more universal conodonts precise the chronostratigraphic relation of the investigated section to other Carboniferous successions.

The calcareous algae and microproblematics are the most significant component of the limestone complexes and bands, which are typical of the paralic portion of the succession in the Lublin Carboniferous Basin. The proportion of these fossils in the composition of limestones grows up towards the upper part of the sequence and this group dominates amongst other particles in the highest thin bands. This luxuriant development of algae has been probably caused by favorable paleogeographic position of the basin, isolated in some extent from the influences of more dynamic sea activity.

The development of algae, observed in the Lublin Basin has been also typical of other parts of the Laurussian Shelf. The commonly observed presence of algae allowed detailed correlation of distant sections from northern England to the Ukrainian Lvov-Volhynian Basin, and farther to the Moscow and Dneper-Donets Basins, in the interval corresponding to the latest Viséan-earliest Namurian.

Recognition of the local algal zones allows to indicate biostratigraphically confirmed overlapping of the succeeding uppermost Viséan limestone complexes.

The conodonts, poorly represented in the Lower Carboniferous part of the section, are extremely numerous in its uppermost part. The specific ecological composition of the Lower Carboniferous assemblage exactly corresponds to that found in the type area of the Yoredale Series in northern England. It indicates the similar environmental factors, which probably have been expressed also in the flourishing of the calcareous algae in both discussed areas. The five conodont zone have been distinguished: the Lochriea nodosa, the Lochriea cruciformis, the Gnathodus bollandensis, the Idiognathodus sinuosus-Idiognathodus delicatus, and Idiognathoides tuberculatus Zones.

The beginning of the Lochriea cruciformis Zone points the positioning of the Viséan/Namurian boundary slightly higher than the hitherto established on the basis of macrofauna and lithological correlations.

The characteristics of conodont assemblages from the marker-horizons *corrugata I* and *Dunbarella* is varying from the assemblages of the preceding complexes, what is possibly caused rather by the salinity or temperature changes than the influx of terrigenic material.

The analysis of conodonts from the Upper Carboniferous indicates the positioning of Namurian *B* / Namurian *C* boundary below the Lst. Band *M*, and points the presence of Idiognathoides tuberculatus Zone, well recognized in the Carboniferous basins of the East European Platform.

PALEOGEOGRAPHIC IMPLICATIONS

The uppermost Viséan/lowermost Namurian interval of cyclic sedimentation from the Lublin Carboniferous Basin is especially convenient to test the sedimentary models proposed by LEEDER & STRUDWICK (1987) for elucidation of the nature of the Yoredale-type cyclicity. The analysis of cyclothems from three observation fields in different parts of the Basin confirms the deltaic origin of the cyclic interval, which is equivalent to the Pendleian stage. The cyclothems are typical of the river-dominated lobate deltas, and the distribution of facies as well as changes of thickness correspond well with the scheme of the Yoredale cyclothem proposed by JOHNSON (1961).

The carbonate members of cyclothems consist of lagoonal microfacies dominated by algal and spiculitic lithotypes, and of the more offshore assemblage composed mainly of foraminiferal and crinoidal microfacies. The local and temporary shoalings were marked by the appearance of peloid microfacies typified by numerous features of early cementation and emersion. Similar microfacies are characteristic of the Viséan part of the Carboniferous succession, but the microfacies spectrum in carbonate layers in the upper part of the Namurian is distinctly impoverished. Nearly monospecific algal-microproblematic packstones are practically the only microfacies in Lst. Bands *M*, *N*, and *O*.

The carbonate buildups are extremely rare in the carbonate complexes, except of the Viséan part where the coral bioherms are abundant. Their development was probably favored by differentiated topography of the bottom, inherited after tectonic movements and volcanic activity in the earliest Carboniferous. The single phylloid algal and microbial bioherms represent the main types of buildups specific of the Carboniferous, and illustrate the change of faunistic reef-association between the Lower and the Upper Carboniferous.

The microfacies spectrum is more or less uniform in respect of geographic position of the sections, but it is different in particular limestone bands (Lst. Band *C* and Lst. Band *F*). The microfacies distribution in the limestone bands shows a random arrangement of microfacies in the older Lst. Band *C* and clearly visible shallowing upward trend in the younger Lst. Band *F*. According to LEEDER & STRUDWICK's models this feature, together with some characteristics of clastic interval, which reveal evidences of periodical erosion, is case for the eustatic nature of the analyzed cyclothems above the Lst. Band *C*. The Lst. Band *C* and underlying carbonate beds were probably deposited in the autocyclic, deltaic sedimentary regime. The appearance of eustatic control of sedimentation is coincident with the beginning of the Gondwanan glaciation, recorded in the South American El Paso Formation.

The investigated cyclothems correspond with 4th order eustatic cycles, according to VAIL & *al*. (1977) terminology. A duration of particular cycle is estimated as about 500 k.y., which is closest to orbital eccentricity period, most frequently assumed for the Upper Carboniferous cycles.

Although the eustatic component of accommodation changes became more significant from the beginning of the Namurian, the tectonic factor still maintained its importance. A comparison of the Pendleian mesothems, recognized in particular basins of the Laurussia shelf, indicates their different number, clearly greater in the areas with faster subsidence (*e.g.* Donetz Basin). In this context, the early Namurian succession from the Lublin Carboniferous Basin, characterized by relatively regular and average subsidence, can be considered as a reference section for eustatostratigraphic correlation allover the world.

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Note added in the proof:

During the printing process the two papers dealing with subject of the present paper appeared. DVORJANIN & *al.* (1996) on the base of Viséan-Serpukhovian sequence from the Dneper-Donets Basin confirmed estimation of cycle duration as 500 k.y., and similarly to the present Author pointed for significant influence of tectonics on the development of cyclicity in the D-D Basin. DZIK (1997) in extensive work summarized the data on the Carboniferous conodonts and goniatites from Poland; the new analytical data presented by this author concern mainly to the Tournaisian fauna, while the Upper Carboniferous information is taken from the older literature, and is not contradictory to the ideas presented in the present paper.

DVORJANIN, E.S., SAMOYLUK, A.P., EGURNOVA, M.G., ZAYKOVSKY, N.YA., PODLADCHIKOV, YU.YU., VAN DEN BELT, F.J.G. & DE BOER, P.L. 1996. Sedimentary cycles and paleogeography of the Dnieper Donets Basin during the late Visean-Serpukhovian based on multiscale analysis of well logs. *Tectonophysics*, **268**, 169-187. Amsterdam.

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