POLSKA AKADEMIA NAUK · KOMITET NAUK GEOLOGICZNYCH

PAŃSTWOWE WYDAWNICTWO NAUKOWE . WARSZAWA

acta geologica polonica

Vol. 30, No. 4 Warszawa 1980

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Stratigraphy and facial development of Middle and Upper Ordovician deposits in the Łeba Elevation (NW Poland)

ABSTRACT: A description is here given of the lithological characters of the Middle and Upper Ordovician deposits on the Łeba Elevation representing the western part of the Peribaltic Syneclise. Three lithostratigraphic formations and one member connected with the central formation have been differentiated. Six biostratigraphic zones and two informal biostratigraphic units have been differentiated on the basis of fossil assemblages varying with the lithofacies. In the light of the currently accepted division of the Ordovician into chronostratigraphic units the presence has been documented of Llanvirnian. Llandeilian, Caradocian and Ashgillian deposits. The facial and paleontological analyses reliably indicate the sedimentary conditions of the particular formations and the assignment of the area under investigation to the outermost zone of the Ordovician Balto-Scandian basin, the so called "Scania—Łeba" zone. Out of the sixty graptolite species and subspecies identified by the writer and belonging to 17 genera, a description has been made of stratigraphically important forms, so far not reported from Poland or interesting from the taxonomic point of view.

INTRODUCTION

The older Paleozoic deposits of the western part of the Peribaltic Syneclise, including those of the Ordovician, have been investigated more than once. The presence of the Ordovician within this area was observed for the first time in the Lębork *IG-1* profile (Tomczykowa 1964). The Żarnowiec *IG-1* profile, the first one to be fully cored, is still the fixed datum Ordovician profile. It has been investigated by Modliński (1971, 1976a), Modliński & Topulos (1974), Langier-Kuźniarowa (1971a, 1976), Tomczyk (1972), and Topulos (1976).

New boreholes drilled during the seventies in the western part of the Peribaltic Syneclise have provided numerous new data on the stratigraphy, petrography and paleogeography of the Ordovician in this region (Modliński 1973, 1976, 1978; Langier-Kuźniarowa 1976b, c; Topulos 1973, 1979). The most recent studies of the microfossil remains, in the first place those of conodonts and Chitinozoa, have often led to a more precise determination of the stratigraphy of Ordovician deposits occurring on the Łeba Elevation (Bednarczyk 1979, Podhalańska 1978, 1979).

The present paper has been based on the lithological and paleontological material collected from the profiles of eight boreholes drilled by the Oil Research Enterprise of Piła. Going west to east these boreholes are as follows: Łeba *8*, Białogóra *1*, Białogóra *2*, Żarnowiec *5*, Piaśnica *2*, Dębki *2*, Dębki *3* and Mieroszyno *8* (Fig. 1). The Ordovician has

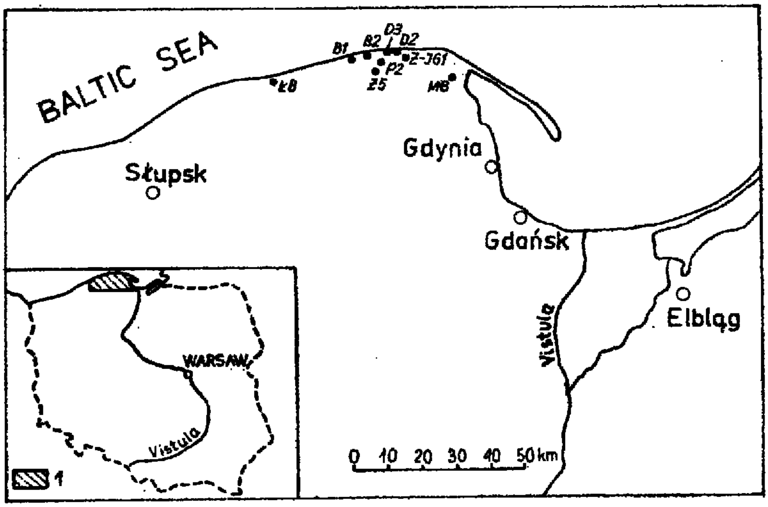


Fig. 1. Sketch showing the locality of the boreholes in the Łeba Elevation
1 — Łeba Elevation, *Ł8* — Łeba *8*, *B1* — Białogóra *1*, *B2* — Białogóra *2*, *Ż5* — Żarnowiec *5*, *P2* — Piaśnica *2*, *D2* — Dębki *2*, *D3* — Dębki *3*, *M8* — Mieroszyno *8*, *Ż-IG1* — Żarnowiec *IG-1*

not been fully cored in anyone of these boreholes, hence the lithological boundaries in the non-cored sections of the profiles have been determined on the geophysical measurement analysis.

Similarities in the facial development of the deposits and in their stratigraphic succession have been observed in all the profiles. Macroscopic observations enriched by the microscopic examination of several tens of thin sections reliably determine the lithostratigraphic division.

This has been correlated with the biostratigraphic division based chiefly on graptolites and — in deposits without graptolites — on conodonts, inarticulate brachiopods and trilobites. The correlation of the profiles here considered with the universal biostratigraphic classification reasonably indicates their position in the chronostratigraphic division of the Middle and Upper Ordovician. Moreover an attempt has been made to reconstruct the varying with time sedimentary conditions prevailing in the Łeba zone of the epicontinental basin. The paleogeographic position has also been presented of the area under investigation in the Middle and Upper Ordovician in the background of the whole basin of Balto-Scandia.

The present paper has been prepared in the Stratigraphic Laboratory of the Institute of Geological Sciences of the Polish Academy of Sciences, in the framework of problem *MR.I.16*, under the scientific guidance of Docent Wiesław Bednarczyk, to whom the writer conveys her grateful thanks for initiating the Ordovician studies, for the helpful advice and discussions during the preparation of this paper and for the accession to a part of the needed material.

To Dr. Teresa Przybyłowicz sincere thanks are due for the valuable remarks on the petrographic problems of Ordovician rocks in the Łeba region.

The writer is also most obliged to Messrs Dr. D. Kaljo, R. Männil, V. Viira and J. Nõlvak from the Institute of Geology of the Estonian Academy of Sciences in Tallinn for their most helpful remarks on the Ordovician stratigraphy of the Baltic region, as well as for assistance in the solution of several problems concerning the taxonomy of conodonts and Chitinozoa.

Dr. H. Jaeger from the Paleontological Museum of Humboldt University of Berlin must be very much thanked for the accession to the comparative graptolite collections from Thuringia, Rugia, Scania and Bornholm.

Mrs. E. Kowalczyk from the Institute of the Geological Sciences of the Polish Academy of Sciences must be thanked for the pains taken in working out the graphs in the present paper.

I wish to thank Mrs. K. Boruta from the Institute of Geological Sciences of the Polish Academy of Sciences as well as to Mr. L. Dwornik from the Museum of the Earth of the Polish Academy of Sciences for photographing the specimens of the fossil remains and the thin sections.

The managers of the Oil Research Enterprise in Piła have kindly enabled the writer to study their borehole and archival materials.

The lithological samples and the paleontological material are housed in the Stratigraphic Laboratory of the Institute of Geological Sciences of the Polish Academy of Sciences.

LITHOSTRATIGRAPHY

The lithostratigraphic units here differentiated are informal in character because they do not comply with all the requirements set out in the *"Rules for Polish classification, terminology and stratigraphic nomenclature"* (Alexandrowicz & al. 1975), particularly those on the determination of the stratotypes of some units and boundary stratotypes. However, when working out the divisions here presented, attempts have been made as fully as possible to comply with the *"Rules"* in order more readily to formalise the here introduced differentiations. Moreover, with this aim in view, when determining the lithostratigraphic sequence, the results were considered of the full-cored Żarnowiec *IG-1* (Modliński 1976a) analysis. This has been compared with the profiles worked out by the writer and it may be used as a stratotype profile for most of the differentiated units. On the other hand, index profiles have been differentiated in the not fully cored profiles on which the present paper is based. These may be regarded as the hypostratotypes of the differentiated formations.

Two criterions have been used in the determination of the boundaries of lithostratigraphic units: distinct changes in lithology and changes in the character of fossils due to facial factors. Hence, when discussing the features of the particular lithological formations, an account has been taken of relatively comprehensive scope of information on the fauna present in the corresponding lithostratigraphic units.

The pattern presented below displays the features of a cumulative profile worked out on the basis of eight fractional profiles, the Żarnowiec *IG-1* profile described by Modliński (1976a) having been taken into consideration.

Three basic lithostratigraphic units — formations and one member have been differentiated in the Middle and Upper Ordovician profile of the Łeba region.

The definite formations on the whole correspond to the geophysical complexes differentiated by Modliński and Topulos (1974) also Topulos (1979). The organodetrital limestone formation differentiated by the writer may correspond to the *II* geophysical complex; the graptolitic claystone formation to complex *III*, while the marly formation to complex *IV* of the Topulos (1979) division or to the *15th* correlation horizon of Modliński & Topulos (1974).

The lithostratigraphic units have been described in their stratigraphic sequence (from the oldest to the youngest). These units correspond to the observed and readily distinct facial types.

The lithological descriptions are based on macroscopic examinations of rock samples and microscopic examination of 50 thin sections.

The boundaries of units and their thickness in the non-cored parts of profiles are based on the analysis of geophysical measurements.

ORGANODETRITAL LIMESTONE FORMATION

Definition: Marly-micritic grey limestones abounding in organic detritus, locally with nodular structure.

Index Profile: In the Piaśnica *2* borehole at a depth of 2668.0—2648.6 m.

Occurrence: Owing to incomplete coring no complete sequence of the differentiated formation has been observed in any of the profiles worked out by the writer. The most complete profile is to be noted in borehole Piaśnica *2* at a depth of from 2661.8 to 2648.6 m (Fig. 2) and in Dębki *3* at a depth from 2667.6 to

2649.2 m (Fig. 4). In the Żarnowiec *IG-1* profile this formation occurs at a depth between 2707.8 and 2689.2 m. In the remaining profiles the coring covered only small fragments of this lithostratigraphic unit.

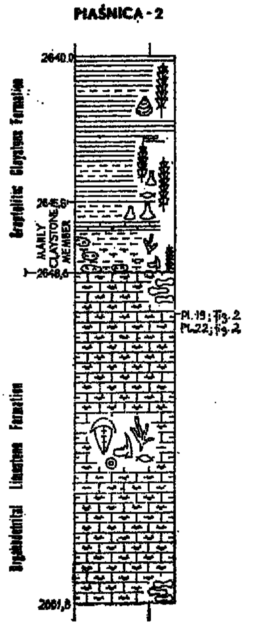


Fig. 2
Profile of the borehole
Piaśnica *2*

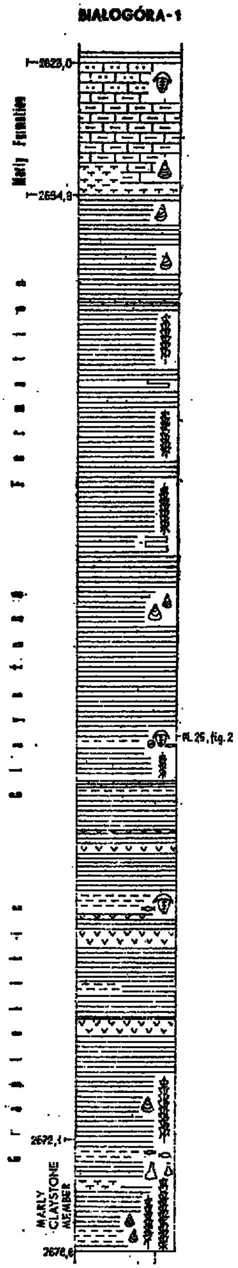
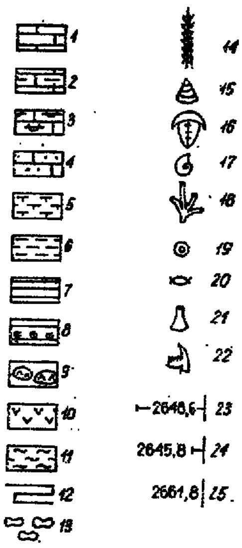


Fig. 3
Profile of the borehole
Białogóra *1*

1 — limestone
2 — marly limestone
3 — organodetrital marly limestone
4 — sandy limestone
5 — marl
6 — marly claystone
7 — claystone
8 — ferrous ooids
9 — phosphorite
10 — bentonites and tuffs
11 — mudstone
12 — parallel flat lamination
13 — nodular structure
14 — graptolites
15 — non-articulate brachiopods
16 — articulate brachiopods, trilobites and their detritus
17 — gastropods
18 — bryozoans
19 — crinoides
20 — ostracods
21 — Chitinozoa
22 — conodonts
23 — formation's boundary
24 — member's boundary
25 — boundary of cored interval



Lower boundary: The passage of the limestones to the underlying claystones has been observed in the Białogóra *2* profile (Figs 5 and 10) at a depth of 2667.1 m. In the remaining profiles the base of this formation has been determined on electric logging; in the Łeba *8* profile it has been delimited at the depth 2726.0 m, in the Białogóra *1* profile at 2685.0 m, in the Żarnowiec *5* profile at 2717.0 m, in Piaśnica *2* at 2668.0 m, in Dębki *3* at 2670.0 m, in Dębki *2* at 2650.0 m, in the Mieroszyno *8* profile at 2840.0 m. In the cored Żarnowiec *IG-1* profile it has been determined at the depth of 2707.8 m.

Upper boundary: It is assigned by the bottom of the overlying claystone graptolite bearing formation. This passage may be noted in the Piaśnica *2* profile at the depth of 2648.6 m, in Dębki *3* at 2649.2 m depth and in Żarnowiec *IG-1* profile at the depth of 2689.2 m (Figs 2, 4, 10).

Thickness: The total thickness of the formation determined on electric loggings roughly 11.0 m in the Łeba *8* profile; 8.0 m in the Białogóra *1* profile; 13.1 m in Białogóra *2*; 20.0 m in Żarnowiec *5* profile; 19.4 m in Piaśnica *2*; 17.8 m in Dębki *3* profile, 20.0 m in the Dębki *2* and Mieroszyno *8* profiles. In the Żarnowiec *IG-1* profile the thickness of this formation is 18.6 m (Fig. 10).

Description: The basic lithological type is represented by light-grey or greenish marly micrites with numerous bioclasts. The uneven structure of the rock under investigation is its most characteristic feature expressed by the presence of more or less marly fragments of the sediment (Pl. 19, Figs 1—2; Pl. 20, Fig. 1) often shaped as nodules. These nodules range in size from some millimetres to a few centimetres. Both, sharp-edged and rounded forms are encountered. Microscopic examinations have, moreover, allowed to detect wavy streaks enriched in clayey substance (Pl. 20, Fig. 1).

The limestones contain abundant pyrite most often occurring as irregular accumulations, also glauconite grains replacing the decaying organic substance, for instance in the trochites of crinoids. In the marly-micritic rock mass there occur irregular accumulations of neomorphic sparite most probably a result of the re-crystallisation of micrite matrix.

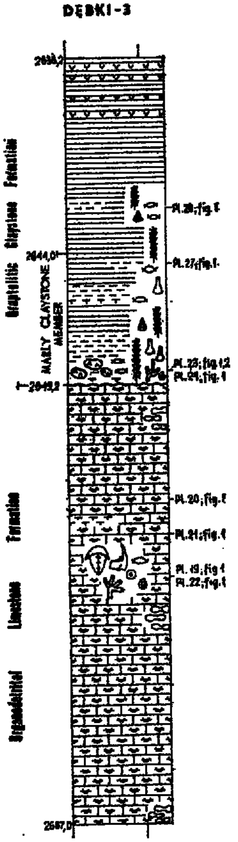
Bioclasts are the chief grain components of the limestones here described (Figs 2, 4, 7): fragments of trilobites (Pl. 19, Fig. 1), brachiopod shells, smooth and ornamented (Pl. 19, Figs 1—2; Pl. 20, Figs 1—2), complete and incomplete ostracod carapaces, numerous bryozoans (Pl. 21, Fig. 2), gastropods (Pl. 21, Fig. 2), trochites of crinoids (Pl. 22, Fig. 2), spines of indeterminate organisms (of trilobites or brachiopods), conodonts. Traces of borings have also been detected in brachiopod shells (Pl. 22, Fig. 1), but it is hardly possible to determine their origin. The organic remains are often arranged in streaks and strongly crushed (Pl. 19, Figs 1—2; Pl. 20, Figs 1—2; Pl. 21, Fig. 1).

GRAPTOLITIC CLAYSTONE FORMATION

Definition: Darkgrey, black or greenish, graptolite-bearing claystones abounding in bituminous substance with bentonite and tuffite laminae, locally marly, rary intercalated by grey limestones.

A marly claystone member has been differentiated in the bottom part of this formation because of the strongly marly nature of the sediment as compared with the upper parts. The remaining part of the formation is only sporadically intercalated by thin laminae of marly claystones.

The index profile: It has been located in the Białogóra *1* borehole at a depth from 2677.0 to 2634.3 m.



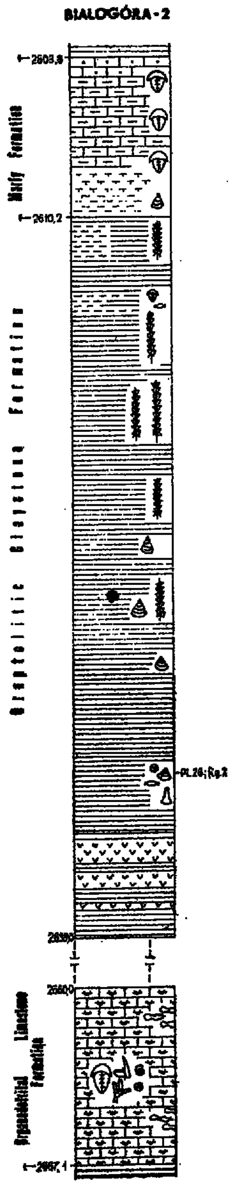


Fig. 4
Profile of the borehole Dębki *3*

Fig. 5
Profile of the borehole Białogóra *2*

For legend and explanations see Fig. 2

Occurrence: A full sequence of the unit here described has not been observed in anyone of the cored parts of the profiles (*cf.* Fig. 10). The most complete sequence of the formation here described, its lower part excepted, has been observed in the Białogóra *1* borehole (Fig. 3) at a depth between 2676.6 and 2634.3 m, in Łeba *8* between 2712.3 and 2667.8 m (Fig. 6) and Białogóra *2* at a depth from 2639.2 and 2610.2 m (Fig. 5). These boreholes show the upper part of the formation and the passage into the overlying sediments (*cf.* Figs 3, 5—6, 10). In the Dębki *3* (depth 2649.2—2636.2 m) and Piaśnica *2* (depth 2648.6—2640.0 m) it has been possible to observe the lower part of the formation and the passage to the underlying organodetrital limestone formation (Figs 2, 4, 10). The least known sediments of this unit are those occurring in the Dębki *2* profile (Fig. 7) at a depth of 2620.6—2617.7 m and 2600.0—2595.7 m), Żarnowiec *5* (Fig. 8) at a depth from 2675.0 to 2668.0 m, and Mieroszyno *8* (depth 2818.0—2811.0 m) (Fig. 9). In the Żarnowiec *IG-1* profile this formation has been differentiated at a depth from 2689.2 to 2655.3 m (Fig. 10).

On the geophysical measurements analysis the graptolitic claystone formation has been differentiated in all of the here worked out profiles: in the Łeba *8* profile at a depth roughly from 2715.0 to 2667.8 m, in Białogóra *1* (at 2677.0—2634.3 m), Białogóra *2* (2654.0—2610.2 m), Żarnowiec *5* (2697.0—2664.0 m), Piaśnica *2* (2648.6—2607.0 m), Dębki *3* (2649.2—2598.0 m), Dębki *2* (2630.0—2595.7 m), Mieroszyno *8* (2820.0—2790.0 m) (*cf.* Fig. 10).

Lower boundary: It represents at the same time the lower boundary of the marly claystone member. It has been determined at the contact with the underlying marly-micritic organodetrital limestones. The passage of these two lithological types has been noted in the Piaśnica *2* profile at a depth of 2648.6 m and in Dębki *3* at a depth of 2649.2 m (Figs 2, 4, 10).

Upper boundary: The uppermost lamina of the black non-calcareous claystones bearing a planctonic type of fauna has been recognised as the upper boundary of this unit. Practically speaking it corresponds to the disappearance of the graptolite shale facies.

Thickness: The thickness determined on electric loggings is (Fig. 10): 47.2 m in the Łeba *8* profile. 42.7 m in Białogóra *1*, 43.8 m in Białogóra *2*, 33.0 m in Żarnowiec *5*, 41.6 m in Piaśnica *2*, 51.2 m in Dębki *3*, 34.0 m in Dębki *2*, 30.0 m in Mieroszyno *8*. In the fully cored Żarnowiec *IG-1* profile the thickness is 33.9 m.

Description: The basic lithological type here are the darkgrey and black, locally marly claystones rary intercalated by grey limestones. Spotty claystones (Pl. 25, Fig. 2) also occur besides the darkgrey and black ones. The microscopic examinations show that the colouration of the rock depends mainly on its content of bituminous substance which, after the clayey minerals is the second most important component of the sediment. A subordinate component is the dispersed quartz and carbonate pelite, single biotite flakes and pyrite. Pyrite excepted, rather abundant throughout the formation, the content of the other mineral components here mentioned is variable and quite subordinate.

The presence of pyroclastic rocks (Figs 3—5, 7) has been documented in the claystone series in the Białogóra *1* profile at a depth between 2667.9 and 2659.9 m, Białogóra *2* between 2638.2 and 2635.0 m, Dębki *2* between 2620.6 and 2617.7 m, and Dębki *3* between 2639.0 and 2636.2 m. These pyroclastic rocks are developed as tuffs and bentonites (Langier-Kuźniarowa 1976, Przybyłowicz 1977, 1980) intercalating the claystones as thin layers and laminae. The thickness of the layers varies ranging from 40.0 to 0.1 cm. Thin layers of pyroclastic deposits varying in thickness also occur in the Żarnowiec *IG-1* profile (Modliński 1976a) in the interval between 2683.0 and 2661.5 m. These deposits most probably occur throughout the profiles here considered but their differentiation on the geophysical measurements analysis is hardly possible.

Investigations (Przybyłowicz 1977, 1978) show that these deposits represent the acid volcanism probably connected with magma of the dacite or ryodacite type. The size of the pyroclastic material

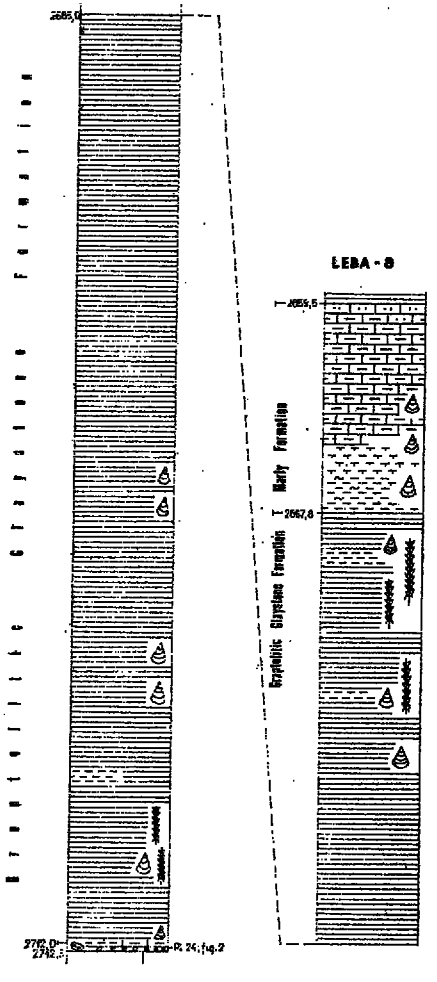


Fig. 6
Profile of the borehole Łeba 8
For legend and explanations see Fig. 2

in the tuffs, up to 0.4—0.5 and 1.2 mm testifies that their transport from the volcanic explosion site had not been very distant.

Unfossiliferous limestone intercalations ranging from a dozen or so to some tens centimetres are a subordinate lithological type occurring in the graptolitic claystone formation.

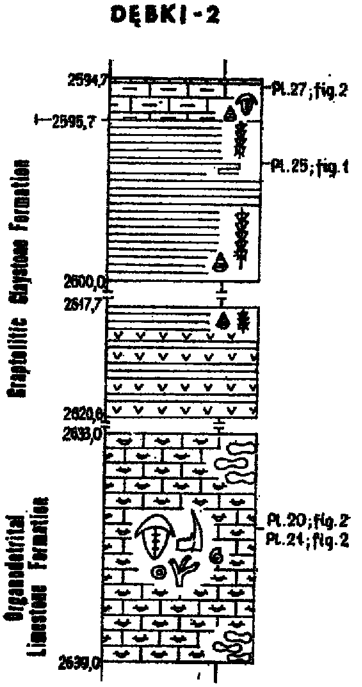
Microscopic investigations have led to the differentiation of various textural types in the claystone sediments. Roughly speaking two types of claystones may be determined: the nonlaminated of uniform internal structure with a haphazard arrangement of the clayey and bituminous substance and the laminated claystones with a conspicuously parallel texture (Pl. 25, Fig. 1) stressed by the colouration of the rock. This latter type is the predominant one in the formation here considered. As has been mentioned, the lamination of the deposit is expressed by the varied hue of the rock due to the alternation of the laminae with a variable bituminous substance content. Two lamination types have been distinguished by the examination of the thin sections: in some sections very thin wavy laminae are readily detectable while others the lamination is distinctly flat, the thickness of the laminae ranging from 0.1 to 2—3 mm (Pl. 2, Fig. 1). Quite often the laminae are wedged out (Pl. 25, Figs 1—2); subjected to streaking.

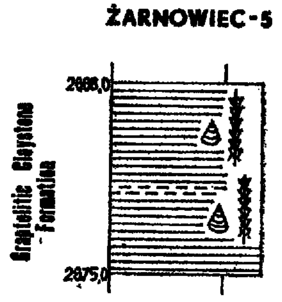
Graptolites and non-articulate brachiopods (Figs 2—9) are the chief fossil group in the black claystones. Sporadically, mostly in rather marly sediment, the presence may be noted of ostracod carapaces (Pl. 26, Fig. 1) complete or fragmentary, brachiopod shells occasionally conspicuously ornamented (Pl. 26, Fig. 2). The organic fossil remains are often aranged streak-like, parallel to the lamination. Forms flattened by compaction and complete ones, not flattened are encountered (Pl. 27. Fig. 1).

MARLY CLAYSTONE MEMBER

The presence of the complete profile of this member and its passage to the underlying organodetrital limestone formation has been noted in the Dębki *3* and Piaśnica *2* (Figs 2, 4, 10) profiles. The lower boundary of the member is at the same the lower boundary of the whole graptolitic claystone formation. It is hardly possible to determine the upper boundary of this unit because of the gradual changes in the calcium carbonate content as well as those of the bentonite fauna. In the Piaśnica *2* profile this upper boundary has been placed at a depth of 2645.8 m, in the Dębki *3* profile at 2644.0 m. In the Żarnowiec *IG-1* profile this member occurs between 2689.2 and 2687.0 m. Deposits most probably belonging to the marly claystone member also occur in the Białogóra *1* profile between 2677.0 and c. 2672.1 m, as well as in Łeba *8* at a depth from roughly 2715.0 to 2712.0 m. Owing, however, to a discontinuation of the coring a direct passage into the underlying limestones has not been noted. In the remaining boreholes this unit has been differentiated on the geophysical measurements analysis (Fig. 10).

The bottom part of the claystone complex, separated into the marly claystone member, is developed as darkgrey marly claystones or non-laminated marls, variously bituminous, with a high pyrite content occurring dispersed as well as





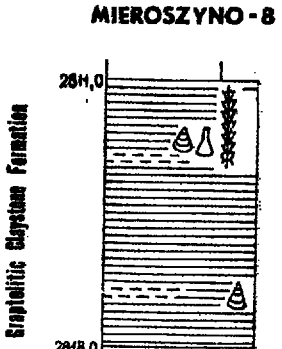


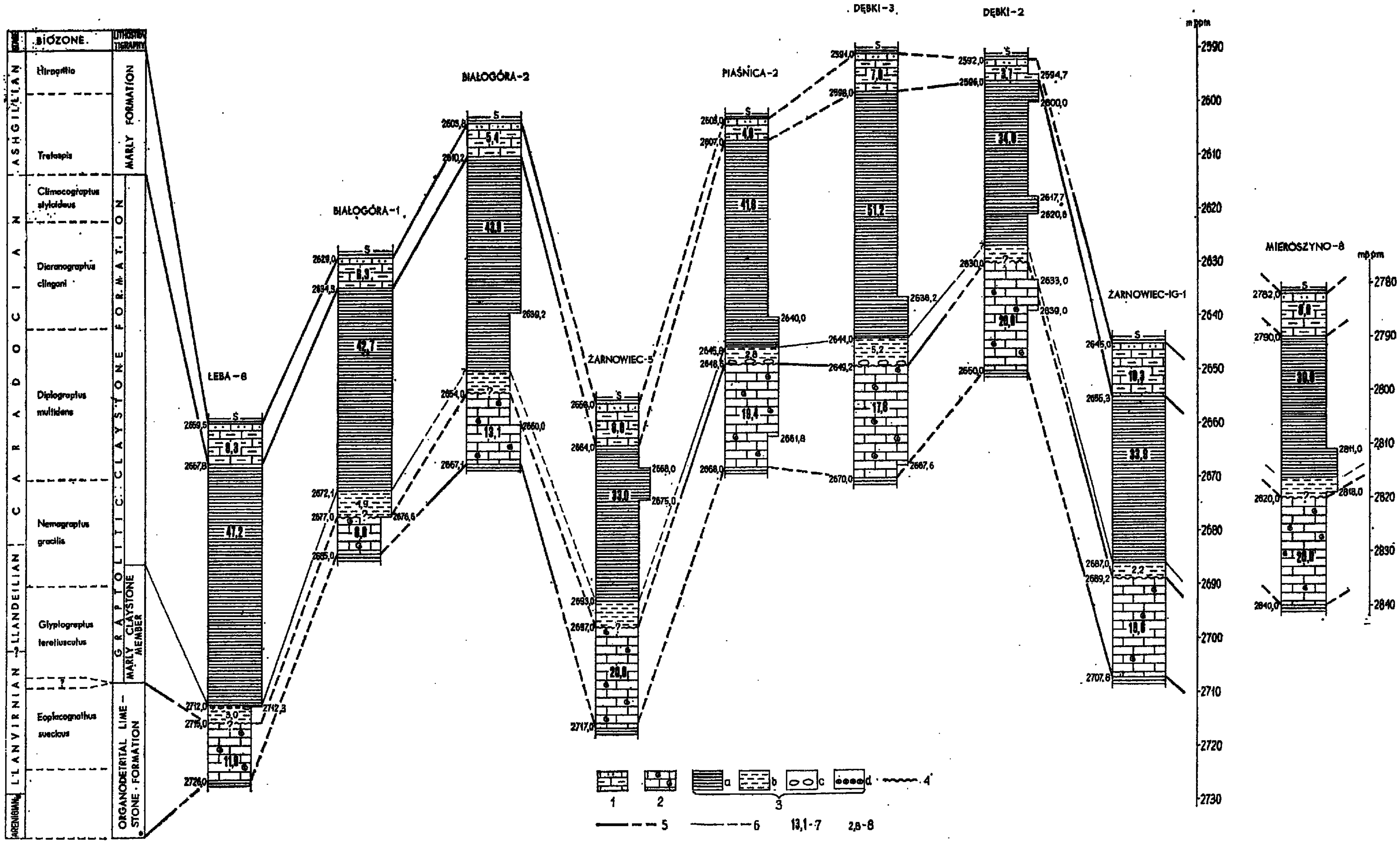
Fig. 7
Profile of the borehole Dębki *2*

Fig. 8
Profile of the borehole Żarnowiec *5*

Fig. 9
Profile of the borehole Mieroszyno *8*

For legend and explanations see Fig. 2

Correlation of the Middle and Upper Ordovician profiles in the Łeba Elevation



Left of the profiles are given the occurrence depths of the lithostratigraphic units; right of the profiles are the cored parts
In the non-cored parts of the profiles the boundaries of the lithostratigraphic units and their thickness have been determined on geophysical measurements

* The bottom of the organodetrital limestone formation after Bednarczyk (1979)
1 — marly formation, *2* — organodetrital limestone formation, *3* — graptolitic claystone formation: *a* claystones, *b* marly claystone member, *c* phosphorites, *d* ferrous ooids; *4* — erosional surface, *5* — correlation line of formation, hypothetical where discontinuous, *6* — correlation line of the member, hypothetical where discontinuous, *7* — thickness of lithostratigraphic formation, *8* — thickness of lithostratigraphic member

automorphic crystals. The strong pyritisation of the organic remains is very conspicuous here.

Phosphate accumulation (Pl. 23, Figs 1—2; Pl. 24, Figs 1—2) occur in marly claystones and marls at a depth of from 2648.6 to 2647.3 m in the Piaśnica *2* profile (Figs 2, 10), between 2649.2 and 2648.2 m in Dębki *3* (Figs 4, 10), and between 2712.3 and 2712.0 m in the Łeba *8* profile. The presence of iron ooids (Fig. 6; Pl. 24, Fig. 2) has been observed in the Łeba *8* profile at a depth of 2712.3 m.

In the marly member, along with graptolites and non-articulate brachiopods there is an abundance of ostracod carapaces, trilobite fossil remains, Chitinozoa, while bryozoans, conodonts and scolecodonts occur sporadically. It is noteworthy that, within the member here differentiated, the organic fossil remains content (the graptolites excepted) is considerably higher than in the upper parts of the graptolitic claystone formation (*cf.* Figs 2, 4).

MARLY FORMATION

Definition: In the lower part — marly claystones with an admixture of the siltstone fraction passing upwards into marls, and marly limestones, in the highest part into sandy limestones.

Index Profile: Placed in the Białogóra *2* borehole at a depth between 2610.2 and 2603.8 m.

Occurrence: Deposits of this formation have been noted in the cored parts of the following profiles: Łeba *8* at a depth between 2667.8 and 2659.5 m (Figs 6, 10), Białogóra *1* from 2634.3 and 2629.0 m (Figs 3, 10), Białogóra *2* from 2610.2 to 2603.8 m (Figs 5, 10) and in Dębki *2* profile between 2595.7 and 2594.7 m (Figs 7, 10).

On the geophysical measurements this formation has been differentiated in the Żarnowiec *5* profile at a depth between 2664.0 and 2656.0 m, in Piaśnica *2* from 2607.0 to 2603.0 m, in Dębki *3* between 2598.0 and 2591.0 m, Dębki *2* between 2595.7 and 2592.0 m, and in the Mieroszyno *8* profile at a depth from 2790.0 to 2782.0 m.

In the Żarnowiec *IG-1* profile, sediments possibly representing the lithostratigraphic unit here described occur at a depth from 2655.3 and 2645.0 m (Fig. 10).

Thickness: A full development of this formation has been observed in profiles Łeba *8*, Białogóra *1*, Białogóra *2* with a thickness of 8.3, 6.3 and 5.4 m respectively. The thickness of this formation determined on geophysical data is as follows: in the Żarnowiec *5* profile 8.0 m, in Piaśnica *2* — 4.0 m, Dębki *3* — 7.0 m, Dębki *2* — 3.7 m, and Mieroszyno *8* — 8.0 m, while in the Żarnowiec *IG-1* profile it is 10.3 m (Fig. 10).

Lower boundary: The lower boundary of the formation represents at the same the top of the underlying graptolite bearing black claystones.

Upper boundary: The passage of the sandy limestones into the overlying graptolite bearing claystones has been directly noted only in the profiles Łeba *8* at a depth of 2659.5 m, Białogóra *1* at 2629.0 m and Białogóra *2* at 2603.8 m (*cf.* Fig. 10).

Description: The basic lithological type in the lower part of the formation is represented by grey marly claystones, locally with an admixture of siltstone material, also marls to the top passing into marly limestones. Marly limestones to the top passing into sandy limestones predominate in the higher part of the lithostratigraphic unit here considered.

In addition to the lithological features such as a relatively high calcium carbonate content in the deposit and its colouration this formation differs from the surrounding rocks by the presence of benthonic organisms, especially trilobites and articulate brachiopods.

In the marls and marly limestones, various sized accumulations of neomorphic sparite are detectable due to the recrystallisation of micritic matrix. These rocks are characterised by a poorly pronounced flat parallel lamination expressed in the succession of more or less marly laminae. Poorly sorted and mostly fragmental bioclasts are the chief grain components represented by fragmentary brachiopod valves and trilobite carapaces (Figs 3, 5, 7). The presence has also been noted of rare calcisferes and indeterminate organic detritus. A macroscopic examination shows these rocks to contain a poorly differentiated faunal assemblage made up of articulate brachiopods and fragmentary trilobites.

Besides the components already mentioned the deposits here described also contain detrital quartz, single glauconite grains, feldspars and automorphic barite and dolomite crystals. The sandy material content in the marly claystones, marls and marly-micritic limestones is low, the quartz grains are small, sharp-edged or poorly rounded, haphazardly arranged. A gradual increase in the growth content towards the top of the profile has been observed by microscopic examination. Its content in the upper parts is so high as to assign these deposits to the sandy limestones.

The matrix of the sandy limestones is made up of carbonate-claystone material. Single pyrite and glauconite crystals occur along with extremely numerous quartz grains. The quartz grains are poorly sorted, their size ranges from 0.1 to 2.0 mm. The rounding of the particular grains varies; the larger ones being mostly well or poorly rounded while most of the smaller ones are sharp-edged. As a rule the laminae enriched in quartz grains are separated by claystone-carbonate laminae with a trace quartz content (Pl. 27, Fig. 2). This may reasonably suggest a changeable supply of terrigenous material to the sedimentary basin.

The organic fossil content in the sandy limestones is very low indeed and is limited to single fragmentary shells of brachiopods and trilobites and other indeterminate calcite remains.

BIOSTRATIGRAPHY

The biostratigraphic analysis aimed at the age determination of the differentiated lithostratigraphic units. Because of the changing of the fossil assemblages along with the changing lithology the stratigraphic succession has been based not on one but on several faunal groups, namely the graptolite, conodont, trilobite and articulate brachiopod groups.

In view of the facial-paleontological relations with the Ordovician profiles in other areas of Baltoscandia the writer has used the currently there accepted division of the Ordovician system into three chronostratigraphic units: the Lower Ordovician (Oelandian), the Middle Ordovician (Viruan) and the Upper Ordovician (Harjuan). This division was for the first time introduced into Estonia by Kaljo, Rõõmusoks & Männil (1958). According to this division the Oelandian includes the Tremadocian, the Arenigian and the Lower Llanvirnian; the Viruan comprises the Upper Llanvirnian, the Llandeilian and the Caradocian without the

Table 1

Bio- and chronostratigraphical subdivision of standard sections of Middle and Upper Ordovician of Great Britain and Baltoscandia

SERIES	STAGE	Graptolite zones: Great Britain (Ingham & Wright 1970, Williams et al. 1972, Williams 1976)	Graptolite zones: Balto-Scandia (Bergström 1971a,b, 1973)	Conodont zones and subzones (Bergström 1971a,b; 1973): Zone	Subzone
UPPER ORDOVICIAN HARJUAN	ASHGILLIAN	Dicellograptus anceps	Dicellograptus anceps	Amorphognathus ordovicicus	
UPPER ORDOVICIAN HARJUAN	ASHGILLIAN	Dicellograptus complanatus	Dicellograptus complanatus	Amorphognathus ordovicicus	
UPPER ORDOVICIAN HARJUAN	ASHGILLIAN / CARADOCIAN	Pleurograptus linearis	Pleurograptus linearis	Amorphognathus superbus	
MIDDLE ORDOVICIAN VIRUAN	CARADOCIAN	Dicranograptus clinganl	Dicranograptus clingani	Amorphognathus superbus	
MIDDLE ORDOVICIAN VIRUAN	CARADOCIAN	C. wilsoni / D. multidens	Diplograptus multidens	Amorphognathus tvaerensis	Prioniodus alobatus
MIDDLE ORDOVICIAN VIRUAN	CARADOCIAN	C. peltifer / D. multidens	Diplograptus multidens	Amorphognathus tvaerensis	Prioniodus gerdae
MIDDLE ORDOVICIAN VIRUAN	CARADOCIAN	Nemagraptus gracilis	Nemagraptus gracilis	Amorphognathus tvaerensis	Prioniodus variabilis
MIDDLE ORDOVICIAN VIRUAN	LLANDEILIAN	Nemagraptus gracilis	Nemagraptus gracilis	Pygodus anserinus	Upper
MIDDLE ORDOVICIAN VIRUAN	LLANDEILIAN	Glyptograptus teretiusculus	Glyptograptus teretiusculus	Pygodus anserinus	Lower
MIDDLE ORDOVICIAN VIRUAN	LLANVIRNIAN	Didymograptus murchisoni	Glyptograptus teretiusculus	Pygodus serrus	E. lindstroemi
MIDDLE ORDOVICIAN VIRUAN	LLANVIRNIAN	Didymograptus murchisoni	Glyptograptus teretiusculus	Pygodus serrus	E. robustus
MIDDLE ORDOVICIAN VIRUAN	LLANVIRNIAN	Didymograptus murchisoni	?	Pygodus serrus	E. reclinatus
MIDDLE ORDOVICIAN VIRUAN	LLANVIRNIAN	Didymograptus murchisoni	Didymograptus murchisoni	Pygodus serrus	E. foliaceus
MIDDLE ORDOVICIAN VIRUAN	LLANVIRNIAN	Didymograptus murchisoni	Didymograptus murchisoni		E. suecicus

uppermost part while the Harjuan contains the Upper Caradocian and the Ashgillian (*cf.* Table 1).

The tripartite division of the Ordovician system also has its long traditions in the Polish literature. Detailed pertinent data are given in a paper of Tomczykowa (1964). In the Ordovician of the East European Platform within Poland that author has differentiated the following strata: those of Białowieża corresponding to the Tremadocian and the Arenigian; those of Pomerania covering the Llanvirnian, the Llandeilian and the Caradocian, and the Masurian strata representing the Ashgillian. This division roughly corresponds to the Estonian one (see above).

The twopartite division first adopted by Lapworth (1879) in the Ordovician system, is on the other hand, currently used in Great Britain, the boundary between the Lower and the Upper Ordovician being placed in the bottom of the Caradocian. The twopartite division of the Ordovician in the Holy Cross Mts has likewise been used by Bednarczyk (1971).

Since the present investigations cover the rocks of the Middle and Upper Ordovician, the biostratigraphic description only is given of the top-Upper Llanvirnian part of the organodetrital limestone formation. The remaining part of this unit belonging to the Lower Llanvirnian and the Arenigian has been worked out by Bednarczyk (1979).

In the biostratigraphic analysis the division of the Middle and Upper Ordovician mostly used is that into the graptolite zones differentiated within Scania and Bornholm. These zones fit more or less into the British zones. The range of the graptolite zones in relation to the boundaries of the Ordovician stages, as determined and currently used in Great Britain and in Baltoscandia i.a. by Williams & al. (1972), Ingham & Wright (1970), also Bergström (1971b, 1973) is shown in Table 1.

The biostratigraphy of deposits without graptolites has been based on conodonts or trilobites and articulate brachiopods.

The lower boundary of Middle Ordovician has been accepted in the bottom of the Viruan (Bergström 1971a) differentiated within Baltoscandia. The lower boundary of these two units is indicated by the bottom of the Didymograptus murchisoni zone (Jaanusson 1960), and in the division on conodonts by the bottom of the Eoplacognathus suecicus subzone (Bergström 1971 a, b).

BIOSTRATIGRAPHIC ZONES

On the ground of various fossil groups, occurring in the particular lithostratigraphic formations, several biostratigraphic units ranked as zones have been differentiated in the ordovician profiles of the Łeba region. Since the vertical range of the particular taxons do not probably coincide with their full range the boundaries of the differentiated zones and their correlation with the standard zones can be but approximately determined.

UPPER LLANVIRNIAN

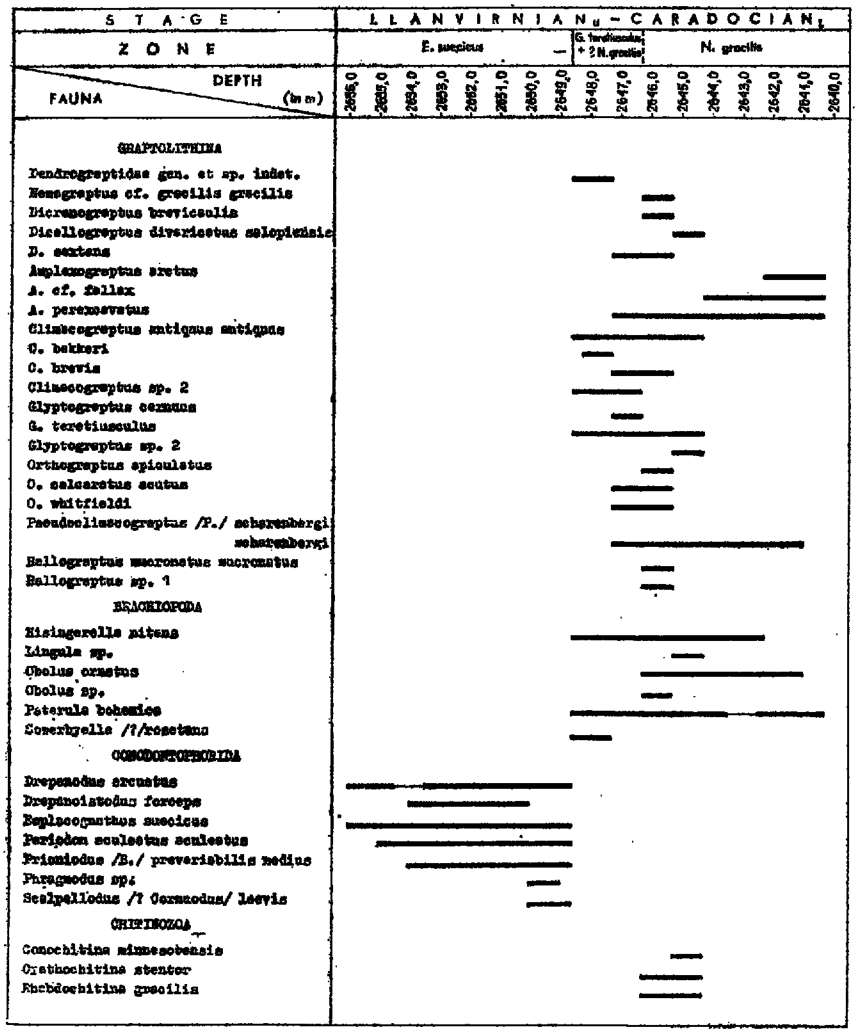
EOPLACOGNATHUS SUECICUS ZONE

This zone has been differentiated on the basis of a conodont assemblage occurring in an organodetrital limestone formation.

In the Piaśnica 2 profile, at a depth between 2656.0 and 2648.6 m, the presence has been observed of single conodonts of minor stratigraphic importance (Table 2)

Table 2

Stratigraphy and vertical ranges of fauna in the Piaśnica 2 profiles



and of numerous fragments of *Prioniodus (Baltoniodus) prevariabilis medius* Dzik, *Eoplacognathus suecicus* Bergström, *Periodon aculeatus aculeatus* Hadding and *Phragmodus* sp. Firstly on the basis of the index species and also on the presence of *Prioniodus (B.) prevariabilis medius* Dzik these sediments have been referred to the Eoplacognathus suecicus Zone. A more comprehensive description of conodonts from the Piaśnica 2 profile has been given separately (Podhalańska 1978).

In the Dębki 3 profile the conodont assemblage is much poorer (Table 3). In the interval between 2655.0 and 2651.4 m the presence has been observed of fragments belonging to the *Prioniodus (B.) prevariabilis medius* Dzik species also to *Scolopodus cornuformis* Sergeeva. Typically Lower Ordovician forms occur beginning with the depth of 2661.6 m.

Because of the taxons occurring in common the zone here differentiated may be correlated with the subzone Eoplacognathus suecicus (Tables 10—11) (Bergström 1971a). In the graptolitic classification it is correlated with the lower part of the Didymograptus murchisoni Zone (Bergström 1971 a, b; 1973) (Table 1).

In the chronostratigraphic classification it corresponds to the stage Aseri (Bergström op. cit.) differentiated in the Baltic area. According to Löfgren (1978) the stratigraphic range of the Eoplacognathus suecicus Zone is slightly greater comprising also the upper part to the Kunda stage (Lower Llanvirnian).

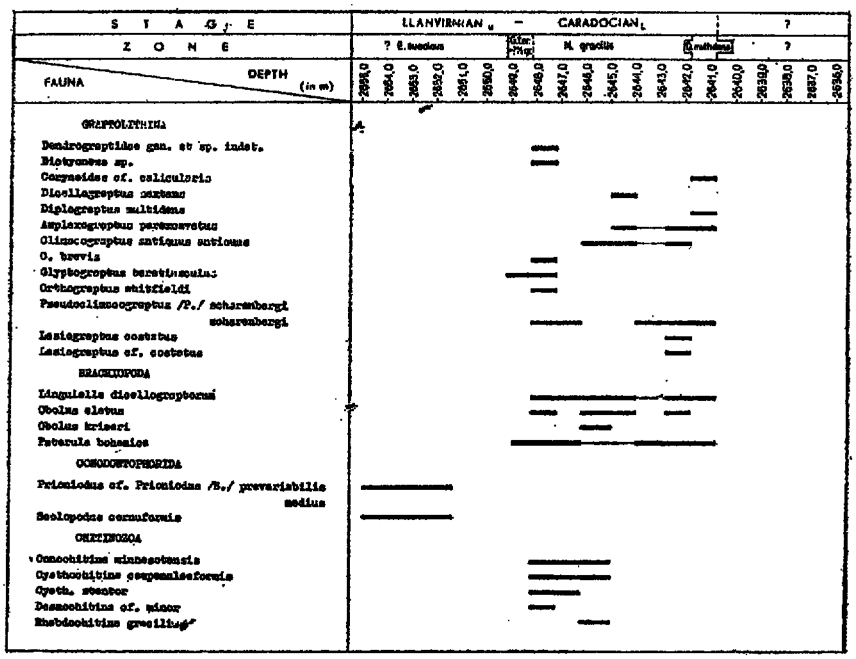
UPPER LLANVIRNIAN, CARADOCIAN

GLYPTOGRAPTUS TERETIUSCULUS AND NEMAGRAPTUS GRACILIS ZONES

In the lower part of the graptolitic claystone formation there occurs a graptolite assemblage characteristic of both the Glyptograptus teretiusculus and the Nemagraptus gracilis Zones. Hence it is hardly possible undoubtedly to determine the age of deposits containing these species.

Table 3

Stratigraphy and vertical range of fauna in the Dębki *3* profile



In the Piaśnica *2* profile rocks corresponding to the Zones Glyptograptus teretiusculus and Nemagraptus gracilis occur at a depth between 2648.6 and 2640.3 m (Table 2). In the lower part of this interval, at a depth from 2648.6 and 2646.3 m, the marly rocks of the marly claystone member have been observed to contain i.a.: *Climacograptus antiquus antiquus* Lapworth, *C. bekkeri* (Öpik), *Climacograptus* sp. 2, *Glyptograptus teretiusculus* (Hisinger), *Pseudoclimacograptus (Pseudoclimacograptus) scharenbergi scharenbergi* (Lapworth). Most of these occur both in the Glyptograptus teretiusculus and the Nemagraptus gracilis Zones. Some taxons have been encountered on the Łeba Elevation even in younger deposits.

At a depth between 2647.3 and 2646.3 m (Table 2) the presence has been observed of *Glyptograptus cernuus* Jaanusson, known from the limestones of Furudal in Sweden. These limestones have been correlated with sediments from the Glyptograptus teretiusculus Zone (Jaanusson 1960).

At a depth from 2646.3 and 2640.3 m there occurs a graptolite assemblage dominated by representatives of the species *Dicellograptus sextans* Hall, *Amplexograptus arctus* Elles & Wood, *A. perexcavatus* (Lapworth), *Orthograptus whitfieldi* (Hall), *O. apiculatus* (Elles & Wood), *O. calcaratus acutus* Elles & Wood, *Climacograptus brevis* Elles & Wood, *Pseudoclimacograptus (Pseudoclimacograptus) scharenbergi scharenbergi* (Lapworth). Together with the accompanying fewer representatives of *Hallograptus mucronatus mucronatus* (Hall) and *Nemagraptus* cf. *gracilis gracilis* (Hall) this assemblage is regarded as a characteristic one of the Zone Nemagraptus gracilis (Bergström, Riva & Kay 1974, Elles & Wood 1904—1908, Helwig 1969, Ruedemann 1947).

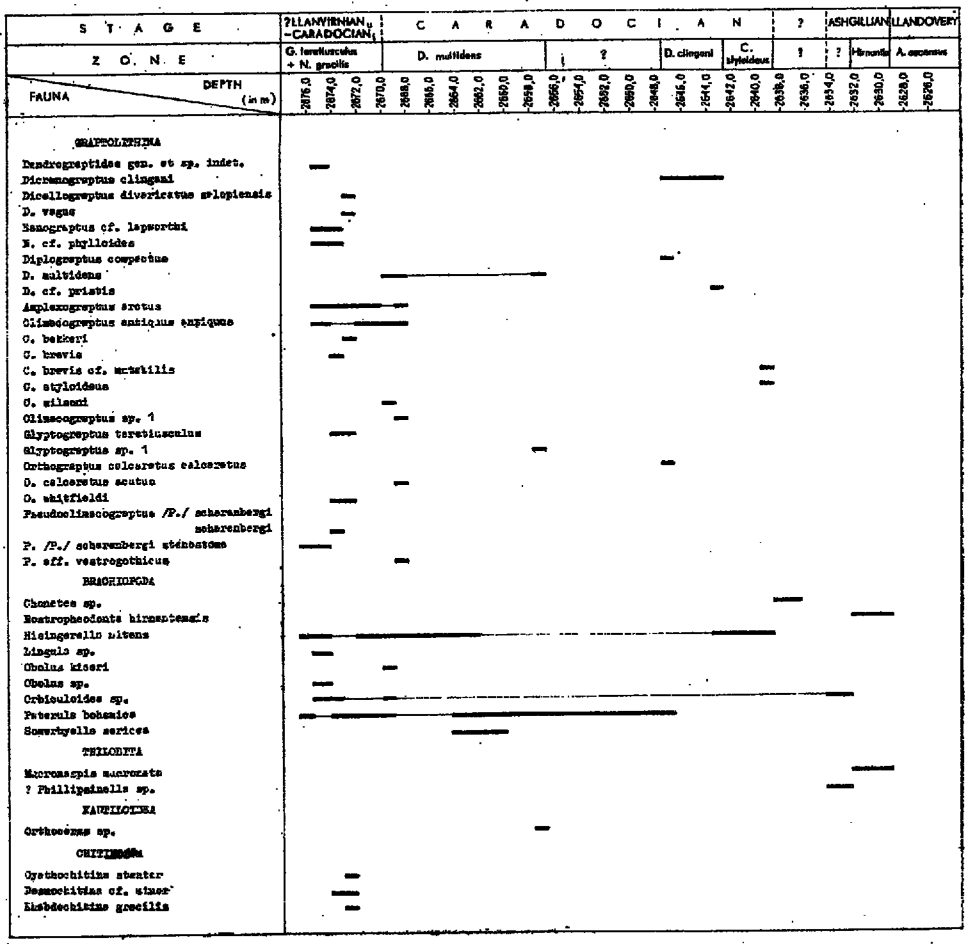
Moreover, in the interval from 2646.3 to 2644.3 m the presence has been observed of a rather abundant assemblage of Chitinozoa (Table 2). Since the stratigraphic range of *Cyathochitina stentor* (Eisenack) is, through Estonia and Sweden in the Baltic area, limited to the Kukruse Stage (Laufeld 1967), this stage corresponding in the graptolite facies to the Zone Nemagraptus gracilis (Bergström 1971b, Jaanusson 1960, Männil 1966, Modliński 1973), it is reasonable to suppose that deposits from the interval 2646.3 to 2640.3 m probably represent the Nemagraptus gracilis Zone. The age of rocks lying lower down between 2648.3 and 2646.3 m, is, however, questionable since they may correspond to both, the Glyptograptus teretiusculus and the Nemagraptus gracilis Zones. Some light is shed by the fact that the phosphate bearing zone reported from the Piaśnica *2* profile at a depth from 2648.6 to c. 2647.3 m, as well as from the Dębki *3* profile between 2649.2 and 2648.2 m is likewise known from the Fägelsång area in Scania. The phosphates there occur in the top of the Glyptograptus teretiusculus Zone (Bergström & Nilsson 1974). Hence, it may be supposed that in the Łeba Elevation the phosphates occupy a similar stratigraphic position.

In the Dębki *3* profile, at a depth from 2649.2 to 2641.8 m, (Table 3) numerous graptolites have been found, i.a.: *Dictyonema* sp., *Dendrograptidae* gen. et sp. indet., *Dicellograptus sextans* (Hall), *Amplexograptus perexcavatus* (Lapworth), *Climacograptus antiquus antiquus* Lapworth, *C. brevis* Elles & Wood, *Glyptograptus teretiusculus* (Hisinger), *Orthograptus whitfieldi* (Hall), *Pseudoclimacograptus (P.) scharenbergi scharenbergi* (Lapworth), and higher up (at a depth from 2642.8 and 2641.8 m) also *Lasiograptus costatus* Lapworth. Among the taxons here mentioned only *Lasiograptus costatus* Lapworth is an index form for deposits younger than the Glyptograptus teretiusculus Zone, its stratigraphic range being limited to the Zones Nemagraptus gracilis — Dicranograptus clingani. The remaining species occur both in the Glyptograptus teretiusculus and the Nemagraptus gracilis Zones. It might be stressed that, analogously as in the Piaśnica *2* profile and in the profile here discussed, at a depth from 2648.2 and 2645.0 m, fossil remains of Chitinozoa with *Cyathochitina stentor* (Eisenack) have been observed. Hence it is reasonable to suppose that deposits occurring from at least the depth of 2648.2 m represent the Nemagraptus gracilis Zone.

In the Białogóra *1* profile, dark claystones occurring between 2676.6 and 2669.9 m contain a graptolite assemblage characteristic of both the Glyptograptus teretiusculus and the Nemagraptus gracilis (Table 4) Zones. Hence, the presence is

Table 4

Stratigraphy and vertical range of fauna in the Białogóra *1* profile



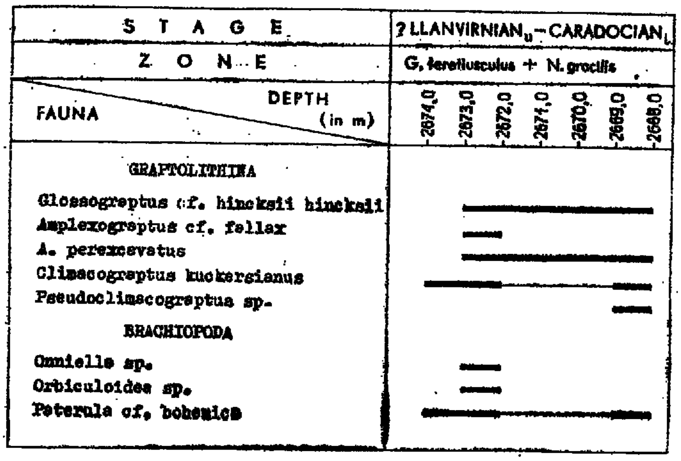
* In connection with the subject of the present paper the distribution has been shown only of the Ordovician fossil remains. The occurrence of graptolites documenting the Llandoverian age of the deposits is shown in the text-chapter "Biostratigraphy".

noted of: *Dicellograptus vagus* Hadding, so far known from the Glyptograptus teretiusculus Zone of Norway and Sweden (Bergström 1973, Berry 1964, Hadding 1913), *Nanograptus* cf. *lapworthi* Hadding and *N.* cf. *phylloides* Elles & Wood, whose typical specimens were cited from the Nemagraptus gracilis Zone of Scania (Hadding 1915b), *Climacograptus bekkeri* (Öpik) occurring in the deposits of the Kukruse Stage in Estonia and, as has been here mentioned, corresponding to the Nemagraptus gracilis Zone. The remaining taxons occur both in the Glyptograptus teretiusculus and the Nemagraptus gracilis Zones.

In the Żarnowiec *5* profile (Table 5), in deposits occurring between 2674.0 and 2668.0 m, the presence has been observed of *Glossograptus* cf. *hincksii hincksii* (Hopkinson), *Amplexograptus* cf. *perexcavatus* (Lapworth), *Climacograptus kuckersianus* Wiman and *Pseudoclimacograptus* sp. In the opinion of Bergström (1973)

Table 5

Stratigraphy and vertical range of fauna in the Żarnowiec 5 profile



Glossograptus hincksii hincksii (Hopkinson) is one of the diagnostic taxons of the Glyptograptus teretiusculus Zone. In the classic Moffat area of Scotland, however, the stratigraphic range of this species is much greater, comprising the so called Glenkiln Shales as well as the lower part the Hartfell Shales which includes the Climacograptus wilsoni Zone (Lapworth 1878). This species has also been reported from the Didymograptus murchisoni Zone of Scania (Ekström 1937).

The species *Climacograptus kuckersianus* Wiman, observed in that part of the Żarnowiec 5 profile here discussed, has so far been known from deposits of the Kukruse Stage of Estonia (Jaanusson 1960). In connection with the above data it is hardly possible undoubtedly to determine the stratigraphic position of deposits in the interval under consideration. They may represent both the Glyptograptus teretiusculus as well as the Nemagraptus gracilis Zones.

In profile Mieroszyno 8, at a depth from 2813.0 to 2811.0 m there occurs a rather strongly differentiated graptolite assemblage (Table 6), out of which *Glossograptus hincksii hincksii* (Hopkinson) is the only one to have been found also in deposits older than the Nemagraptus gracilis Zone. *Dicranograptus ziczac* (Lapworth), *Dicellograptus divaricatus salopiensis* Elles & Wood, *Amplexograptus perexcavatus* (Lapworth) are, however, a graptolite assemblage characteristic of the Nemagraptus gracilis Zone.

In the lower part of the cored fragment of profile Łeba 8 (Table 7), at a depth between 2712.3 and 2707.5 m, in black claystones intercalated by iron ooids, the presence has been noted of *Nemagraptus* cf. *gracilis gracilis* (Hall), *Dicellograptus sextans* Hall and *Glyptograptus teretiusculus* (Hisinger), also of fragmentary fossil remains of Dichograptidae (?*Didymograptus* sp.). None of these taxons, however, are characteristic only of the Nemagraptus gracilis or the Glyptograptus teretiusculus Zones.

The graptolite assemblages of the Glyptograptus teretiusculus and Nemagraptus gracilis Zones, occurring in the Łeba Elevation, differ from the fossil assemblage encountered in the next graptolite zone. The graptolite assemblage characterised above may be noted by the presence of several species not found in younger deposits in the Łeba region. Among them are representatives of the genera *Nanograptus*, *Glossograptus*, and firstly of *Nemagraptus* and *Dictyonema*.

Table 6
Stratigraphy and vertical range of fauna in the Mieroszyno 8 profile

STAGE	?					LLANDEILIAN-CARADOCIAN		
ZONE	?					N. gracilis		
FAUNA / DEPTH (in m)	2618,0	2617,0	2616,0	2615,0	2614,0	2613,0	2612,0	2611,0
GRAPTOLITHINA								
Corynoides cf. calicularis						—	—	
Dicranograptus ziczac.						—	—	
Dicellograptus divaricatus salopiensis						—	—	
Glossograptus cf. hincksii hincksii						—	—	
Amplexograptus perexcavatus						—	—	—
Lasiograptus costatus						—	—	
BRACHIOPODA								
Hisingerella nitens		—	—					
Sericoidea sp.	—	—	—					
Paterula portlocki						—	—	
CHITINOZOA								
Conochitina minnesotensis						—	—	
Cyathochitina campanulaeformis						—	—	

Moreover, there also occur fragmentary rhabdosomes referable to the family of Dendrograptidae and Dichograptidae. The fossil assemblage is also characterised by fairly great numbers of the representatives of the genera *Dicellograptus* and *Dicranograptus*.

DIPLOGRAPTUS MULTIDENS ZONE

According to the classification accepted in the present paper this zone comprises deposits between the fauna-bearing deposits of the Zones Glyptograptus teretiusculus and Nemagraptus gracilis or Nemagraptus gracilis and the graptolite assemblage of the Dicranograptus clingani Zone.

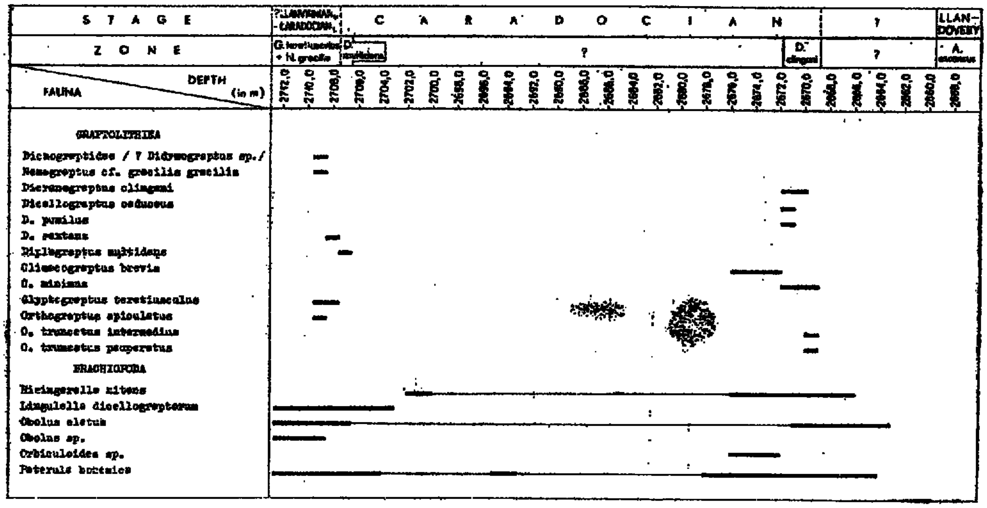
The presence of the Diplograptus multidens Zone has been documented in the profiles of Białogóra *1*, Białogóra *2*, Łeba *8* and Dębki *3*. It is developed as dark-grey and black claystones containing graptolites and non-articulate brachiopods, with intercalations of greenish claystones bearing scanty fossil remains. In the latter a microscopic analysis has led to the differentiation of several thin intercalations of bentonites and tuffs (Przybyłowicz 1977, 1980).

Graptolites of the species *Corynoides* cf. *calicularis* Nicholson, *Diplograptus multidens* Elles & Wood, *Amplexograptus perexcavatus* (Lapworth), *Climacograptus wilsoni* Lapworth and *Orthograptus calcaratus acutus* Elles & Wood, are those most characteristic of the zone here discussed. A characteristic feature of the graptolite assemblage here differentiated is to be noted in the sporadical occurrence of the representatives of the genera *Dicellograptus* and *Dicranograptus* or in their absence.

In the profile Białogóra *1* (Table 4), in the interval from 2669.9 and 2667.9 m the presence has been observed of *Diplograptus multidens* Elles & Wood, *Climaco-*

Table 7

Stratigraphy and vertical range of fauna in the Łeba *8* profile



graptus wilsoni Lapworth, *Orthograptus calcaratus acutus* Elles & Wood, *Pseudoclimacograptus* aff. *vestrogothicus* Jaanusson & Skoglund, *Climacograptus* sp. 1. They are accompanied by *Climacograptus antiquus antiquus* Lapworth and *Amplexograptus arctus* Elles & Wood. Above the depth of 2667.0 m as far as 2657.7 m no determinate graptolite fossil remains have been found. But there occur some few non-articulate brachiopods of the species *Hisingerella nitens* Hisinger and *Paterula bohemica* Barrande.

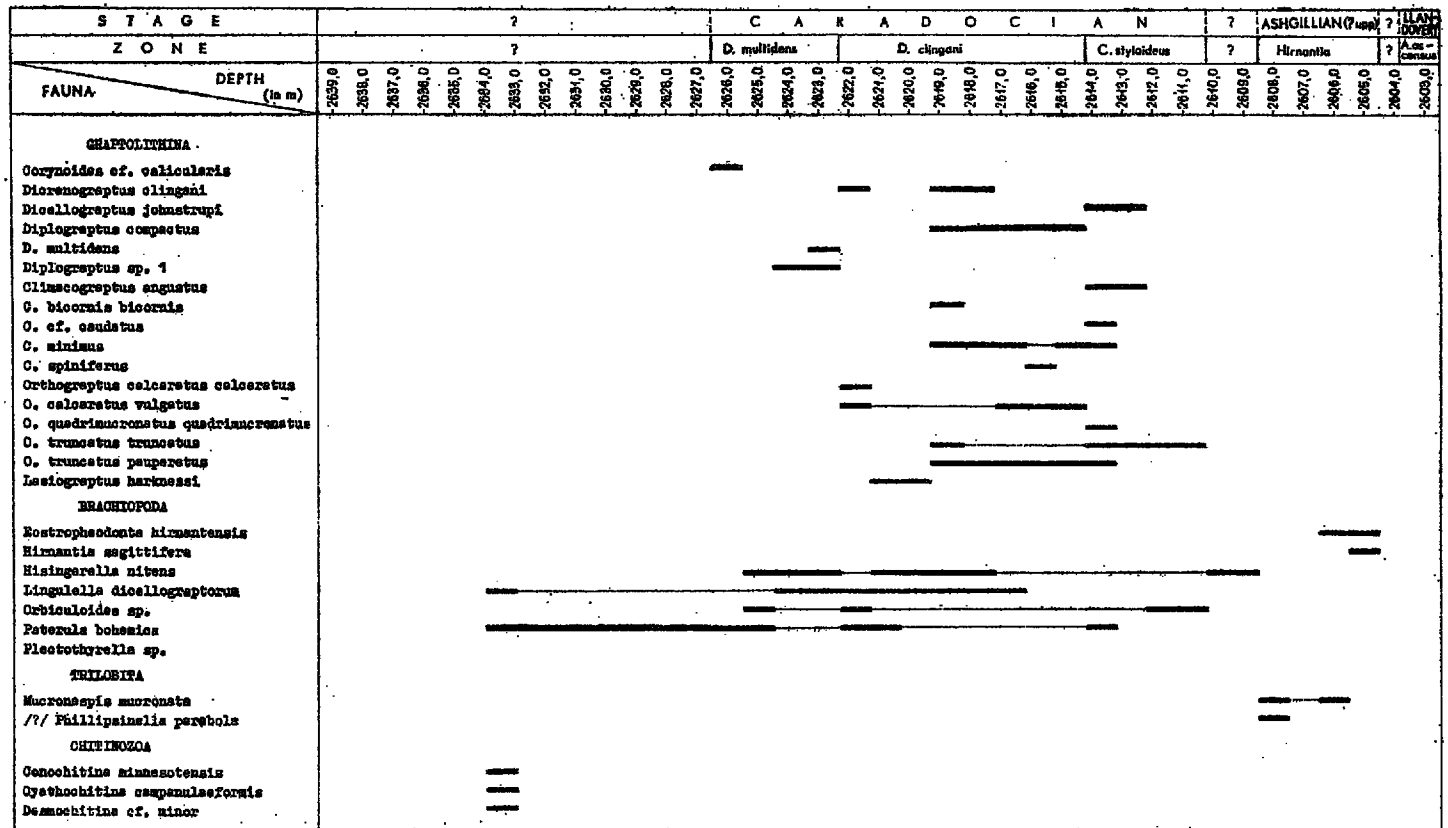
At a depth of 2657.7 to 2656.7 m the presence has again been observed of *Diplograptus multidens* Elles & Wood and of *Glyptograptus* sp. 1. The here quoted graptolite assemblage reasonably suggests the correlation of the sediments yielding them with the Zone Diplograptus multidens.

Graptolites documenting the Zone Diplograptus multidens also occur in the profile Białogóra *2* in the interval from 2626.5 to 2622.3 m (Table 8). This assemblage is, however, specifically and numerically less strongly differentiated. *Corynoides* cf. *calicularis* Nicholson, *Diplograptus multidens* Elles & Wood, *Orthograptus calcaratus vulgatus* Elles & Wood and *Lasiograptus harknessi* (Nicholson) have been here found, associated with non-articulate brachiopods (Table 8). No determinate fossil graptolite remains have been observed below the interval mentioned above. Chitinozoa (Table 8) occur at a depth from 2634.0 to 2633.0 m; all the species here quoted, however, are characterized by a wide stratigraphic range.

The uppermost part of the dark claystones containing graptolites and non--articulate brachiopods in the profile Dębki *3* (a depth from 2641.8 to 2640.8 m) may be a correspondent of the Diplograptus multidens Zone because of the presence there of the index taxon *Diplograptus multidens* Elles & Wood associated with *Corynoides* cf. *calicularis* (Nicholson) and *Amplexograptus perexcavatus* (Lapworth) (Table 3). Below the depth of 2640.8 m there occurs in a cored section of the profile a paleontologically unfossiliferous claystone series intercalated by pyroclastic rocks.

Table 8

Stratigraphy and vertical range of fauna in the Białogóra 2 profile



The fossil graptolite remains of *Diplograptus multidens* Elles & Wood, occurring in the Łeba *8* profile at a depth of 2707.5—2706.5 m in a lithologically uniform black claystone complex, may reasonably suggest these deposits as being a stratigraphically corresponding to the Diplograptus multidens Zone differentiated in other profiles on the Łeba Elevation. It is, however, hardly possible exactly to determine the stratigraphic position of deposits lying higher up, at a depth from 2706.5 to 2671.8 m because they contain a poor and non-diagnostic assemblage of graptolites and non-articulate brachiopods (Table 7).

On the basis of the material available to the writer it has not been possible to differentiate the Zones Diplograptus molestus and Climacograptus wilsoni (*cf.* Table 11) identified by Modliński (1973) as equivalents of the Zone Diplograptus multidens.

DICRANOGRAPTUS CLINGANI ZONE

The next graptolite assemblage, possibly an equivalent of the Dicranograptus clingani Zone is characterised by a taxonomic composition differing from that of the graptolite assemblage discussed above. The differences are on both generic and specific level. The new and at the same time younger assemblage is again characterised by the numerous and differentiated occurrence of the genera *Dicellograptus* and *Dicranograptus* as well as by the predominance of orthograptids from the "truncatus" group.

On the presence of such taxons as: *Dicranograptus clingani* Carruthers, *Dicellograptus caduceus* (Lapworth), *D. pumilus* (Lapworth), *Climacograptus bicornis bicornis* (Hall), *C. minimus* Carruthers and *Orthograptus truncatus truncatus* (Lapworth) this assemblage may reasonably be regarded as characteristic of the Dicranograptus clingani Zone. The taxons mentioned above, the species *Dicellograptus pumilus* (Lapworth) excepted, have been accepted by Lapworth (1878) as diagnostic for the Dicranograptus clingani Zone identified in the classical Moffat profiles. *Dicellograptus pumilus* (Lapworth) from the Moffat area is characteristic rather of the Pleurograptus linearis Zone (Lapworth op. cit.), it occurs, however, also in the Dicranograptus clingani Zone (Elles & Wood 1904).

The graptolite assemblage mentioned above may be encountered in the profiles of Białogóra *1*, Białogóra *2* and Łeba *8* (Tables 4, 7—8).

In the Białogóra *1* profile specimens belonging to the species *Dicranograptus clingani* Carruthers have been found at a depth between 2647.6 and 2642.6 m (Table 4). It is associated with *Orthograptus calcaratus* (Lapworth), *Diplograptus compactus* Elles & Wood and *Diplograptus* cf. *pristis* (Hisinger). Together with the non-articulate brachiopods (Table 4) they occur in the higher part of the graptolitic claystone formation.

The presence of an abundant graptolite assemblage of the Dicranograptus clingani Zone has been observed in analogous deposits from the Białogóra *2* profile at a depth from 2622.3 to 2614.2 m (Table 8). Besides the index species there have been identified here *Diplograptus compactus* Elles & Wood, *Climacograptus bicornis bicornis* (Hall), *C. minimus* (Carruthers) and, in the upper part of the above interval, *C. spiniferus* Ruedemann, *Orthograptus calcaratus calcaratus* (Lapworth), *O. calcaratus vulgatus* Elles & Wood, *O. truncatus truncatus* (Lapworth) and *O. truncatus pauperatus* Elles & Wood. The occurrence of the associated non-articulate brachiopods is shown in Table 8.

The upper part of the graptolitic claystone formation in the Łeba *8* profile is paleontologically poorly documented. The interval from 2671.8 to 2669.8 m has yielded the graptolite species *Dicranograptus clingani* Carruthers together with *Dicellograptus pumilus* Lapworth and *D. caduceus* Lapworth (Table 7). Hence, it is reasonable supposed that deposits occurring at this depth represent the Dicranograptus clingani Zone.

At a depth between 2669.8 and 2668.8 there occur *Orthograptus truncatus intermedius* Elles & Wood and *O. truncatus pauperatus* Elles & Wood. The latter is known from the Zone Pleurograptus linearis or its equivalents (Modliński 1973, Toghill 1970); but it is also markedly characteristic of the Dicranograptus clingani (Elles & Wood 1907) Zone. *Orthograptus truncatus intermedius* Elles & Wood has not so far been reported from deposits younger than the Dicranograptus clingani Zone. Hence it may be supposed that also deposits from a depth between 2669.8 and 2668.8 represent the Dicranograptus clingani Zone. The grey clayey deposits encountered in the top of the graptolitic claystone formation (at a depth from 2668.8 to 2667.8 m) are without graptolites, therefore, it is difficult to determine their age.

CLIMACOGRAPTUS STYLOIDEUS ZONE

In the top of the black claystone graptolite-bearing complex above the Dicranograptus clingani Zone there occurs a fossil assemblage characterising the Climacograptus styloideus Zone which is a stratigraphic equivalent of the Pleurograptus linearis Zone in the classical profiles of Great Britain (Hadding 1915a; Modliński 1973, 1976).

The presence of the graptolite assemblage characteristic of the Climacograptus styloideus Zone has been documented in the profiles of Białogóra *1* (Table 4), Białogóra *2* (Table 8) and Dębki *2* (Table 9). Deposits of this age may perhaps occur in the Łeba *8* profile (Table 7), above the Dicranograptus clingani Zone, but they are not documented by the presence of index graptolites.

The fauna of the Climacograptus styloideus Zone is characterized chiefly by the presence of graptolites from the genera *Climacograptus*, *Dicellograptus* and *Orthograptus*. On the other hand, the genus *Pleurograptus*, so characteristic of the British fauna, as well as — to a smaller extent — *Leptograptus* and *Amphigraptus* are absent, or extremely rare in the Scandinavian area and within Poland.

In the dark claystones and marly claystones from the Białogóra *2* profile, at a depth from 2614.2 to 2610.2 m, above the deposits of the Dicranograptus clingani Zone, the presence has been observed of *Dicellograptus johnstrupi* Hadding described by Hadding (1915a) from deposits of the Climacograptus styloideus Zone of Bornholm. It is accompanied by *Climacograptus angustus* (Perner), *C.* cf. *caudatus* Lapworth, *C. minimus* (Carruthers), *Orthograptus truncatus truncatus* (Lapworth) and *O. truncatus pauperatus* Elles & Wood. *Dicellograptus johnstrupi* Hadding and *Climacograptus angustus* (Perner) have so far been known only from the Climacograptus styloideus Zone or from its stratigraphic equivalents.

The graptolite assemblage characteristic of the Climacograptus styloideus Zone also occurs in the cored fragment of the Dębki *2* profile (Table 9) at a depth from 2598.7 to 2595.7 m. Besides the index species the presence here has been noted of several fragments of *Leptograptus* sp., numerous *Dicellograptus johnstrupi* Hadding, *Orthograptus truncatus truncatus* (Lapworth), *O. truncatus pauperatus* Elles & Wood as well as the youngest species of the genus *Pseudoclimacograptus-Pscl. clevensis* Skoglund. This has, so far, been known only from the Pleurograptus linearis Zone differentiated in deposits of the Fjäcka formation in

Table 9

Stratigraphy and vertical range of fauna in the Dębki *2* profile

STAGE	?				CARADOCIAN$_u$					ASHGILLIAN (? top)	
ZONE	?				C. styloideus					Tretaspis	
FAUNA \ DEPTH (in m)	-2624,0	-2620,0	-2619,0	-2618,0	-2600,0	-2599,0	-2598,0	-2597,0	-2596,0	-2595,0	-2594,0
GRAPTOLITHINA											
? Leptograptus sp.								—	—		
Dicellograptus johnstrupi							—	—	—		
Climacograptus minimus						—	—	—			
C. spiniferus							—	—			
C. styloideus						—	—	—			
Orthograptus calcaratus vulgatus						—	—				
O. quadrimucronatus quadrimucronatus							—	—			
O. truncatus truncatus							—	—			
O. truncatus pauperatus							—	—	—		
Pseudoclimacograptus /P./ cleavensis								—	—		
P. /P./ scharenbergi scharenbergi			—	—							
BRACHIOPODA											
Hisingerella nitens			—	—				—	—		
Lingulella dicellograptorum			—	—			—	—			
Paterula portlocki			—	—			—	—	—	—	
Obolus ornatus							—	—	—		
Orbiculoidea sp.							—	—			
TRILOBITA											
Calliops cf. callicephalus									—	—	
? Opsimasaphus sp.									—	—	
Tretaspis sp.									—	—	

the Västergötland area of Sweden (Skoglund 1963). A rich assemblage of non--articulate brachiopods is represented i.a. by *Hisingerella nitens* (Hisinger), *Paterula portlocki* (Geinitz), (Pl. 18, Figs 4, 10), *Obolus ornatus* Hadding (Pl. 18, Fig. 8) and *Orbiculoidea* sp. Their distribution in the Dębki *2* profile is shown in Table 9.

In the Białogóra *1* profile (depth from 2639.6 to 2638.5 m) the occurrence has been observed of the index species *C. styloideus* Elles & Wood, also of *C. wilsoni* Lapw., may reasonably document the biostratigraphic zone here discussed.

The assemblage of the youngest graptolites from the deposits here considered, documented by the Białogóra *1*, Białogóra *2* and Dębki *2* profiles, very closely resembles the assemblage occurring in the black shales of the Fjäcka formation differentiated in Sweden (*cf.* Skoglund 1963). The graptolites present in the deposits of this formation have been recognised as diagnostic for the Zone Pleurograptus linearis (Henningsmoen 1948, Skoglund 1963, Thorslund 1940). The occurrence in the deposits under consideration of an almost identical assemblage of fossil remains reasonably suggests that they represent an equivalent of the Zone Pleurograptus linearis differentiated in Sweden.

ASHGILLIAN

The disappearance of the graptolite fauna in the top of the graptolitic claystone formation does not allow precisely to determine the Caradocian/Ashgillian boundary. The age of the youngest Ordovician deposits on the Łeba elevation has been documented on trilobites and articulate brachiopods found in the marly formation. This scanty and often fragmentary fauna did not lead to the differentiation of formal biostratigraphic zones of the Ashgillian. The upper Ordovician boundary has been recognised at the bottom of the Akidograptus ascensus Zone in the Llandoverian.

In the Białogóra *1* profile (Table 4) Ashgillian deposits have been documented at a depth from 2634.3 to 2629.0 m. Scanty trilobite remains belonging to the species *Mucronaspis mucronata* (Brongniart) and, slightly lower down, fragments of (?)*Phillipsinella* sp. have been found in grey marls, marly claystones and micritic marly limestones at a depth from 2632.2 to 2629.0 m. *Eostropheodonta hirnantensis* (M'Coy) (Pl. 16, Fig. 1) and *Orbiculoidea* sp. have been identified among the brachiopods. Above the brachiopod-trilobite assemblage there appear graptolites of the Akidograptus ascensus Llandoverian Zone with *Akidograptus ascensus* Nicholson, *Climacograptus scalaris miserabilis* Elles & Wood, *Diplograptus modestus* Lapworth and *Diplograptus* ? *rarus* Rickards.

In the Białogóra *2* profile at a depth from 2608.5 to 2604.5 m the presence has been observed of articulate brachiopods and trilobites indicating the Ashgillian age of the deposits (Table 8). The brachiopods identified here are: *Eostropheodonta hirnantensis* (M'Coy), *Hirnantia sagittifera* (Davidson) (Pl. 16, Fig. 2), *Plectothyrella* sp. and the trilobites: *Mucronaspis* cf. *mucronata* (Brongniart) (Pl. 16, Fig. 4; Pl. 17, Fig. 3) and (?)*Phillipsinella parabola* (Barrande) (Pl. 17, Fig. 2). With the exception of (?)*Phillipsinella parabola* (Barrande) the above quoted association of brachiopods and trilobites represents a characteristic assemblage of the so called "Hirnantia" fauna. Underlying them at a depth from 2610.2 to 2608.5 m occurs a series of marly claystones and marls, lacking paleontological documentation, possibly deposits of Ashgillian age, too.

In connection with the discussions still continued relating to the determination of the Ordovician/Silurian boundary the stratigraphic position of deposits bearing the "Hirnantia" fauna has not been unquestionably indicated. In the stratotype profile of Bala in Wales, the "Hirnantia" fauna and the Hirnantian Stage differentiated thereon is the youngest stratigraphic Ashgillian member (Bancroft 1933, Ingham & Wright 1970), while the upper boundary of the Hirnantian at the same time indicates the top of the Ordovician. In some parts of the world (cf. Podhalańska 1977) the "Hirnantia" fauna is noted to occur together with graptolites of the Glyptograptus persculptus Zone, in the stratotype profile of Dobb's Linn near Moffat regarded as the oldest biostratigraphic zone of the Silurian (Cocks, Toghill & Ziegler 1970). Hence the "Hirnantia" fauna is sometimes regarded as a Lower Silurian assemblage (Alikhova 1975; Jaeger, Havlíček & Schönlaub 1975; Lespérance 1974). There are also opinions (Cocks & Price 1975) suggesting diachronism of the "Hirnantia" fauna connected with the adaptation of the particular assemblage to the environmental conditions changing with time and space. Thus the stratigraphic range of the "Hirnantia" fauna would not coincide with the age limit of the Hirnantian. However, in Great Britain and Scandinavia as wel as in Czechoslovakia and Poland the above mentioned brachiopod-trilobite assemblage is currently regarded as the youngest organic assemblage known from the Upper Ordovician. In this connection, deposits occurring on the Łeba Elevation and bearing elements the "Hirnantia" fauna may reasonably be regarded as the youngest Ordovician deposits and correlated with the Hirnantian Stage of Great Britain, deposits of the Kosov formation in Czechoslovakia (Havlíček & Marek 1973), with the Tommarpian Stage of Sweden

(Bergström 1971b, Jaanusson 1963), the Dalmatina mucronata Zone of the Holy Cross Mts (Bednarczyk 1971, Kielan 1956, Temple 1965). The correlation of the "Hirnantia" bearing deposits occurring in profiles of the Łeba Elevation with some of the just mentioned stratigraphic units has been shown in Table 11.

In the Białogóra 2 profile here discussed, at a depth of 2603.8 m black clay rocks yielding Lower Silurian graptolites make their appearance (Table 8). Hence the Ordovician/Silurian boundary is determined in the interval from 2604.5 to 2603.8 m.

In the Dębki 2 profile (Table 9) in the interval from 2595.7 to 2594.7 m *Calliops* sp. cf. *C. callicephalus* Hadding (Pl. 17, Fig. 4), ?*Opsimasaphus* sp. (Pl. 16, Fig. 6) and several fragments of *Tretaspis* sp. (Pl. 17, Fig. 5), have been found in the grey-green marly limestones occurring above the black graptolite-bearing claystones. The presence of the above trilobites is characteristic of Ashgillian deposits older than the strata with *Mucronaspis mucronata* (Brongniart) of Poland, Czechoslovakia and Sweden (Kielan 1959, Modliński 1973). Hence, the marly-micrite limestones encountered in the Dębki 2 profile may possibly represent the Lower Ashgillian. Because of the lack of coring above the depth of 2594.7 m the presence of deposits of the upper part of the Ashgillian has not been shown in this profile.

It is hardly possible to determine the age of the grey marly claystones, marls and of the strongly marly limestones occurring in the Łeba 8 profile (Table 7) at a depth between 2667.8 to 2659.5 m because the preserved core fragments are practically unfossiliferous. Overlying these deposits, at a depth of c. 2659.5 m, black claystones make their appearance containing graptolites of the Akidograptus ascensus Zone with *Akidograptus ascensus* Nicholson, *Climacograptus medius* Törnquist, *Climacograptus normalis* Lapworth, *C. scalaris miserabilis* Elles & Wood and *Diplograptus*(?) *rarus* Rickards. Therefore, the marly rocks which have yielded no fossil remains may represent Ashgillian deposits because of the lithological resemblance with paleontologically documented Ashgillian deposits in other profiles of the Łeba region.

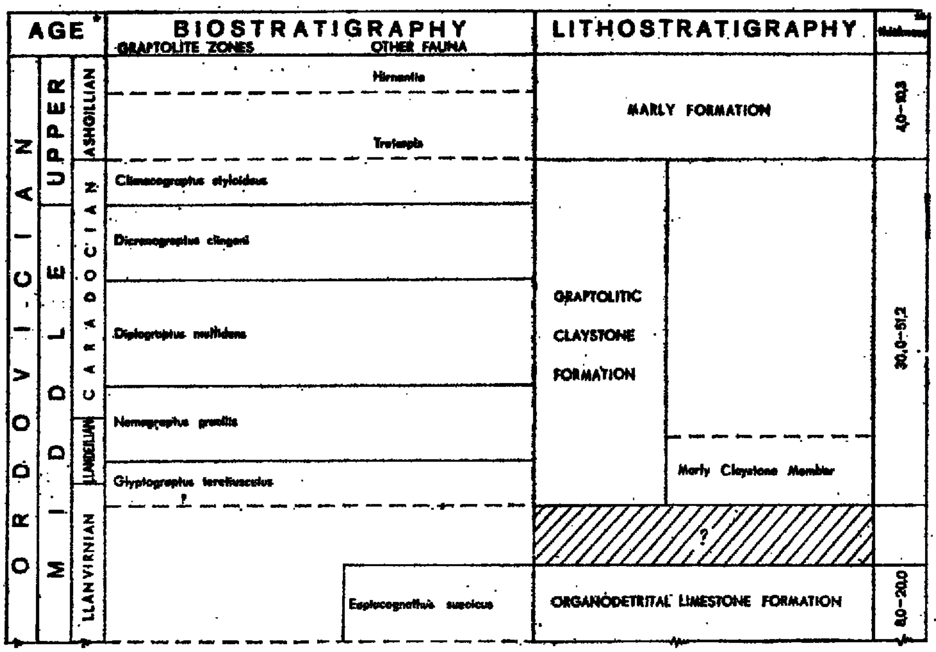
AGE AND BOUNDARY DATING OF LITHOSTRATIGRAPHIC UNITS

In connection with the absence of a fossil group in common for all the formations and because of the difficulties presented above in the differentiation of separate biostratigraphic zones the exact boundary dating of lithostratigraphic units and, consequently their age, may be but approximately determined (Table 10, Fig. 10).

The conodonts encountered in the organidetrital limestone formation of the Piaśnica 2 and Dębki 3 profiles indicate Zone Eoplacognathus suecicus, correlated with the lower part of the Didymograptus murchisoni Zone (Table 1). Since the oldest Middle Ordovician graptolites present in the graptolitic claystone formation belong to the Glyptograptus teretiusculus Zone the lack is reasonably supposed of paleontological documentation in the profiles that have been investigated to confirm the presence of deposits of the upper part of the Didymograptus murchisoni Zone (*cf.* Table 1). In the light of available facts it is hardly possible to take the decision whether the lack of paleontological docu-

Table 10

Correlation of litho- and biostratigraphic units of the Middle and Upper Ordovician of the Łeba Elevation



* Bio- and chronostratigraphic subdivision of Llanvirnian, Llandeilian and part of Caradocian after Bergström (1971b).

** Approximate thickness in meters.

mentation of these deposits is due to a stratigraphic lacuna or to inadequate data resulting from insufficient coring of deposits in this interval. Neither can an error be excluded due to difficulties in the correlation of the graptolite and conodont division. Yet, because of the unimportant and variable thickness of Ordovician deposits on the Łeba Elevation the existence of a stratigraphic lacuna between the graptolitic claystone formation and that of organodetrital limestone formation seems quite probable (Table 10). This is, moreover, supported by the presence of phosphates as well as by the mass agglomeration of organic remains in the lower part of the marly claystone member indicating a strong slowing down of the sedimentary rate, possibly even a break in deposition.

Deposits occurring in the Piaśnica *2* profile at a depth between 2646.3 and 2640.0 m, also in the Dębki *3* profile between 2648.2 and 2641.8 m, may, in the light of the writer's previous considerations, be accepted as corresponding to the Nemagraptus gracilis Zone. Thus, the upper boundary of the marly claystone member in the Piaśnica *2* profile at a depth of c. 2645.8 m and that of 2644.0 m in the Dębki *3* profile, would be determined within the biostratigraphic zone mentioned above (*cf.* Table 10).

The top part of the graptolitic claystone formation is documented by the presence of graptolites from the Climacograptus styloideus Zone. As has been previously mentioned, an exact determination of the upper boundary of this unit in the deposits here considered is hardly possible owing to the disappearance of the graptolite facies.

The oldest fossil remains in the marly formation probably document the lower Ashgillian age, while elements of the "Hirnantia" fauna, encountered in the Białogóra *1* and Białogóra *2* profiles prove the presence of the youngest Ashgillian and, at the same time, the youngest Ordovician deposits on the Łeba Elevation. The upper boundary of the marly formation on the Łeba Elevation is accurately indicated by the defined bottom of the Akidograptus ascensus Zone of the Llandoverian.

In the light of the most recent opinions on the division of the Ordovician into chronostratigraphic units (Table 1), the part of the organodetrital limestone formation investigated by the writer would represent Llanvirnian deposits without its upper part; the graptolitic claystone formation would include the Llandeilian and the Caradocian, probably also the Uppermost Llanvirnian, the marly formation — the Ashgillian (Table 10).

The lithostratigraphic correlation of the worked out profiles of the Middle and Upper Ordovician of the Łeba Elevation, including the Żarnowiec *IG-1* profile and the hypothetical dating of the particular lithostratigraphic units have been shown in Fig. 10.

FACIAL DEVELOPMENT AND SEDIMENTARY CONDITIONS IN THE MIDDLE AND UPPER ORDOVICIAN OF THE ŁEBA ELEVATION

An analysis of the differentiated lithostratigraphic units and the character of the fossil assemblages they contain reasonably indicate that the Middle and Upper Ordovician deposits occuring in the Łeba Elevation are of a platform type and were formed in a shelf sea environment. In all the examined profiles the thickness of the Ordovician was rather small ranging around 80 m and suggesting a slow rate of sedimentation. A certain variability has also been observed in the thickness of deposits occurring in the particular profiles of the Łeba region. In the organodetrital limestones formation the thickness increases eastward ranging from c. 8.0 m in the Białogóra *1* profile to about 20.0 m in the Dębki *2* and Mieroszyno *8* profiles (Fig. 10). No regularity in the changes of thickness has, however, been observed in the graptolitic claystone formation or in the marly formation, though even there some slight differences in thickness have been noted in the particular profiles. Namely, the thickness of the graptolitic claystone formation changes from a. 30.0 m in the Mieroszyno *8* profile to c. 51.2 m in the Dębki *3* profile while that of the marly formation ranges from c. 3.7 m in the Dębki *2* profile to 10.3 m in the Żarnowiec *IG-1* profile (*cf.* Fig. 10).

Changes in the thickness of deposits may be referred to lack of uniformity in the supply of material or to the erosional action of currents and waves.

On the basis of information given above three main lithological types may be distinguished in the Middle and Upper Ordovician deposits. These types contain definite faunal assemblages representing definite environmental types at that time prevailing in the Łeba Elevation area.

LIMESTONE FACIES

A great abundance of the fossil remains of trilobites, brachiopods, bryozoans, crinoids, gastropods, ostracods and conodonts has been observed in the marly micrites of the organodetrital limestone formation (Figs 2, 4, 7). This suggests conditions favourable to the development of benthonic organisms in well-oxygenated and rich in food waters near to the sea bottom. The organic fossil remains are in most cases strongly fragmentary, sometimes with a streaky arrangement, reasonably indicating that this area of the marine bottom probably existed above the wave base.

The latest opinions (Barnes & Fåhraeus 1975, Fåhraeus & Barnes 1975) postulate that the taxonomic composition of the conodont assemblage in a given deposit may also be made responsible for the environment of sedimentation. A connection has, namely, been noted of certain conodont taxons with definite rocks formed in a definite zone of the marine basin.

With a preference for the necto-benthonic regime of life of most conodonts Fåhraeus and Barnes have differentiated in the Ordovician of the North-Atlantic province several conodont biofacies changing in dependence from the off-shore distance and on the depth of the sea basin. Among samples from the investigated profiles of the Łeba region none has yielded a conodont assemblage characteristic of one biofacies. Still, the *Eoplacognathus-Baltoniodus* Llanvirnian assemblage indicates a shallower part of the sublittoral zone (Fåhraeus 1966) while the observed elements of the *Periodon-Microozarcodina* assemblage are characteristic of a somewhat deeper part of the sublittoral zone farther removed from the shore.

It is hardly possible to account for the origin of the nodular structure encountered here and there in the complex of the organodetrital limestones because various, simultaneously acting factors may contribute to the formation of this type of limestones. The action of the sea-bottom waters seems quite probable; it leads to the formation of soft pebbles, resulting from the scouring of not fully consolidated calcareous layers. The scouring of freshly laid down deposit similarly as the presence of strongly fragmentary organic fossil remains would reasonably suggest sedimentation in an environment above the wave base. The action of a mechanic agent may also be reasonably suggested by traces of the corrosion of organic remains (brachiopod shells and fragments of trilobite carapaces) encountered on the boundary of some nodules and marly streaks (Pl. 1, Fig. 2; Pl. 20, Fig. 1).

In summing up the above information it may be observed that in the Llanvirnian the sedimentation of deposits of the organodetrital limestone formation in the Łeba Elevation occurred in a sublittoral environment, within a relatively shallow mobile basin, above the wave base, in well oxygenated and rich in food waters. This is supported by the abundance of organic remains, chiefly those of benthos (*cf.* Figs 2, 4, 7; Pl. 19, Figs 1—2; Pl. 20, Figs 1—2; Pl. 21, Figs 1—2; Pl. 22, Figs 1—2). However, an analysis of the deposits has not provided adequate data to determine the absolute values, expressed in metres, of the depth at which they had been formed.

GRAPTOLITE BLACK SHALE FACIES

The deposits of the next differentiated formation decidedly differ from the underlying deposits of the carbonate facies. Claystones, marly in the bottom, with rare thin intercalations of limestones and marly claystones higher up the complex (*cf.* Figs 2—9) replace the organodetrital limestones with features of a deposit formed in a mobile environment. Along with the change in character the deposit also change its colour from a light-grey into dark-grey practically black.

The sudden change in the character of the deposit does not, by any means, indicate a sudden change in the environment of sedimentation. As has already been suggested the accumulation of deposits of the organodetrital limestone formation and that of the graptolitic claystone formation is probably separated by break in sedimentation or at least a time of strongly retarded deposition resulting in the condensation of the deposit. A strong slowing down of the rate of sedimentation in the uppermost Llanvirnian and Lower Llandeilian (*cf.* Table 10) is indicated by the presence of phosphates observed in the profiles Piaśnica 2, Dębki 3 and Łeba 8 within the marly claystone member (Figs 2, 4, 6, 10; Pl. 23, Figs 1—2; Pl. 24, Fig. 2) as well as by the great accumulation of fossil remains in these deposits.

The change in lithofacies at the boundary of the two formations is correlated with a distinct change in the biofacies. Namely, in the graptolitic claystone formation the main fossil group is represented by planktonic forms (Figs 2—9), while benthonic and nectonic organisms are but of minor importance in the composition of the taphocoenosis.

PLANKTON

Graptolites belonging to the order of Graptoloidea are the dominant group among the planktonic organisms. According to the latest opinions the Graptoloidea — throughout their life or at a certain period of astogenetic development — led a non-active mode of life as plankton or pseudoplankton, or perhaps as an autoplankton actively mobile in the sea waves (Bulman 1964; Erdtmann 1973, 1976a; Kirk 1969).

While marine zones lying on the edge of a shelf and the continental slopes (hemipelagic and pelagic zones) are the optimal life environment for graptolites, black clay shales being the deposits of the occurrence of the most abundant and strongly differentiated of their assemblages, they are encountered also in other, practically all the known lithological types.

Similarly as in the case of some benthonic organisms a dependence has been noted — within a definite zoogeographic province — of certain Graptoloidea taxons on definite facies, and, on the other hand, the independent active movements of at least some of the species. These characters have become a basis for speculations on the possible adaptability of certain graptolite assemblages to definite environments, differing in their distance from the sea shore and in bathymetric conditions (Berry 1977, Erdtmann 1976a). Our state to knowledge on the distribution of the Graptoloidea suggests that at least some graptolites were closely connected with definite water masses or with waters above the specific types of environmental sedimentation. Such suggestions interpret the presence or absence of certain graptolites within certain areas or within definite faunal associations. Thus, for instance, representatives of the genera *Dicellograptus* and *Dicranograptus* are known foremost from deposits whose formation probably occurred on the edge of a shelf or of a continental slope.

Erdtmann (1976a) was one of the first to attempt the presentation of the dependence of various graptolite assemblages on definite sedimentary environments. He has differentiated three graptolite biofacies in the Ordovician, dependent on the depth of water in the sedimentary basin. Erdtmann's model is analogous with that worked out for conodonts, accepting their planktonic mode of life (Druce 1973; Seddon & Sweet 1971). Both of them are based on the adaptation of definite taxons to certain bathymetric zones in the ocean.

The bathymetric model worked out for the planktonic graptolites is only a hypothetical attempt at interpreting the uneven distribution in the deposits of the various graptolite taxons and it may arouse uncertainties with regard, for example, to the nutrient sources for graptolite assemblages existing in deeper ecological niches.

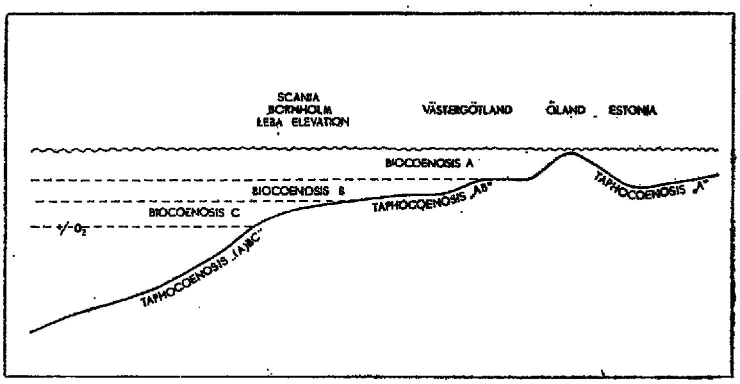


Fig. 11. The hypothetical model of the vertical distribution of the graptolitic biofacies in the Ordovician of Baltoscandia (on Erdtmann's 1976a, Fig. 1, bathymetric pattern for planktonic graptolites, supplemented by the writer), showing the interdependence of definite biocoenoses, their taphocoenoses and the particular zones of the sea basin

The model presented by Erdtmann (Fig. 11) suggests that the composition of the taphocoenosis is decidedly dependent on the zone of the sea bottom where the sedimentation occurred simultaneously with the burying by the deposit of the extinct graptolitic rhabdosomes.

An analysis of the graptolite assemblage observed in the Llandeilian and Caradocian deposits on the Łeba Elevation and a comparison of their composition with the taxonomic composition of the taphocoenoses differentiated by Erdtmann show the occurrence in the investigated deposits of the "A/BC" type of taphocoenosis. Hence, in accordance with Erdtmann's hypothesis, the Middle and Upper Ordovician graptolitic deposits of the Łeba region seem to have formed on the edge of the shelf or on its slope (*cf.* Fig. 11). It seems, however, that no conclusive and doubtless suppositions may be advanced on the paleontological analysis relative to the sedimentary environment of these claystones. That this is so is supported by the existence — especially in the mobile environment of the post-mortem transport of rhabdosomes — of certain events, also by the uneven chances for complete burial of certain biocoenoses in the deposits (the surface-water community "A" has the smallest chance, because of the destruction by currents, waves and bacterial or detritus-feeding activities).

In some areas, however, it is possible to observe the sequence of bathymetrically controlled biofacies in the Ordovician deposits. For example, in Great Britain, from eastern England across Wales to the Lake District and south Scotland there occurs a change in the sedimentary environments from shallow-water ones to eugeosynclinal. A similar sequence is observable in the Baltoscandia area where — from the island of Öland across Västergötland as far as Oslo, Scania and Bornholm — the deposits assume a gradually more and more pelagic character with a consequent change in the graptolite assemblages (Erdtmann 1976a).

A comparison of the taxonomic composition of graptolites from the Łeba Elevation with that from other areas of the Baltoscandia reasonably suggests that it bears the strongest resemblance to the graptolite assemblages in Scania (Fågelsång) and Bornholm (Väsagärd) (*cf.* Bergström & Nilsson 1974; Berry 1964; Glimberg 1961; Hadding 1913, 1915b; Hede 1951; Lindström 1953; Nilsson 1953, 1960). Some taxons, however, occurring in the Łeba region, such as *Climacograptus kuckersianus* Wiman, *Glyptograptus cernuus* Jaanusson have, so far, been known only from the shallow-water limestones of Estonia and Sweden (Jaanusson 1960). The graptolite assemblage from the Łeba Elevation also shows a great taxonomic likeness with assemblages known from Wales and Scotland (*cf.* Elles & Wood 1903—1907; Toghill 1970). Outside of Europe, the greatest number of species in common with those from the Łeba area occur in the Caradocian assemblage from the central part of New Foundland (Erdtmann 1976) within the area of the Basin Ranges in the state of Nevada and California (Ross & Berry 1963), from the area of Kazakhstan (Tsai 1976) and Taimyr (Obut & Sobolevskaya 1964). It should be noted that in all regions here mentioned graptolites occur in a similar type of deposits, namely in black shales or claystones.

The second characteristic fossil group occurring together with graptolites is represented by minute, thin-shelled non-articulate brachiopods (Pl. 18, Figs 1—13). Their distribution in the particular profiles is shown in Tables 2—9. This fauna is usually associated with the Ordovician and Silurian graptolites in the typical black shales facies. The side-by-side occurrence suggests similarity in the mode of life and adaptation to the same environment. Most probably these brachiopods led an epiplanktonic mode of life, floating automatically on the water surface attached to sea weeds (Bergström 1968; Havlíček 1967; Spjeldnaes 1967).

Another opinion postulates that these brachiopods led a benthonic mode of life (Sheehan 1977).

BENTHOS

The benthonic organisms are of a minimum importance in the composition of the fauna occurring in the graptolitic claystone formation suggesting conditions unfavourable to their development. Their greatest number has been encountered in the marly claystone member differentiated in the lower part of the formation (*cf.* Figs 2, 4). Ostracods are here the dominant group, along with some few articulate brachiopods. In the residuum after the solution of the rock in hydrofluoric acid some few trilobites have been found (possibly the remains of planktonic trilobites), also single gastropods, bryozoans and conodonts which are now currently regarded as nectobenthonic organisms (Barnes & Fåhraeus 1975).

In the black non-calcareous claystones of the higher part of the formation, however, the number of benthonic organisms is quite sub-ordinate. Microscopic observations have shown the presence of single ostracods and articulate brachiopods (Pl. 26, Fig. 2). Representatives of the genus *Lingula* are more numerous; the lingulids of to-day are known for their adaptability to low-oxygen environments (Paine 1970).

The characteristic features of the faunal assemblage present in the deposits of the graptolitic claystone formation and the lithological characters presented above reasonably suggest a number of conclusions regarding the conditions of their sedimentation.

The presence of marly claystones and of marls with a poorly differentiated but undoubted benthonic fauna in the bottom part of the graptolitic claystone formation indicates the continuation into the Llanvirnian and Lower Llandeilian of conditions favouring the existence of sessile organisms. The black colouration of the deposit, however, indicates a great oxygen deficiency in the near-to-the--bottom zone as compared with the conditions of sedimentation of the organodetrital limestones in the lower part of the Llanvirnian.

The prevalence during the sedimentation of these claystones of abiotic conditions near to the bottom of the sedimentary basin is suggested by the following facts: absence in the non-calcareous claystones of a rich in numbers and well differentiated assemblage of benthonic organisms, the absence of any traces of bioturbation resulting in the preservation of the primary micro-textures (f.i. of parallel flat lamination, Pl. 25, Fig. 1); first of all the presence of planktonic organisms. The dark colouration of the deposit due to non-oxidised organic substance reasonably indicates that the life conditions unfavourable to organisms were most probably connected with the oxygen deficiency of the near-to-the--bottom zone of the sedimentary basin. This is likewise indicated by the presence of lingulids today adapted to low-oxygen environments.

Anoxic conditions near to the bottom and below the surface of deposits may perhaps be connected with the lack of free water circulation, both vertically and horizontally. This would hinder the mixing of the well oxygenated surface waters with the poorly oxygenated or anoxic bottom waters. In Byer's opinion (1977, 1979) the existence of morphological barriers in the ocean and the density stratification of waters produced by a salinity gradient provide conditions favouring the formation of stagnant basins. However, anoxic conditions in the near-to-the-bottom zone and in the deposit may occur without isolation of the sedimentary basin or limited water circulation if the quantity of oxygen dissolved in water is not sufficient for oxidation of organic matter accumulated on the sea floor. A study of the present basins characterized by oxygen deficiency has shown that the 0.1 ml/l or smaller oxygen content will be responsible for abiotic conditions in the near-to-the-bottom zone (Rhoads & Morse 1971). Neither is the development of benthonic fauna favoured by abundant residuum in water above the bottom of the basin.

The absence or scarcity of benthonic organisms as observed in the dark claystones reflect the specific chemical conditions prevailing during the accumulation of these deposits but do not permit the drawing of any conclusions whatever as to the depth of the sedimentary basin.

The thin intercalations of marly claystones and limestones with the scanty benthonic fauna, occurring in the higher parts of the graptolitic claystone formation may suggest a brief pulse of oxygenated water. The result of such a flow might be short-living, very poorly differentiated benthic communities. The life--source of the single benthonic forms observed in laminated, non-calcareous claystones may be sought for in well aerated bottom zones, abounding in food and inhabited by benthonic organisms. Because of the satisfactory state of preservation of these fossils (absence of abrasion, complete shells and absence of any traces of roundness; Pl. 26, Fig. 2) it may reasonably be supposed that these zones were most probably situated not far from the burial site of the fossil remains here considered.

The tuff and bentonite intercalations observed in the graptolitic claystone formation indicate intensified volcanic activity in the adjacent areas. The position of volcanoes as well as their distance from the site of deposition of volcanic dusts, have not, so far been undoubtedly determined.

According to the most recent opinions it has been accepted that the alimentation area of the piroclastic rocks may have been situated in the area of the Protoatlantic Ocean (Bergström & Nilsson 1974).

MARLY FACIES

The transition from the black claystones with a pelagic fauna to the grey clay-carbonate deposits with a benthonic fauna was gradual; nevertheless it probably indicates a slow shallowing of the sedimentary basin (Tomczykowa & Tomczyk 1970) and, foremost, an important change in the chemical conditions within its part here considered, consisting in the disappearance of anoxic conditions in the near-to-the-bottom zone. Yet, the absence of the traces of wave action and of the activity of currents in theh marly formation reasonably suggests the persistance of a calm sedimentation within the zone below the wave base, similarly as during the accumulation of graptolite yielding claystones.

The benthonic fauna occurring in marls, marly claystones and marly micrites is represented by a rather monotonous assemblage of articulate brachiopods and trilobites. In this assemblage there occur numerous species in common with the "Hirnantia" fauna. The latter is regarded as a shallow-water assemblage because of the frequent association with typically littoral deposits, such as oolitic or reef limestones (Wright 1968).

The presence in the higher part of the marly formation of single grains of detrital quartz and feldspars indicates the supply into the sedimentary basin of terrigenous material. The gradual increase to the top of the profile of the detrital quartz content may suggest the growing intensity of erosion during the Upper Ashgillian. The sandy and clayey-micritic laminae (Pl. 27, Fig. 2), interdigitating and mutually pinching out, so often encountered in the top of the formation, indicate periods of increased terrigenous material supply separated by times of calmer sedimentation. The poorly sorted grains and their various roundness (rounded or poorly rounded grains occurring along with an abundance of angular ones) may perhaps suggest transport from not too distant a site.

The presence of sandy material in the top of the Ordovician reflects erosion in the alimentary field connected with the Taconian phase of Caledonian orogeny (Tomczykowa & Tomczyk 1976).

The occurrence above the marly or sandy limestone of black clayey deposits with a Silurian pelagic fauna indicates the return of anoxic conditions of sedimentation, probably in a deeper marine basin.

THE PALEOGEOGRAPHIC POSITION IN THE ORDOVICIAN OF THE INVESTIGATED AREA

During the Ordovician the area of the Łeba Elevation was part of an epicontinental basin covering a broad area to the east and south east of the Scandinavian branch of the Caledonian geosyncline (Jaanusson 1973, 1976). To the east this basin was most probably connected with the Moscow basin (Alikhova 1969). To the south the sediments laid down within the same epicontinental basin are known from the north-eastern part of Poland. Thin, most likely littoral, Ordovician deposits are encountered in Podolia and Moldavia (Sokolov 1961; Tsegelnjuk 1969).

Variously developed deposits of the sublittoral and littoral facies zones are known from Sweden, Lithuania and Estonia. The northern and eastern boundaries of the occurrence of Ordovician deposits on the East-European Platform are erosional. In this connection a reconstruc-

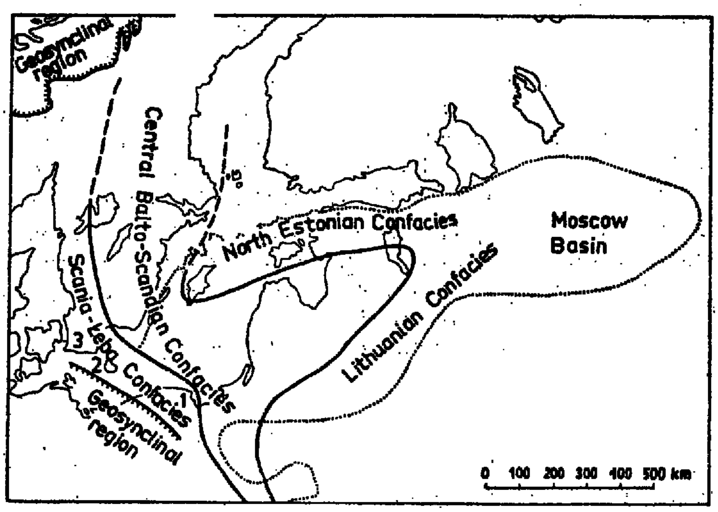


Fig. 12. Map showing approximate boundaries of the Ordovician confacies belts in the Baltoscandian region (after Jaanusson 1976, modified)
1 — Łeba Elevation, *2* — Bornholm, *3* — Scania

tion of the range of the epicontinental Ordovician sea in this area presents major difficulties.

A number of sub-meridionally directed confacies belts (Fig. 12) has been differentiated in this basin, characterised by litho- and biofacies peculiar for the particular belt. They reflect the specific sedimentary conditions dependent on paleogeographic factors, the distance from the shore and their thickness.

An analysis of the litho- and biofacies in the Middle and Upper Ordovician strata of the Łeba Elevation indicates strong similarities between the development of this region and that of Scania and Bornholm. A similar type of sediments, namely a distinct predominance of the clay deposits over the carbonate ones, as well as the resemblance in paleontology, reasonably suggest that in the areas of the Łeba Elevation, Scania and Bornholm sedimentation occurred under similar conditions in the same Scania-Łeba confacies belt of an epicontinental marine basin. This belt corresponding to a deep-neritic part of the sea, was characterised by important quantities of terrigenous material in the sediments as compared with those confacies belts of the epicontinental sea lying farther east (Fig. 12).

The small thickness of the Ordovician sediments within the Scania--Łeba confacies belt, ranging from a. 120.0 m in Scania, a. 20.0 m in Bornholm and a. 80.0 within the area of the Łeba Elevation, suggests a slow rate of sedimentation.

On the other hand, the Ordovician deposits accumulating at a small distance from the Scania-Łeba confacies belt to the west and north-west are characterized by considerably greater thickness and by the predominance of siltstones, greywackes and conglomerates typical of the geosynclinal part of the marine basin (Fig. 12). This type of sediments has, i.a, been observed in Rugia (Jaeger 1967), and in the Koszalin--Chojnice region (Bednarczyk 1974, Modliński 1968).

An increase in the clastic deposits and in their thickness westward of the Łeba region suggest that the alimentation area of the terrigenous material lay west of the Scania-Łeba also of the Koszalin-Chojnice and Rugia regions. Areas lying nearer to the site of erosion were a sedimentation zone of conglomerates, greywackes and siltstones, while the most finely grained material represented by clay sediments was deposited in regions farther east.

A part of the basin lying east and south-east of the Scania-Łeba confacies belt was characterized chiefly by the sedimentation of carbonate deposits developed as limestones bearing an abundance of benthonic fossil remains. This part of the sea, known as the "central Baltoscandian confacies belt" (Jaanusson 1976), corresponding to the Swedish-Latvian facies zone sensu Männil (1966), occupied most of the mainland of Sweden (Jaanusson 1973), the north-eastern part of Poland (Modliński 1973) and stretched farther east across Lithuania and southern Estonia (Männil 1964, 1966) (Fig. 12). The type of sediments and the character of the fauna suggest that this belt represented a shallow-neritic part of the marine basin. To the north, the east and the south of the central Baltoscandian confacies the sediments are typical of the littoral part of the marine basin with a predominance of organodetrital and organogenous limestones and frequent oolithic deposits.

A comparison of the development of the middle and upper Ordovician in the Łeba region with those i.a. described by Tomczyk (1957, 1959), Tomczyk & Turnau-Morawska (1964, 1967), and by Bednarczyk (1971) deposits of the same age occurring in the Holy Cross Mts shows many similarities in the type of sedimentation and composition of fauna.

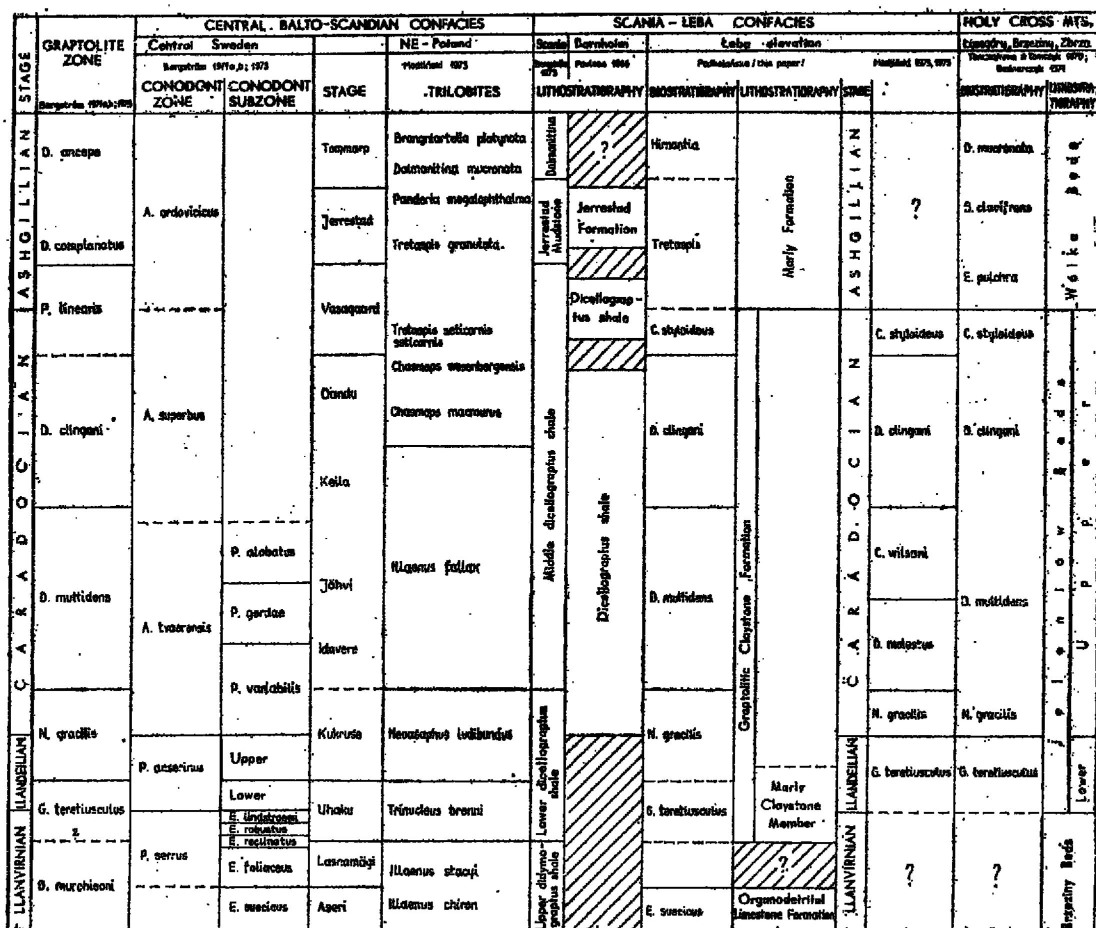


Table 11

Correlation of Middle and Upper Ordovician sequences in the Scania-Łeba confacies belt with other regions of Baltoscandia and Holy Cross Mts

Remarkably noticeable resemblance is observable in the facial development of the middle and upper Ordovician of the Łeba Elevation and that in the Łysogóry region and the Brzeziny and Zbrza areas of the Holy Cross Mts. Black claystones with graptolites formed there during the Llandeilian and the Caradocian allowing their correlation with the sediments of the Scania-Łeba confacies co-equal in age. The stratigraphy of the Middle and Upper Ordovician deposits within the Scania--Łeba confacies and their correlation with selected areas of the central Baltoscandian confacies and of the Holy Cross Mts is shown in Table 11.

As is shown by investigations within the Scania-Łeba confacies certain differences are observable in the development of the Ordovician deposits (*cf.* Table 11). In Scania the Llanvirnian is represented by clay, graptolite-bearing deposits, referable to the so called Upper Didymograptus Shale. Simultaneously, at the Łeba Elevation there formed carbonate deposits with abundant organic detritus, analogously as in the central Baltoscandian confacies.

As compared with the continuous Ordovician profile of Scania, in the Upper Llanvirnian deposits of the Łeba Elevation there probably occurs a stratigraphic lacuna observed in some profiles of this area and including the upper part of the Didymograptus murchisoni Zone. A broader stratigraphic lacuna has been observed in Bornholm (Poulsen 1966) including the Llanvirnian and Llandeilian strata (as far as the Nemagraptus gracilis Zone, *cf.* Table 11).

Thus, during the Ordovician the Łeba area was a region intermediate between the Scania area, the most stabile one and characterised by continuity of sedimentation, and Bornholm which represented a zone of the marine basin affected by the strongest uplifting movements.

FINAL CONCLUSIONS

1. A similar facial development of the Middle and Upper Ordovician deposits has been observed in all the profiles of the Łeba Elevation here discussed.

2. Facial development resemblance has permitted the differentiation of three basal lithostratigraphic units: the organodetrital limestone formation, the graptolitic claystone formation and the marly formation. These units represent the three chief deposit types containing their corresponding faunal assemblages.

3. A detailed analysis of the differentiated lithostratigraphic units and faunal assemblages has led to the reconstruction of the environments of sedimentation prevailing during the Middle and Upper Ordovician in that part of the sea basin.

a. The available lithological and paleontological data suggest that sedimentation of the organodetrital limestone formation occurred in a sublittoral environment, in a relatively shallow and mobile basin above the wave base.

b. The sedimentation of the graptolitic claystone formation, differing in lithology and paleontology, separated from the foregoing formation by a stratigraphic break or by a time of marked slowing down of the sedimentary rate, occurred in a zone below the wave base under anoxic conditions prevailing near to the bottom and below the surface of the deposit.

c. The features of the marly formation reasonably suggest the continuation of calm sedimentation within the zone below the wave base but within the well oxygenated zone. The sandy character of the deposit observed in the top of the formation indicates intensified vertical movements within the alimentation area referable to the Taconian phase of the Caledonian orogeny.

4. The biostratigraphic analysis was the basis for determining the age of the differentiated lithostratigraphic units and for a more precise division of the Middle and the Upper Ordovician represented by the following eight zones: Eoplacognathus suecicus, Glyptograptus teretiusculus, Nemagraptus gracilis, Diplograptus multidens, Dicranograptus clingani, Climacograptus styloideus, also Tretaspis and Hirnantia.

5. The correlation of the investigated Ordovician profiles of NW Poland with similarly developed deposits of Scania and Bornholm has allowed to determine the genetic connections of the above areas resulting from a resemblance in development of the Scania-Łeba confacies belt stretching along the edge of the shelf.

6. Because of the high content of the clay lithofacies in the Middle and Upper Ordovician profiles from the Łeba region graptolites are most important in the stratigraphy of these profiles. Their paleontological descriptions and photographic documentation in the present paper are the first to be presented in Poland.

It might also be stressed that a considerable number from among the 60 graptolite species and subspecies here differentiated have not so far been reported in the Polish geological literature.

PALEONTOLOGY

MATERIAL, PROCEDURE, TERMINOLOGY

The paleontological part of this paper contains descriptions of selected graptolites differentiated in the profiles under investigation within the Łeba Elevation. Because of their great importance for the stratigraphy of the Ordovician deposits in this region all of the differentiated taxons have been figured (Pl. 1—15). Sixty species and subspecies belonging to 17 genera have been differentiated from among the c. 2,000 specimens selected for investigation. Species so far not known from Poland, stratigraphically important taxons or those interesting from the taxonomic point of view are being described. In the case of commonly known species the descriptions are limited to synonymics, remarks and comparisons with other taxons or no descriptions are given.

Within the Łeba Elevation graptolites occur in darkgrey, black and greenish claystones and marly claystones. Most of the specimens are compressed and have a preserved periderm. Not compressed or preserved in semi-relief graptolites have been encountered but such findings are very rare indeed.

Fusellar structure may sometimes be seen on the compressed specimens. Unflattened rhabdosomes are usually impregnated by pyrite; such forms have resulted from the infilling of the empty places of the graptolite colony by a clayey deposit with a high content of sulphides which had crystallised before the compression of the rhabdosome. The crystallising process caused the exclusion of the periderm the rhabdosome of this kind being preserved as an interior cast.

A part of the specimens is complete, more often, however, the forms represent various fragments of the rhabdosome. Such a preservation of the graptolites limits a detailed analysis of their morphology.

The taxonomic classification and the terminology used in the descriptions of graptolites is that commonly accepted in the paleontological descriptions of this group (Bulman 1970).

In order fully to characterise the faunal assemblage, most of the trilobites and articulate and non-articulate brachiopods occurring in the Middle and Upper Ordovician deposits here considered have been indicated and figured in plates 16—18. The paleontological descriptions and photographs of conodonts and Chitinozoa have been given in the writer's previous papers (Podhalańska 1978, 1979). The stratigraphic range of all the species figured in the present paper are shown on the tables.

DESCRIPTION OF GRAPTOLITES

Genus *DICRANOGRAPTUS* Hall, 1865

Dicranograptus ziczac Lapworth, 1876
(Pl. 3, Fig. 6; Pl. 4, Fig. 3)

1876. *Dicranograptus ziczac* sp. nov.; Lapworth, Pl. 3, Fig. 77.
1904. *Dicranograptus ziczac* Lapworth; Elles & Wood, p. 177—179, Fig. 113, Pl. 25, Fig. 3a—d.
1938. *Dicranograptus ziczac*; Harris & Thomas, p. 72, Pl. 3, Fig. 85.
1964. *Dicranograptus ziczac* Lapworth; Obut & Sobolevskaya, p. 47—48, Pl. 8, Figs 3—5.

Material. — c. 50 rhabdosome fragments, all flattened.

Description. — Rhabdosome consists of a very short biserial part and two characteristically bent uniserial branches. Length of biserial part 2.0—3.0 mm, width 0.7—0.9 mm. Shape of thecae poorly visible: in biserial part free ventral walls of thecae bearing thin thecal spines (Pl. 4, Fig. 3); proximal end rounded, terminating in a thin virgella 0.3 mm long. Course of the uniserial parts of rhabdosome greatly varied, dependent on course of compression, but always very characteristic. First two uniserial parts of rhabdosome branch at an angle of 160—180°, to change their course at a few mm from the point of branching mutually approaching again (Pl. 4, Fig. 3). Width of uniserial parts constant and even all along the length 0.65 mm.

Remarks. — The figured specimens do not differ from the typical representatives of the species *Dicranograptus ziczac* Lapw. The characteristic curving of the uniserial parts of the rhabdosome is most usually repeated two or three times.

Occurrence. — Lower Caradocian, Nemagraptus gracilis — Climacograptus peltifer Zones of Great Britain (Elles & Wood 1904, Lapworth 1876, 1878), North America (Ruedemann 1947), Australia (Harris & Thomas 1938; Thomas 1960), USSR — Tajmyr (Obut & Sobolevskaya 1964). So far this species had not been known in Poland. The Łeba Elevation: Mieroszyno 8 profile (depth 2813.0—2812.0 m); Nemagraptus gracilis Zone.

Genus *DICELLOGRAPTUS* Hopkinson, 1871

Dicellograptus caduceus Lapworth, 1876
(Pl. 3, Fig. 4)

1904. *Dicellograptus caduceus* Lapworth; Elles & Wood, p. 161—163, Fig. 102a—c, Pl. 23, Fig. 4a—c.
1964. *Dicellograptus caduceus* Lapworth; Obut & Sobolevskaya, p. 36, Pl. 4, Figs 4—5.

Material. — One flattened specimen.

Remarks. — In the shape of the rhabdosome, and particularly in the characteristically bent stipes *Dicellograptus caduceus* Lapw. resembles *Dicellograptus intortus* Lapw. These two species differ, however, in the shape of thecae. Namely in *Dicellograptus intortus* Lapw. the thecae are with straight free ventral walls, while in *Dicelograptus caduceus* Lapw. the analogous walls are consicuously curved and apertures markedly introverted and introtorted.

The specimen described from the Łeba Elevation is characterized by its dimensions being smaller than the forms cited by Elles & Wood (1904) and by Obut & Sobolevskaya (1964).

Occurrence. — Lower Hartfell Shales/Dicranograptus clingani Zone of Great Britain (Elles & Wood 1904); Middle and Upper Caradocian of Australia and eastern Tajmyr (Obut & Sobolevskaya 1964). The Łeba Elevation — Łeba 8 profile (depth 2671.8—2670.8 m); Dicranograptus clingani Zone.

Dicellograptus divaricatus salopiensis Elles & Wood, 1904
(Pl. 2, Fig. 4; Pl. 6, Fig. 5)

1904. *Dicellograptus divaricatus* var. *salopiensis, var. nov.*; Elles & Wood, p. 145—146, Fig. 86a—b, Pl. 20, Fig. 7a—c.
1947. *Dicellograptus divaricatus* var. *salopiensis* Elles & Wood; Ruedemann, p. 380, Pl. 63, Figs 2—3.
1963. *Dicellograptus divaricatus* var. *salopiensis* Elles & Wood; Ross & Berry; p. 104—105, Pl. 6, Figs 21, 24.
1964. *Dicellograptus salopiensis* (Elles & Wood); Obut & Sobolevskaya, p. 41, Pl. 6, Fig. 7.
1976. *Dicellograptus salopiensis* (Elles & Wood); Tsai, p. 19, Pl. 1, Fig. 12.

Material. — 2 specimens.

Remarks. — The rhabdosomes known from the Łeba Elevation are analogous with those described as *Dicellograptus salopiensis* Elles & Wood occurring in Kazakhstan (Tsai 1976) and Tajmyr (Obut & Sobolevskaya 1964). Because of the slight morphological differences between *Dicellograptus divaricatus divaricatus* (Hall) and *Dicellograptus salopiensis* Elles & Wood (sensu Obut & Sobolevskaya 1964), in the present paper the latter taxon has been recognised as not being a separate species but, following the original taxonomic classification (*cf.* Elles & Wood 1904) it is the *Dicellograptus divaricatus divaricatus* (Hall) subspecies.

Occurrence. — The species *Dicellograptus divaricatus salopiensis* Elles & Wood occurs in the Lower Caradocian deposits (the Nemagraptus gracilis and Climacograptus peltifer Zones in Great Britain, Elles & Wood 1904). In North America it was cited from the N. gracilis and C. bicornis Zones (Berry 1960). In the USSR it occurs in the N. gracilis Zone of Tajmyr and in the Erkebidaik Stage (Lower Caradocian) of Kazakhstan (Tsai 1976). Within the Łeba Elevation it has been found in the Piaśnica 2 profile (depth 2645.3—2644.3 m), in the Nemagraptus gracilis Zone.

Dicellograptus johnstrupi Hadding, 1915
(Pl. 3, Figs 2, 3, 5)

1915a. *Dicellograptus johnstrupi* n. sp.; Hadding, p. 24, Pl. 3, Figs 12—18.
1948. *Dicellograptus johnstrupi* Hadding; Henningsmoen, p. 401—402, Fig. 2.
1963. *Dicellograptus johnstrupi* Hadding; Skoglund, p. 32—33, Pl. 1, Figs 4—8.

Material. — A dozen or so of flattened specimens, a few preserved as exterior casts; 8 fragmentary rhabdosomes preserved in semi-relief.

Description. — Both, distal and proximal parts of the rhabdosome, often with the sicula extinct, found in the material here investigated. In the figured specimen (Pl. 3, Fig. 5) the sicula is 1.5 mm long. Free ventral walls proximally slightly sinusoidal, apertural excavations semi-circular, introverted. Thecae 1^1—1^2 with short thecal spines, slightly below the apertures. Free ventral walls of distal thecae more straight with apertural margin not so introverted; 9—10 thecae in 10.0 mm. Free ventral walls of proximal thecae roughly 0.8 mm in height, that of distal thecae 0.9—1.0 mm.

Remarks. — The above species resembles *Dicellograptus complanatus* Lapworth; it has been accepted as the direct ancestor of *Dicellograptus complanatus* Lapworth (Skoglund 1963). Morphological differences mostly conspicuous in the distal part. *D. johnstrupi* Hadding is namely with more convex free ventral walls of distal thecae. The inter-stipe angle is likewise higher in *D. johnstrupi* Hadding than in *D. complanatus* Lapworth.

Occurrence. — The Upper Caradocian — in the Fjäcka Formation of the Västergötland region (Sweden), the Pleurograptus linearis Zone of Bornholm (Skoglund 1963). *Dicellograptus* cf. *johnstrupi* is likewise cited from deposits of the Climacograptus styloideus Zone in Northern Poland (Modliński 1971).

The Łeba Elevation: Białogóra 2 profile (depth 2614.2—2612.2 m), Dębki 2 profile (depth 2597.2—2595.7 m); Upper Caradocian — the Climacograptus styloideus Zone.

Dicellograptus vagus Hadding, 1913
(Pl. 2, Fig. 6)

1913. *Dicellograptus vagus* sp. nov.; Hadding, p. 53—55, Pl. 4, Figs 15—19.
1964. *Dicellograptus vagus* Hadding; Berry, p. 120—122, Pl. 10, Figs 3—4.

Material. — 1 specimen.

Description. — Rhabdosome small, stipes 1.3 mm long, with width equal to 0.7 mm. This width is constant throughout the rhabdosome length. Proximally (to the level of 5^1—5^2 thecae) the stipes enclose a 35-degree angle then to grow higher up to 85 degrees. Thecae with slightly convex free ventral walls 0.72 mm in height. Apertural margin somewhat concave, apertures inside pouch shaped excavations; the thecae number 11 in 10 mm. Sicula not extinct. Virgella short, 0.5 mm in length. Thecae 1^1 and 1^2 bearing short thecal spines.

Remarks. — The figured specimen shows many features in common with representatives of this species known from Sweden (Hadding 1913) and Norway (Berry 1964). The species *Dicellograptus vagus* Hadding resembles *Dicellograptus smithi* Ruedemann; differing in somewhat fewer thecae in 10 mm there being 10—11/10 mm in *D. vagus* and 14/10 mm in *D. smithi*. Distally in *D. vagus* the stipes enclose a higher angle, too.

Occurrence. — The Llandeilian — Glyptograptus teretiusculus Zone of Norway and Sweden (Hadding 1913, Berry 1964). The Łeba Elevation: Białogóra *1* profile (depth 2673.1—2672.1 m); the Nemagraptus gracilis + Glyptograptus teretiusculus Zones.

Genus *NANOGRAPTUS* Hadding, 1915

Nanograptus cf. *lapworthi* Hadding, 1915

(Pl. 5, Figs 5—6, 9)

Material. — 30 specimens representing various ontogenetic stages.

Remarks. — The figured specimens strongly resemble representatives of the species *Nanograptus lapworthi* Hadding described and figured by Hadding (1915b). The specimen figured in Pl. 5, Fig. 6 represents the juvenile stadium of ontogenetic development (*cf.* Hadding, Pl. 6, Figs 4—5); the specimens figured in Pl. 5, Figs 5, 9 represent the passage and mature stadia respectively of ontogenetic development (*cf.* Hadding, Pl. 6, Figs 6—9).

Occurrence. — Lower Caradocian (Hadding 1915b). The Łeba Elevation: Białogóra *1* profile (depth 2675.6—2673.1 m); the Glyptograptus teretiusculus + Nemagraptus gracilis Zones.

Nanograptus cf. phylloides (Elles & Wood, 1908)

(Pl. 5, Fig. 4)

Material. — Several fragmental flattened rhabdosomes.

Description. — Species containing small specimens, rounded in shape. The specimen figured here is 2.0 mm long and 1.9 mm wide. The complete rhabdosome consists of 5 pairs of thecae. The apertures of two first thecae dipping downward, the remaining ones gradually taking on a horizontal course, the distal thecae (5^1—5^2) being directed upwards. Sicula very long, virgella well pronounced.

Remarks. — The specimens encountered in the Łeba region have many features in common with representatives of this species described by Elles and Wood (1908), also by Hadding (1915b). They differ from *Nanograptus lapworthi* Hadding in being roundly shaped.

Occurrence. — The Nemagraptus gracilis Zone of Great Britain (Elles & Wood 1908, Hadding 1915b). The Łeba Elevation: Białogóra *1* profile (depth 2675.6—2673.1 m); the Glyptograptus teretiusculus + Nemagraptus gracilis Zones.

Genus *DIPLOGRAPTUS* M'Coy, 1850

Diplograptus multidens Elles & Wood, 1907
(Pl. 6, Fig. 3; Pl. 11, Fig. 1)

1907. *Diplograptus (Mesograptus) multidens* sp. nov.; Elles & Wood, p. 261—262, Pl. 31, Fig. 9a—d, Fig. 178,
1960. *Diplograptus multidens* Elles & Wood; Berry, p. 85, Pl. 16, Fig. 2; Pl. 19, Fig. 6.
1964. *Diplograptus multidens* Elles & Wood; Obut & Sobolevskaya, p. 62—63, Pl. 12, Figs 11—15.

Material. — 15 flattened rhabdosomes, with the predominance of forms representing the juvenile stadium of ontogenic development.

Remarks. — The specimens here examined do not differ from the typical representatives of the species *Diplograptus multidens* Elles & Wood described from Great Britain by Elles and Wood (1907) or from the American forms (Berry 1960). From *Diplograptus preamultidens* Obut & Sobolevskaya they differ in greater number of thecae (18—14 in 10.0 mm in D. *multidens* and 11—10 in 10.0 mm in *D. praemultidens)* also in greater width of the rhabdosome and a stronger outward declination of thecal walls from the rhabdosome axis.

Occurrence. — This species is widely distributed in deposits of the lower part of the Caradocian in various regions of the globe: it is known in the Climacograptus peltifer and Climacograptus wilsoni Zones of Great Britain (Elles & Wood 1907), in the Climacograptus bicornis Zone of North America (Berry 1960), in the Gisbornian Series (Llandeilian, Lower Caradocian) of Australia (Thomas 1960), in the USSR — in the Climacograptus peltifer Zone of Tajmyr (Obut & Sobolevskaya 1964). In Poland it occurs in the Diplograptus multidens Zone of the Holy Cross Mts (Bednarczyk 1971, Tomczyk 1957, 1962, 1963, Tomczyk & Turnau-Morawska 1967). In the following profiles of the Łeba Elevation: Białogóra *1* (depth 2668.9—2667.9 m and 2657.7—2656.7 m), Białogóra *2* (depth 2623.3—2622.3 m), Dębki *3* (depth 2641.8—2640.8 m), also Łeba *8* (depth 2707.5—2706.5 m) in the Diplograptus multidens Zone.

Diplograptus cf. *pristis* (Hisinger, 1837)
(Pl. 7, Fig. 8)

Material. — 10 flattened specimens.

Description. — The largest specimen (Pl. 7, Fig. 8) attains 28.0 mm in length. Width of rhabdosome proximally (at the level of apertures of thecae 2^1 and 2^2) equal to 1.3 mm, at the level of thecae 5^1—5^2 it is 1.6 mm; distally — 2.1 mm. Rhabdosome "biform": in proximal part of rhabdosome thecae of the glyptograpid type with the geniculum poorly pronounced; in the distal direction the ventral walls of thecae tend to straighten out with the thecae taking on an orthograptid character. Apertural margins of thecae roughly perpendicular to the rhabdosome axis. Thecae number 12 in 10.0 mm proximally and 10 in 10.0 mm distally. Sicula not visible, virgella distinct, 1.05 mm long. Length of virgula 11.0 mm.

Remarks. — Specimens from the Łeba region strongly resemble forms described by Skoglund (1963) from the Östergötland area (Sweden). The *Diplograptus pristis* (Hisinger) species occurs there within the Fjäcka Formation together with *Climacograptus styloideus* Elles & Wood and *Climacograptus angustus* (Perner). In his diagnosis of the species Skoglund (1963) mentions the presence of short apertural spines growing from thecae 1^1 and 1^2. The fragmental state of preservation of the proximal parts in the Łeba specimens does not conclusively suggest the presence of such spines. Other features such as: different character of the proximal thecae from the distal thecae, size and shape of the rhabdosome, number of thecae per length unit all agree with the diagnostic features of the species *D. pristis* (Hisinger).

Occurrence. — Pleurograptus linearis Zone (Fjäcka Shales of Sweden, Skoglund 1963). In the Łeba Elevation: Białogóra *1* profile (depth 2643.6—2642.6 m); Dicranograptus clingani Zone.

Diplograptus sp.
(Pl. 7, Figs 5—6)

Material. — 10 fragmental rhabdosomes, two of them complete. All specimens flattened.

Description. — Largest rhabdosome fragment attains 55.0 mm in length. The figured specimen (Pl. 7, Figs 5—6) is slightly smaller, its total length being 45.0 mm, proximal width 1.14 mm, medial width 2.39 mm, distal width 2.71 mm. Thecae change in character along with the growth of the rhabdosome. Proximally thecae intermediate between the climacograptid and the amplexograptid type; medially thecae with a slightly rounded geniculum, distally the free ventral walls tend to straighten out the thecae taking on an orthograptid character. Height of free ventral wall of theca 2^1 is 0.46 mm, that of theca 10^1 — 0.76 mm. Thecae number 7.5 in 5 mm proximally (14/10 mm), and 10 thecae/10 mm medially and distally. Proximal end rounded terminating in a virgella 3.8 mm long. Thecae 1^1 and 1^2 bearing short thecal spines originating below the apertural margin; 0.3 mm in length. Median septum complete.

Remarks. — The specimens here described resemble *Diplograptus pristis* (Hisinger), but differ from representatives of that species in smaller width of the rhabdosome, greater number of thecae in a length unit (thecae more closely packed) and a longer virgella.

Occurrence. — The Łeba Elevation: Białogóra *2* profile (depth 2624.5—2622.3 m); Diplograptus multidens Zone.

Genus *AMPLEXOGRAPTUS* Elles & Wood, 1907

Amplexograptus cf. *fallax* Bulman, 1962
(Pl. 7, Fig. 7)

1963. *Amplexograptus* cf. *fallax* Bulman; Jaanusson & Skoglund, p. 348—350, Figs 2f, 3.

Material. — 8 poorly preserved specimens.

Description. — Rhabdosomes short, gradually widening out. Largest specimen 25.0 mm in length, proximally (at the level of thecae 1^1—1^2 apertures) the width is 0.7 mm; gradually increasing to attain 1.0 mm at the level of thecae 3^1—3^2. Maximum width (at the height of thecae 15^1—15^2) not exceeding 1.7 mm. Thecae number 7.5—8 in 5 mm proximally, 6—7 in 5 mm distally. Thecae alternating, proximally overlapping one third their length; distally one half the length of the next theca. Straight of slightly convex free ventral walls of thecae, particularly so in the proximal part. Apertural margins nearly straight. Proximal end bearing a short virgella. Theca 1^1 with a short spine originating slightly below the aperture. Median septum not conspicuous.

Remarks. — The specimens here described are with most inadequately preserved proximal parts hindering the examination of these parts of the rhabdosome. The specimens described by Jaanusson and Skoglund (1963) as *A.* cf. *fallax* bear 2 apertural spines of sicula, spine of theca 1^1 and the short virgella. Because of the poor preservation of the specimens in our collection the presence or absence of the two sicular processes can hardly be conclusively ascertained. Our specimens resemble representatives of the species *A. arctus* Elles & Wood, but the latter are with a virgella some millimetres long while in our specimens the virgella is extremely short. Forms from the Łeba region also resemble *Amplexograptus vasae* Tullberg. The rhabdosomes of this species, however, widening out more quickly and the apertural excavations being not so deep. The number of thecae in 10 mm of the rhabdosome is also smaller in *A. vasae* Tullberg than that in *A.* cf. *fallax* Bulman.

Occurrence. — Lower and Middle Caradocian of Great Britain (Lower Hartfell and Upper Glenkiln Shales, Bulman 1962), Jöhvi Stage of Estonia (Jaanusson & Skoglund 1963), Erkebidaik Stage (Lower Caradocian of Kazakhstan, Tsai 1976). In the Łeba Elevation: Piaśnica *2* profile (depth 2644.3—2640.0 m); the Nemagraptus gracilis Zone.

Genus *CLIMACOGRAPTUS* Hall, 1865

Climacograptus bekkeri (Öpik, 1927)
(Pl. 11, Fig. 2)

1927. *Diplograptus bekkeri* n. sp.; Öpik, p. 28, Pl. 6, Figs 1—15.
1932. *Climacograptus haljalensis* n. sp.; Bulman, p. 10, Figs 4—8, Pl. 2, Figs 1—34.
1960. *Climacograptus bekkeri* (Öpik); Strachan, p. 53—54, Fig. 8.

Material. — 15 flattened specimens.

Description. — Largest rhabdosome 30.0 mm long. Width of proximal end (at the height of thecae 1^1—1^2) 1.5 mm, that of the distal end — 1.9 mm. Thecae number 7 in 5 mm proximally, 6 in 5 mm distally. Virgella short, well pronounced, 0.15 mm long. Apertural excavations semi-circular, taking up one fourth of the rhabdosome width, proximally extraverted. Thecae bearing short genicular spines, more conspicuous proximally being there curved downward.

Remarks. — In characteristic genicular spines the species *Climacograptus bekkeri* (Öpik) differs from other representatives of the genus *Climacograptus*.

Occurrence. — Lower Caradocian (the Ludibundus Beds of the Tvaren area in Sweden, Strachan 1960); Estonia (Öpik 1927). In the Łeba Elevation: Białogóra *1* profile (depth 2673.1—2672.1 m) and Piaśnica *2* (depth 2648.3—2647.3 m); Glyptograptus teretiusculus + Nemagraptus gracilis Zones.

Climacograptus brevis cf. *mutabilis* Strachan, 1960
(Pl. 7, Fig. 3)

1960. *Climacograptus brevis* var. *mutabilis* nov.; Strachan, p. 54—60, Figs 4—8, 9a, Pl. 1, Figs 6—10, Pl. 2, Figs 2—4.
1963. *Climacograptus brevis* cf. *mutabilis* Strachan; Skoglund, p. 42, Pl. 5, Figs 3—4.

Material. — 2 flattened poorly preserved specimens.

Description. — Rhabdosome small, 4.5 mm long. At first proximal part 0.8 mm in width but increasing to attain 1.0 mm in the distal part of the rhabdosome. Six thecae in 4 mm both proximally and distally. Thecae alternating, of the climacograptid type with well pronounced geniculum (Pl. 7, Fig. 3). Free ventral walls of thecae straight or slightly rounded. Apertural margins horizontal, apertural excavations occupy roughly one third of the rhabdosome width. Median septum complete, sicula not visible, virgella short, well preserved.

Remarks. — The specimens found in the profiles of the Łeba Elevation show many features in common with those of the forms described by Skoglund (1963) from the Västergötland area in Sweden. The species *Climacograptus brevis* cf. *mutabilis* Strachan resembles *Climacograptus angustus* (Perner); differing from it in a wider rhabdosome and more closely packed thecae in 10 mm of the rhabdosome length.

Occurrence. — Strachan (1960) mentions this species from the Ludibundus Beds (Lower Caradocian) of the Tvären area in Sweden. Skoglund (1963) mentions its presence in deposits of the Fjäcka Formation (Upper Caradocian) of the Västergötland area in Sweden. Within the Łeba Elevation it has been identified in the Białogóra *1* profile (depth 2639.6—2638.5 m) in the Climacograptus styloideus Zone.

Climacograptus cf. *caudatus* Lapworth, 1876
(Pl. 10, Fig. 4)

Material. — Two flattened specimens, one of them with the proximal part preserved.

Description. — The preserved rhabdosome fragment is 15.0 mm long (without the virgella), widening out gradually from 0.7 mm proximally to 1.7 mm distally. Thecae number 11—12 in 10 mm. Free ventral walls of thecae straight, slightly inclined away from the vertical axis of the rhabdosome; apertural margin horizontal or slightly introverted. The proximal end in this species markedly characteristic, terminating with a long virgella (this being 7.0 mm long in the specimen here described) partly surrounded by the membrane (over a length of 0.3 mm). Median septum complete.

Remarks. — Specimens from the Łeba Elevation differ from those described by Elles and Wood (1906) in markedly smaller dimensions of the rhabdosome. The British specimens are 20.0—60.0 mm long, 2.0—2.5 mm wide; the virgella 10.0—30.0 mm long surrounded by the membrane over 3.0—13.0 mm. The distal thecae in *C. caudatus* Lapw. change in shape from a climacograptid to the diplograptid type. They become more rounded, the geniculum is less pronounced, their free ventral walls inclined away from the rhabdosome axis. The distal part not being preserved in the specimen here considered it is not possible to determine the shape of thecae in this part of the rhabdosome. Our specimens may possibly resemble *Climacograptus antiquus antiquus* Lapworth differing, however, by the absence of thecal spines in the two first thecae and in a less rounded proximal end.

Occurrence. — The species *Climacograptus caudatus* Lapworth is encountered in the Dicranograptus clingani Zone of Great Britain (Elles & Wood 1906), in the Middle and Lower Caradocian of North America (Erdtmann 1976, Ross & Berry 1963). Also in the Estonian Series (Upper Caradocian) of Victoria in Australia (Harris & Thomas 1955), in the Upper Caradocian (the Climacograptus styloideus Zone) of the Łeba Elevation — Białogóra *2* profile (depth 2614.2—2613.2 m).

Climacograptus kuckersianus Wiman, 1896
(Pl. 7, Fig. 1)

1960. *Climacograptus kuckersianus* Wiman; Jaanusson, p. 333—334, Pl. 4, Figs 11—12.

Material. — 10 fragmental rhabdosomes; all flattened with a poorly preserved proximal part.

Description. — Rhabdosome minute and narrow. The largest of the preserved fragments is 7.0 mm long. The figured specimen (Pl. 7, Fig. 1) 5.0 mm in length, proximal width (thecae 1^1—1^2) 0.53 mm, distal width 0.76 mm. Thecae of the climacograptid type, free ventral walls perpendicular to the rhabdosome axis, their constant height throughout the rhabdosome length being 0.57 mm. Apertural excavations narrow and shallow, apertural margin straight, perpendicular to the rhabdosome axis.

Remarks. — The Łeba region specimens do not differ from representatives of this species described by Jaanusson (1960) from Estonia. *C. kuckersianus* Wiman somewhat resembles *Climacograptus brevis mutabilis* Strachan differing in slightly smaller dimensions of the rhabdosome.

Occurrence. — Kukruse Stage of Estonia (Jaanusson 1960). In the Łeba Elevation: Żarnowiec *5* profile (depth 2669.0—2668.0 m, also 2674.0—2672.0 m); the Glyptograptus teretiusculus + Nemagraptus gracilis Zones.

Climacograptus spiniferus Ruedemann, 1912
(Pl. 8, Figs 1, 7)

1932. *Climacograptus diplacanthus*; Bulman, p. 13—16, Figs 7—8, Pl. 3, Figs 1—20.
1963. *Climacograptus spiniferus* Rudemann; Ross & Berry, p. 130, Pl. 9, Fig. 12.
1974. *Climacograptus spiniferus* Ruedemann; Riva, p. 11—17, Figs 2—4, Pl. 1, Figs 4, 8.
1974. *Climacograptus* cf. *spiniferus* Ruedemann; Strachan, p. 100—102, Fig. 2d, Pl. 6, Figs 2—3, 6.
1976. *Climacograptus spiniferus* Ruedemann; Erdtmann, p. 100—101, Pl. 7, Figs B (3a), B (6a), B (6b), B (6c), G (2a), M (2a), M (5a).

Material. — Several tens of poorly preserved flattened specimens, a few as external casts. Five specimens with well preserved proximal part.

Description. — Largest of the available rhabdosome fragments is 15.0 mm long. Most of the rhabdosomes are, however, smaller, with few thecae representing the juvenile stadium. Specimen figured in Pl. 8, Fig. 1 is. 4.8 mm long. Its proximal width (at the level of thecae 1^1—1^2) equal to 0.8 mm: at that of thecae 6^1—6^2 increasing to 1.2 mm. There are 6.5 thecae in 5.0 mm. The apertural excavations are rather deep and wide, about one-quarter to one-third the width of the rhabdosome. The infragenicular walls are straight or slightly curved. Theca 1^1 bearing a thecal spine together with the virgella forming a dichotomous branching at the proximal end. The virgella often symmetric to the thecal spine of theca 1^1 but as a rule is longer. More often, however, the two proximal spines are asymmetrically arranged around the proximal end. In young individuals both the virgella and the thecal spines are short and narrow (*cf.* Pl. 8, Fig. 1). Median septum originating at the level of thecae 2^1—2^2.

Remarks. — Specimens from the Łeba Elevation represent the juvenile rhabdosomes of the species *Climacograptus spiniferus* Ruedemann. They are mostly small specimens not exceeding 10.0 mm in length, consisting of several thecae. The preserved rhabdosome fragments possibly resemble the species *Climacograptus pygmaeus* Ruedemann both in size and shape of the rhabdosome, the thecae and in the character of the proximal end, especially so in the asymmetrically placed proximal spines of the representatives of the species *Climacograptus spiniferus* Ruedemann. The two here mentioned species differ in the number of thecae in 10.0 mm, as there are 11—12 thecae in *C. spiniferus* and 14—16 thecae in *C. pygmaeus.*

Occurrence. — Upper Caradocian, the Climacograptus spiniferus Zone of the NE part of North America (Riva 1974), the Orthograptus intermedius Zone in Texas (Berry 1960) and in the western part of the USA (Ross & Berry 1963), the Upper Caradocian of Newfoundland (Erdtmann 1976); the Girvan and Moffat areas of Great Britain (Riva 1974); Middle Caradocian — the Diplograptus ingens wellingtonensis Zone in the NE part of USSR. Within the Łeba Elevation area this species has been identified in the Białogóra *2* profile (depth 2616.2—2615.2 m) and Dębki *2* profile (depth 2597.7—2596.7 m) in the Dicranograptus clingani and the Climacograptus styloideus Zones.

Climacograptus sp. *1*
(Pl. 13, Fig. 3)

Material. — One flattened specimen with an incompletely preserved distal part.

Description. — Rhabdosome small and narrow. The preserved fragment is 10.0 mm long. At the height of apertures of thecae 1^1 and 1^2 width of proximal end 0.76 mm to increase to 1.25 mm at the height of thecae 5^1—5^2 and thus to remain constant to the end of the preserved rhabdosome. Thecae closely packed, there being 8 thecae in 5 mm proximally and 7 thecae distally. Free ventral walls of thecae straight or very slightly convex. Apertural excavations deep and broad, taking up one-third of the rhabdosome width; apertural margin straight and nearly perpendicular to the rhabdosome axis. Proximal end rounded, with a short but well pronounced virgella and two fine thecal spines originating below the apertures of thecae 1^1—1^2 (Pl. 13, Fig. 3). Median septum straight, visible from the level of thecae 6^1 and 6^2.

Remarks. — The specimen described above does not resemble any of the known species of *Climacograptus*. The Łeba Elevation: Białogóra *1* profile (depth 2668.9—2667.9 m); the Diplograptus multidens Zone.

Climacograptus sp. *2*
(Pl. 10, Fig. 3)

Material. — 16 flattened rhabdosome fragments without proximal ends.

Description. — The largest rhabdosome fragment (Pl. 10, Fig. 3) 26.0 mm long. Width at the height of apertures of thecae 1^1—1^2 0.98 mm, of thecae 5^1—5^2 1.52 mm, distal width 2.6 mm. Thecae of the climacograptid type, their free ventral walls straight, parallel to the rhabdosome axis; proximally thecal height 0.57 mm, distally 0.76 mm. Apertural excavations deep, oblique to the rhabdosome axis (*cf.* Pl. 10, Fig. 3), with a dorsalo-proximal course. There are 6 thecae/5 mm in the proximal part. 5 thecae/5 mm in the distal part. Proximal thecae conspicuously alternating, overlapping one half their length. Distally less conspicuously alternating.

Remarks. — A description of the proximal part can hardly be given because of its poor state of preservation. In shape of thecae and particularly in the dorsalo-proximal course of the apertural excavations the specimens here described resemble ***Pseudoclimacograptus vestrogothicus*** Jaanusson & Skoglund, though differing in dimensions. From ***Climacograptus antiquus antiquus*** Lapw. they differ in shape of thecae and of the apertural excavations. In *Climacograptus* sp. *2* the course of these excavations being more distinctly dorsalo-proximal than in ***Climacograptus antiquus antiquus*** Lapw.

Occurrence. — In the Łeba Elevation: Piaśnica *2* profile (depth 2648.3—2646.3 m); the Glyptograptus teretiusculus + ? Nemagraptus gracilis Zone.

Genus *GLYPTOGRAPTUS* Lapworth, 1873

Glyptograptus cernuus Jaanusson, 1960
(Pl. 12, Fig. 3)

1960. ***Glyptograptus cernuus*** **n. sp.; Jaanusson, p. 324—325, Fig. 6a, Pl. 2, Fig. 9.**

Material. — One complete flattened specimen, several fragmental rhabdosomes.

Description. — Rhabdosome small; the specimen figured in Pl. 12, Fig. 3 is 8.0 mm long. Proximal width (thecae 2^1—2^2 1.1 mm; distal width 1.9 mm. Proximally there are 6 thecae/5 mm, distally 5.5 thecae/5 mm of the rhabdosome length. Thecae of the glyptograptid type, free ventral walls sinusoidal, apertural margins of thecae slightly concave, thecae distinctly alternating both proximally and distally. Thecae 1^1 and 1^2 bearing short spines originating slightly below the apertures. Spines asymmetrically arranged on either side of the rhabdosome. Virgela short 0.6 mm in length, virgula not visible.

Remarks. — In small dimensions of the rhabdosome *Gl. cernuus* Jaanusson differs from other representatives of the genus *Glyptograptus*. In contradistinction to *Gl. vikarbyensis* Jaanusson whose thecal arrangement on either side of the rhabdosome is subsymmetrical, *Gl. cernuus* Jaanusson is characterized by a well pronounced alternating arrangement of thecae all along the rhabdosome length. From *Gl. uplandicus* (Wiman), by Strachan assigned (1960) to the genus *Orthograptus*, the species *Gl. cernuus* Jaanusson differs in the absence of the two apertural spines of the sicula, present in *Gl. uplandicus* (Wiman), in smaller dimensions of the rhabdosome, more closely packed thecae and more strongly curved ventral walls of thecae.

Occurrence. — Sweden — the Uhaku Stage (Furudal Limestone, Jaanusson 1960). In the Łeba Elevation — Piaśnica *2* profile (depth 2647.3—2646.3 m); the Glyptograptus teretiusculus + ? Nemagraptus gracilis Zone.

Glyptograptus teretiusculus (Hisinger, 1840)
(Pl. 10, Fig. 2; Pl. 12, Fig. 1; Pl. 13, Fig. 4)

1907. *Diplograptus (Glyptograptus) teretiusculus* (Hisinger); Elles & Wood, p. 250—252, Fig. 171a—d, Pl. 31, Fig. 1a—e.
1913. *Diplograptus teretiusculus* His.; Hadding, p. 43—45, Pl. 2, Fig. 15—20.
1960. *Glyptograptus* cf. *teretiusculus* (Hisinger, 1840); Jaanusson, p. 322, Pl. 3, Figs 10—11.
1976. *Glyptograptus teretiusculus* (Hisinger, 1840); Tsai p. 45—46, Pl. 6, Figs. 6—7, 10—13.

Material. — One hundred rhabdosomes, some tens of them complete specimens. All flattened.

Remarks. — Specimens of this species occurring in the Łeba Elevation area have numerous features in common with the British forms (*cf.* Elles & Wood 1907). They differ from them,, however, in somewhat larger dimensions and a smaller number of thecae in 10.0 mm of the rhabdosome length. From the North American specimens (Berry 1964, Ruedemann 1947) and from those of USSR described from the Tajmyr region (Obut & Sobolevskaya 1964) and from Kazakhstan (Tsai 1976) they differ in greater length of the rhabdosome. From the closely related species *Gl. euglyphus* (Lapworth) they differ in the presence of basal spines and greater rhabdosome width. The presence of a well pronounced virgella, in the part adjacent to the thecae sorrounded by the membrane, characterises only the mature specimens; the juvenile stadia of this species being with a very fine virgella free throughout its length.

Occurrence. — This species is widely spread in the Llandeilian and Caradocian deposits of Great Britain (Elles & Wood 1907), North America (Berry 1960, 1964; Ruedemann 1947); USSR (Keller 1956, Keller & Lisogor 1954, Obut & Sobolevskaya 1964, Tsai 1976), South America (Turner 1960), Australia (Thomas 1960), China (Lee 1963), Sweden (Jaanusson 1960). In Poland the range of this species is much the same (Bednarczyk 1971, 1974; Modliński 1968, 1973; Tomczyk 1962; Tomczyk & Turnau-Morawska 1967). In the Łeba Elevation: Piaśnica *2* profile, depth 2648.3—2644.3 m), Białogóra *1* (2674.1—2672.1 m), Dębki *3* (2649.2—2647.2 m) and Łeba *8* (2709.5—2707.5 m); the Glyptograptus teretiusculus and Nemagraptus gracilis Zones.

Glyptograptus sp. *1*
(Pl. 10, Fig. 5)

Material. — 1 complete specimen.

Description. — Rhabdosome small, 11.0 mm long (without the virgella and the virgula). Proximal width (at the height of thecae 1^1—1^2) 0.95 mm, median width (at thecae 9^1—9^2) — 1.71 mm, distal width 1.7 mm; showing a constant width over the greater part of the rhabdosome length. Thecae of the glyptograptid type, with sinusoidal free ventral walls. The apertural margins perpendicular to the rhabdosome axis, straight, proximal slightly directed outward (*cf.* Pl. 10, Fig. 5); proximally 8 thecae in 5 mm, distally 7 thecae in 5 mm. Virgella well pronounced, 1.6 mm long; thecae 1^1 and 1^2 bearing thecal spines directed downward. Sicula 0.83 mm long. Median septum complete.

Remarks. — The specimen here described resembles *Glyptograptus* cf. *G. lorrainensis* (Ruedemann) cited by Jackson (1973) from Manitoba (USA). The dimensions, general shape of the rhabdosome and the character of thecae are similar in these two forms but they differ in a differently developed proximal end. Namely, *Gl.* cf. *G. lorrainensis* (Ruedemann) bears two spines originating from theca 1^2 *Glyptograptus* sp. *1* bearing but 1 thecal spine of theca 1^2.

Occurrence. — Białogóra *1* profile (depth 2657.7—2656.7 m); the Diplograptus multidens Zone.

Glyptograptus sp. *2*
(Pl. 11, Fig. 6)

Material. — 1 flattened specimen.

Description. — The incomplete length (the distal end being absent) of the figured specimen is 18.0 mm (without the virgella). Width of proximal end, at the height of thecae 1^1—1^2, 1.52 mm, in the median part (thecae 6^1—6^2 — 1.9 mm, distally 2.0 mm. Thecae of the glyptograptid type proximally (theca 2^1) 0.98 mm long, in the median part 1.14 mm (thecae 6^1). Thecae number 6 in 5 mm proximally, 5 in 5 mm distally. Free ventral walls of thecae sinusoidal, apertural excavations deep, directed dorsalo-proximally (*cf.* Pl. 11, Fig. 6). Proximal end broad, terminating in a virgella 2.28 mm long, in its part adjacent to the thecae surrounded over a short distance by the membrane. Sicula not visible, sicular aperture bearing two apertural spines 0.76 mm long. Thecae 1^1 and 1^2 also bearing apertural or subapertural spines (the subapertural ones originating just below the apertural margin); the exact position of the spines indeterminate; the spines 0.46 mm long.

Remarks. — The figured specimen (Pl. 11, Fig. 6) resembles *Orthograptus uplandicus* (Wiman), by Strachan (1960) assigned to the genus *Orthograptus* because of its typically orthograptid type of distal thecae. Wiman (1895) and Bulman in Thorslund (1940) referred this species to the genus *Diplograptus* (*?Glyptograptus*). Because of the shape of thecae this specimen from the Łeba region has been reffered to genus *Glyptograptus*, but the shape of the rhabdosome, dimensions and character of the proximal end (2 apertural spines of the sicula) bring *Glyptograptus* sp. *2* to *Orthograptus uplandicus* (Wiman).

Occurrence. — In the Łeba Elevation: Piaśnica *2* profile (depth 2645.3—2644.3 m); the Nemagraptus gracilis Zone.

Genus *ORTHOGRAPTUS* Lapworth, 1873

Orthograptus truncatus truncatus (Lapworth, 1877)
(Pl. 11, Fig. 7; Pl. 12, Fig. 5)

1907. *Diplograptus (Orthograptus) truncatus* Lapworth; Elles & Wood, p. 233—235, Fig. 154a—b, Pl. 29, Fig. 3a—e.
1948. *Diplograptus (Orthograptus)* cf. *truncatus* Lapworth, Henningsmoen, p. 402—403.
1963. *Orthograptus truncatus* (Lapworth); Ross & Berry, p. 148—149, Pl. 11, Fig. 25.
1970. *Orthograptus truncatus truncatus* (Lapworth); Toghill, p. 23, Pl. 16, Figs 3, 6.
1974. *Orthograptus amplexicaulis* (Hall); Riva, p. 29—34, Fig. 9, Pl. 2, Figs 7—10.

Material. — 50 flattened rhabdosomes, representing juvenile as well as mature stadia. Some specimens with well preserved proximal parts.

Description. — Rhabdosome length variable — ranging from 10.0 mm (in the juvenile specimen in Pl. 12, Fig. 5) to 28.0 mm in a mature form in Pl. 11, Fig. 7. Proximal width (at the height of apertures of thecae 1^1—1^2 of a juvenile specimen) 1.03 mm, gradually broadening to achieve a rhabdosome length of 2.09 mm at the height of apertures of thecae 11^1—11^2. Maximum width of the largest specimen is 3.0 mm. Greatest increase in rhabdosome width occurring proximally to attain its maximum value at a distance of 10.0 mm from the proximal end. Some rhabdosomes tending to constrict distally. Thecae alternating; 12—14 in 10.0 mm proximally, 10—12 distally. In the flattened specimens shape of thecae depends on the course and strength of compression. Often the free ventral walls of thecae sinusoidal, the thecae taking on a climacograptid character (Pl. 12, Fig. 5). This is less conspicuous in the specimen figured in Pl. 11, Fig. 7. The free ventral walls of this specimen nearly straight, at an angle of 35—40° from the rhabdosome axis, the apertures straight, rarely perpendicular to the rhabdosome axis, more often inclined away from the axis of the rhabdosome. Proximal end terminating in a short virgella. Theca 1^1 bearing a short subapertural spine; the second proximal spine represented by a sicular spine is not visible in the specimens here examined with a probable length of 2.5 mm as given by Riva (1974).

Remarks. — Riva's (1974) comparison of the material of *O. truncatus truncatus* (Lapworth) from the collection of Elles and Wood with the flattened specimens of *O. amplexicaulis* (Hall) from the Canajoharie Shales in the eastern North American areas has shown the identical morphology of these two forms (Riva 1974). *O. amplexicaulis* Hall, previously described (Hall 1847) is therefore the older synonim of *O. truncatus truncatus* (Lapworth). According, however, to article 23(b) of the International Code of Zoology (Mayr 1974, p. 331) a name used for at least 50 years may not, after 1961, be replaced by on older synonim.

Occurrence. — Lower Caradocian — the Corynoides americanus — Climacograptus spiniferus Zones of North America. Sporadically it also occurs in somewhat younger deposits, including the Cl. manitoulinensis Zone (upper part of the Pleurograptus linearis Zone of the British classification (Riva 1974). Great Britain: the Dicranograptus clingani Zone and less often P. linearis (Toghill 1970, Elles & Wood 1907). Poland: the Climacograptus styloideus Zone of the Holy Cross Mts (Bednarczyk 1971, Kielan 1956, Tomczyk 1957, 1962) and the Peribaltic Syneclise (Modliński 1973). The Łeba Elevation: Białogóra 2 profile (depth 2619.3—2618.3 and 2614.2—2610.2 m) also Dębki 2 profile (depth 2597.7—2596.7 m); the Dicranograptus clingani and Climacograptus styloideus zones.

Genus *PSEUDOCLIMACOGRAPTUS* Přibyl, 1947

Subgenus *PSEUDOCLIMACOGRAPTUS (PSEUDOCLIMACOGRAPTUS)* Přibyl, 1947

Pseudoclimacograptus (P.) clevensis Skoglund, 1963
(Pl. 15, Fig. 6)

1963. *Pseudoclimacograptus clevensis* Skoglund, p. 37—38, Pl. 2, Figs 5—8.

Material. — One poorly preserved flattened specimen without the distal part.

Description. — Rhabdosome minute, 4.0 mm long, proximal width 0.7 mm, distal width 1.2 mm. Five thecae in 4.0 mm. Free ventral walls straight, some slightly convex, height 0.5 mm. Apertural margin straight, perpendicular to rhabdosome, axis Virgella well pronounced, 0.3 mm long, thecae 1^1 and 1^2 without thecal spines. Median septum zigzag in form.

Remarks. — The species belonging to the subgenus *P.* (*Pseudoclimacograptus*) Přibyl are with convex free ventral walls, low and deep apertural excavations and the median septum zigzag throughout the rhabdosome length. The species here described is characteristic by its small rhabdosome dimensions; the length of the specimens not exceeding 9.0 mm (Skoglund 1963). The figured specimen does not differ from the typical representatives of the species *Pscl.* (*P.*) *clevensis* Skoglund. This species was found by Skoglund (1963) in association with graptolites from the Pleurograptus linearis Zone. Other species belonging to the subgenus *Pseudoclimacograptus* (*Pseudoclimacograptus*) are known only from older deposits, hence *Pscl.* (*P.*) *clevensis* Skoglund is the youngest representative of this subgenus. Within the Łeba Elevation this species was found in association with *Dicellograptus johnstrupi* Hadding; *Orthograptus truncatus pauperatus* Elles & Wood; ?*Leptograptus* sp. The above assemblage is characteristic of the Uppermost Caradocian deposits.

Occurrence. — The Pleurograptus linearis Zone (Fjäcka Formation, Sweden, Skoglund 1963). The Łeba Elevation: Dębki *2* profile (depth 2596.7—2595.7 m); Climacograptus styloideus Zone.

Pseudoclimacograptus (P.) scharenbergi stenostoma (Bulman, 1947) (Pl. 7, Fig. 4)

1947. *Climacograptus scharenbergi* var. *stenostoma* Bulman, p. 70, Pl. 7, Figs 11—12, Pl. 8, Figs 2—4, 8.
1974. *Pseudoclimacograptus scharenbergi stenostoma* (Bulman); Riva, p. 26—27, Fig. 8l.
1976. *Pseudoclimacograptus stenostoma* (Bulman); Tsai, p. 39—40, Pl. 5, Figs 15—17.

Material. — 2 specimens, one of them complete.

Description. — Rhabdosome small — 6.2 mm without the virgella and the virgula. Proximal width, at the height of the apertures of thecae 1^1—1^2 0.8 mm; distal width (thecae 9^1—9^2) — 1.1 mm; 8 thecae in 5.0 mm of the rhabdosome length. Free ventral walls of thecae convex, apertures of thecae introverted. Thecal excavations narrow, slitlike. Proximal end round with a short but well pronounced virgella 0.4 mm in length. Thecae 1^1 and 1^2 bearing short thecal spines. Septum zigzag in form.

Remarks. — In smaller dimensions of the rhabdosome, especially its smaller width, and the narrow slitlike apertural excavations, the subspecies *Pseudoclimacograptus* (*P.*) *scharenbergi stenostoma* (Bulman) differs from *Ps.* (*P.*) *scharenbergi scharenbergi* (Lapworth). The specimens identified by the writer markedly resemble the forms shown by Riva (1974) from the east part of North America.

Occurrence. — Lower Caradocian of Great Britain, the Nemagratus gracilis and Climacograptus bicornis Zones of the Marathon region, Texas, Berry 1960); the Llandeilian and Lower Caradocian (Tselinograd and Erkebidaik Stages of Kazakhstan, Tsai 1976). The Łeba Elevation: Białogóra *1* profile (depth 2676.6—2674.1 m); the Glyptograptus teretiusculus + Nemagraptus gracilis Zone.

Pseudoclimacograptus aff. *vestrogothicus* Jaanusson & Skoglund, 1963 (Pl. 9, Fig. 7)

Material. — 2 flattened specimens, one of them complete.

Description. — Rhabdosom small, 8.0 mm long. Proximal width (at the height of apertures of thecae 1^1 and 1^2) 1.14 mm; distal width (at the height of thecae 8^1—8^2) 1.25 mm; proximally 5 thecae in 5 mm; distally 5.5 thecae in 5 mm. Free ventral walls of thecae slightly convex, their height 0.45—0.55 mm. Apertural excavations deep and fairly broad, proximally semicircular, distally growing more markedly slitlike. In the proximal part apertures perpendicular to the rhabdosome axis or even directed outward, higher up somewhat dorsalo-proximally inclined (*cf.* Pl. 9, Fig. 7). Proximal end rounded with a short virgella 0.3 mm in length. Theca 1^1 bearing a short thecal spine originating somewhat below the apertural margin. Another spine poorly visible, representing the spine of theca 1^2 or the sicula. Median septum straight or slightly undulate, readily detectable from the level of thecae 4^1—4^2.

Remarks. — The specimens here described in many aspects resemble *Pscl. vestrogothicus* Jaanusson & Skoglund, but also differ in a number of characters from the last mentioned species. Width of the figured specimen practically constant throughout the rhabdosome length (from 1.14 to 1.25 mm). In *Pscl. vestrogothicus* Jaanusson & Skoglund the difference in the width of the rhabdosome greater, being 1.15—1.30 proximally and 1.8 mm distally. Number of thecae in the same unit of length differs too in these two forms. The maximum number of thecae in the Łeba region specimens is 6 in 5 mm that in the Swedish specimens being 6.5—7 thecae proximally (in 5 mm) and 5.5— thecae in 5 mm distally. The representatives of the species *Pscl. vestrogothicus* described by Jaanusson and Skoglund (1963) are with a rather well pronounced median septum zigzag proximally. On the other hand our specimen is with a poorly conspicuous septum not suggesting anything as to its shape. The rhabdosome length, shape and dimensions of thecae are, however, identical in the two forms.

Occurrence. — Białogóra *1* profile, Diplograptus multidens Zone (depth 2668.9—2667.9 m). Species *Pscl. vestrogothicus* Jaanusson & Skoglund occur in the Middle Ordovician deposits (Dalby Formation — N. gracilis — D. multidens Zones) of the Västergötland area (Sweden, Jaanusson & Skoglund 1963).

Pseudoclimacograptus sp.
(Pl. 8, Fig. 6)

Material. — 2 rhabdosomes, both flattened and poorly preserved.

Description. — The figured rhabdosome fragment (Pl. 8, Fig. 6) is 3.0 mm long, its width at the height of thecae 1^1—1^2 — 0.68 mm; at that of thecae 5^1—5^2 — 0.95 mm. The complete rhabdosome consisting of 5 pairs of thecae with slightly convex free ventral walls, apertural excavations shallow, rounded. Median septum zigzag in form, virgella 0.26 mm long, the virgula 1.52 mm.

Remarks. — The small dimensions of the rhabdosome bring the specimens here described close to *Pscl. (P.) scharenbergi stenostoma* (Bulman) but in the presence in our forms of rounded apertural excavations as against the narrow slitlike ones in *Pscl. (P.) scharenbergi stenostoma* (Bulman) these two taxons differ one from the other (*cf.* Pl. 8, Fig. 6 and Pl. 7, Fig. 4).

Occurrence. — In the Łeba Elevation: Żarnowiec *5* profile (depth 2669.0—2668.0 m); the Glyptograptus teretiusculus + Nemagraptus gracilis Zone.

Genus *LASIOGRAPTUS* Lapworth, 1873

Lasiograptus costatus Lapworth, 1873
(Pl. 14, Fig. 1)

1873. *Lasiograptus costatus* sp. nov.; Lapworth; p. 559.
1908. *Lasiograptus (Thysanograptus) Harknessi* var. *costatus* (Lapworth); Elles & Wood, p. 327, Fig. 215a—g, Pl. 34, Fig. 2a—d.
1963. *Lasiograptus costatus* Lapworth; Geh. p. 255, Fig. 136, Pl. 5, Figs 24—27.

Material. — 10 well preserved flattened specimens, 4 of them complete.

Description. — Largest rhabdosome 7.0 mm in length. In width 0.57 mm at the height of apertures of thecae 1^1—1^2, distal width (thecae 6^1—6^2) — 1.9 mm. Thecae of the lasiograptid type with a well pronounced geniculum, free ventral walls straight (Pl. 14, Fig. 1), low — with height of 0.26 mm. Apertural excavations deep, rounded. 7 thecae in 5.0 mm. Thecae bearing long, double genicular spines, with mean length of 0.57 mm. Virgella well pronounced, 0.5 mm long. Virgula 2.0 mm long.

Remarks. — The double genicular spines are rarely seen (*cf.* Pl. 14, Fig. 1). In most cases one long spine is visible representing the elongated geniculum of every theca. This excepted the specimens here examined do not differ from the typical representatives of the species *L. costatus* Lapworth. The latter species resembles *L. harknessi* (Nich.) but differs from it in somewhat larger dimensions (the length of *L. costatus* sometimes being 15.0 mm with width of 3.0 mm).

Occurrence. — Species *Lasiograptus costatus* Lapworth is known from the N. gracilis — Cl. wilsoni Zones of Great Britain (Elles & Wood 1908), China (Geh 1963), USSR (Tsai 1976), Argentine (Bulman 1931; Turner 1960). In the Łeba Elevation: Mieroszyno *8* profile (depth 2813.0—2812.0 m), Dębki *3* profile (2642.8—2641.8 m); the Nemagraptus gracilis Zone.

Genus *HALLOGRAPTUS* Lapworth, 1876

Hallograptus sp.
(Pl. 15, Fig. 5)

Material. — 1 complete flattened specimen.

Description. — Rhabdosome short and broad. Length 15.0 mm, width 1.14 mm at the height of thecae 1^1—1^2. Proximally the rhabdosome width gradually increasing to attaint its maximum and thereon constant width to the end of the rhabdosome of 4.0 mm at the height of thecae 10^1—10^2 (a distance of 0.6 mm from the proximal end). 13 thecae in 10.0 mm of the rhabdosome length, (proximally 7 thecae in 5.0 mm). Proximal end poorly preserved. Thecae 1^1 and 1^2 bearing short thecal spines, virgella not preserved. Median septum running along the rhabdosome, most conspicuous from the level of thecae 4^1—4^2. Virgula well pronounced, 0.3 mm long. Thecae of the lasiograptid type with strongly pronounced geniculum and maximally shortened introverted free ventral walls. Apertural excavations deep and rounded. Every theca bearing 1 or 2 genicular spines (*cf.* Pl. 15, Fig. 5).

Remarks. — On the general shape of the rhabdosome, the shape of thecae and the presence of genicular spines the specimen here described is reasonably referable to the genus *Hallograptus* though in the considerable width of the rhabdosome, particularly so in the distal part, also in the very short genicular spines it differs from other representatives of this genus.

Occurrence. — In the Łeba Elevation: Piaśnica *2* profile (depth 2646.3—2645.3 m); the Nemagraptus gracilis Zone.

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TERESA PODHALAŃSKA

STRATYGRAFIA I ROZWÓJ FACJALNY ŚRODKOWEGO I GÓRNEGO ORDOWIKU WYNIESIENIA ŁEBY (NW POLSKA)

(Streszczenie)

W opracowaniu przedstawiono rezultaty badań osadów środkowego i górnego ordowiku z obszaru wyniesienia Łeby, stanowiącego zachodnią część syneklizy perybałtyckiej.

Podstawę opracowania stanowiły materiały litologiczne i paleontologiczne zebrane z profilów ośmiu wierceń wykonanych przez Przedsiębiorstwo Poszukiwań Nafty i Gazu w Pile. Są to następujące wiercenia: Łeba *8*, Białogóra *1*, Białogóra *2*, Żarnowiec *5*, Piaśnica *2*, Dębki *2*, Dębki *3* oraz Mierószyno *8* (fig. 1).

We wszystkich tych profilach stwierdzono podobny rozwój facjalny osadów ordowiku. Fakt ten umożliwił wyróżnienie trzech podstawowych jednostek litostratygraficznych: formacji wapieni organodetrytycznych, formacji iłowców graptolitowych i formacji marglistej oraz jednego ogniwa związanego z formacją środkową.

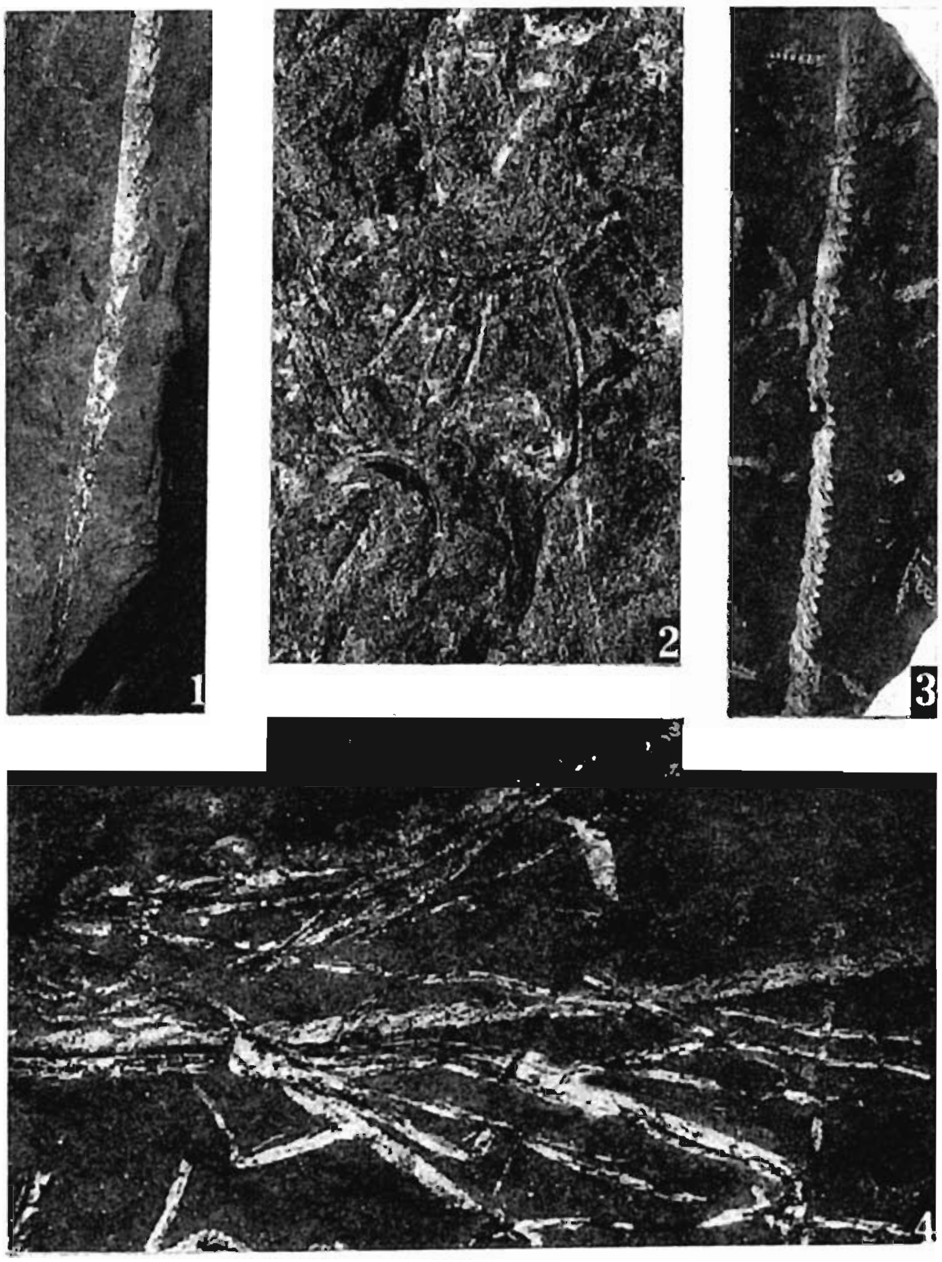
Zmieniające się wraz z litofacją zespoły skamieniałości spowodowały, że następstwo stratygraficzne ustalono na podstawie różnych grup: konodontów, trylobitów, brachiopodów a przede wszystkim graptolitów, spośród których oznaczono 60 gatunków i podgatunków należących do 17 rodzajów. Na podstawie tej fauny

udokumentowano obecność osadów od lanwirnu górnego do aszgilu włącznie.

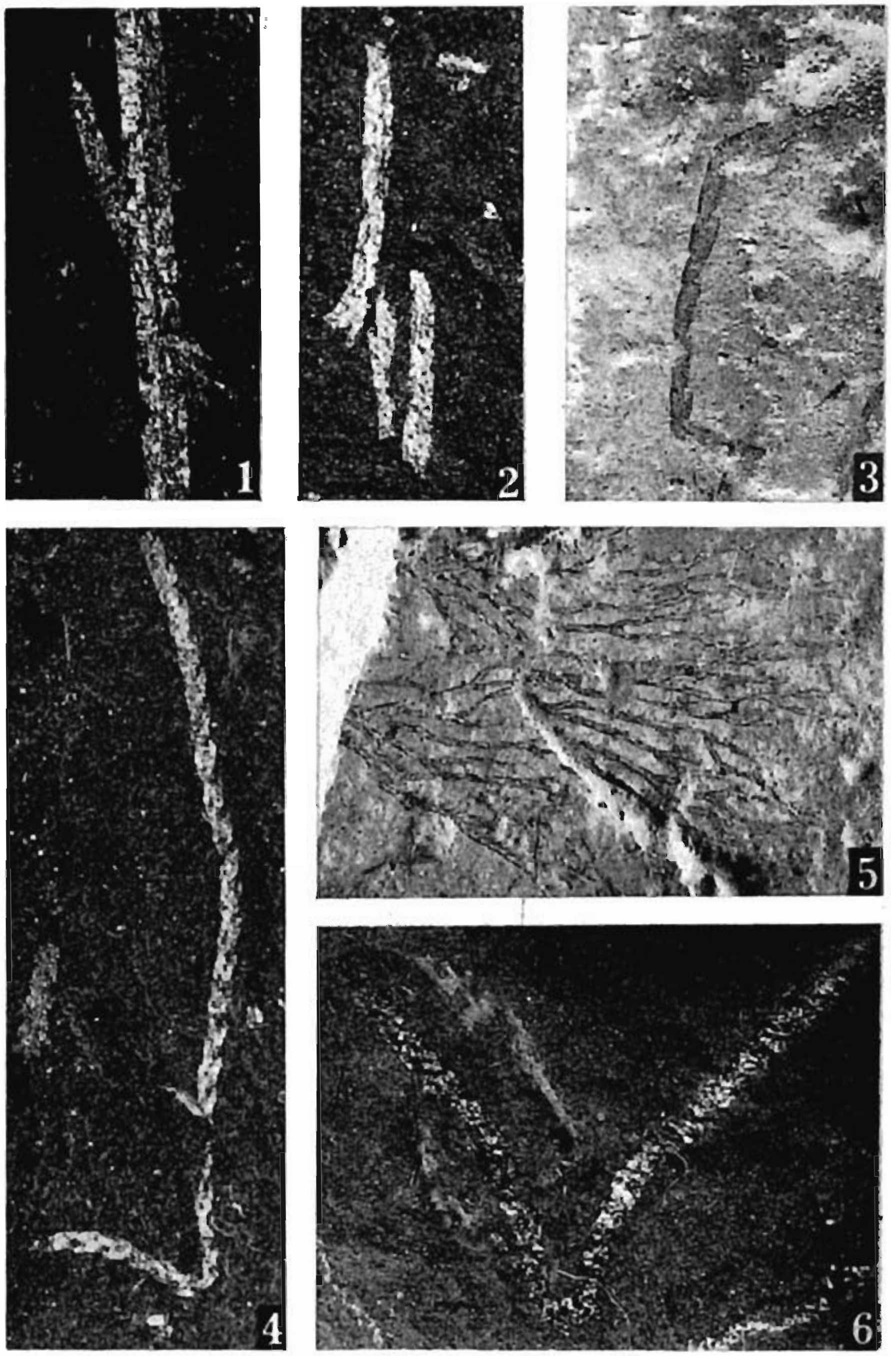
Pionowe zasięgi taksonów w poszczególnych profilach przedstawiono w tabelach od 2 do 9. Na planszach (1 do 18) zilustrowano wszystkie zebrane i oznaczone graptolity, brachiopody oraz trylobity. Ponadto przedstawiono opisy graptolitów nie znanych do tej pory w Polsce lub posiadających zasadnicze znaczenie dla stratygrafii badanych osadów.

Analiza wyróżnionych jednostek litostratygraficznych oraz zespołów skamieniałości pozwoliła na rekonstrukcję środowisk sedymentacyjnych panujących w łebskiej strefie ordowickiego zbiornika epikontynentalnego.

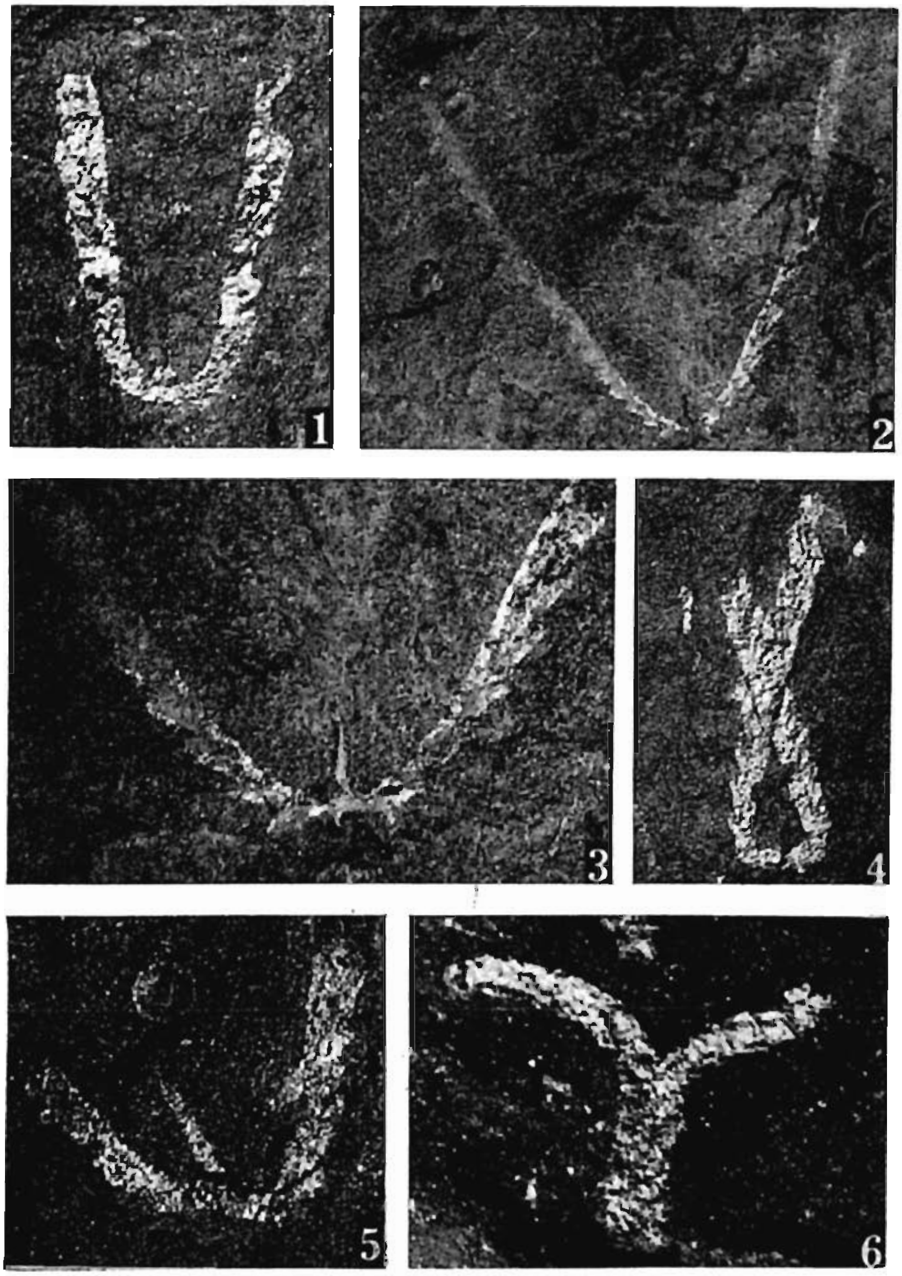
Przedstawiono także rozwój facjalno-paleogeograficzny środkowego i górnego ordowiku w rejonie Łeby. Korelacja opracowanych profilów ordowiku północno-zachodniej Polski z podobnie wykształconymi osadami Skanii i Bornholmu wykazała genetyczne związki między tymi obszarami, wynikające z podobnego rozwoju skańsko-łebskiej strefy zbiornika morskiego rozciągającej się wzdłuż krawędzi szelfu (por. tab. 11, fig. 12).



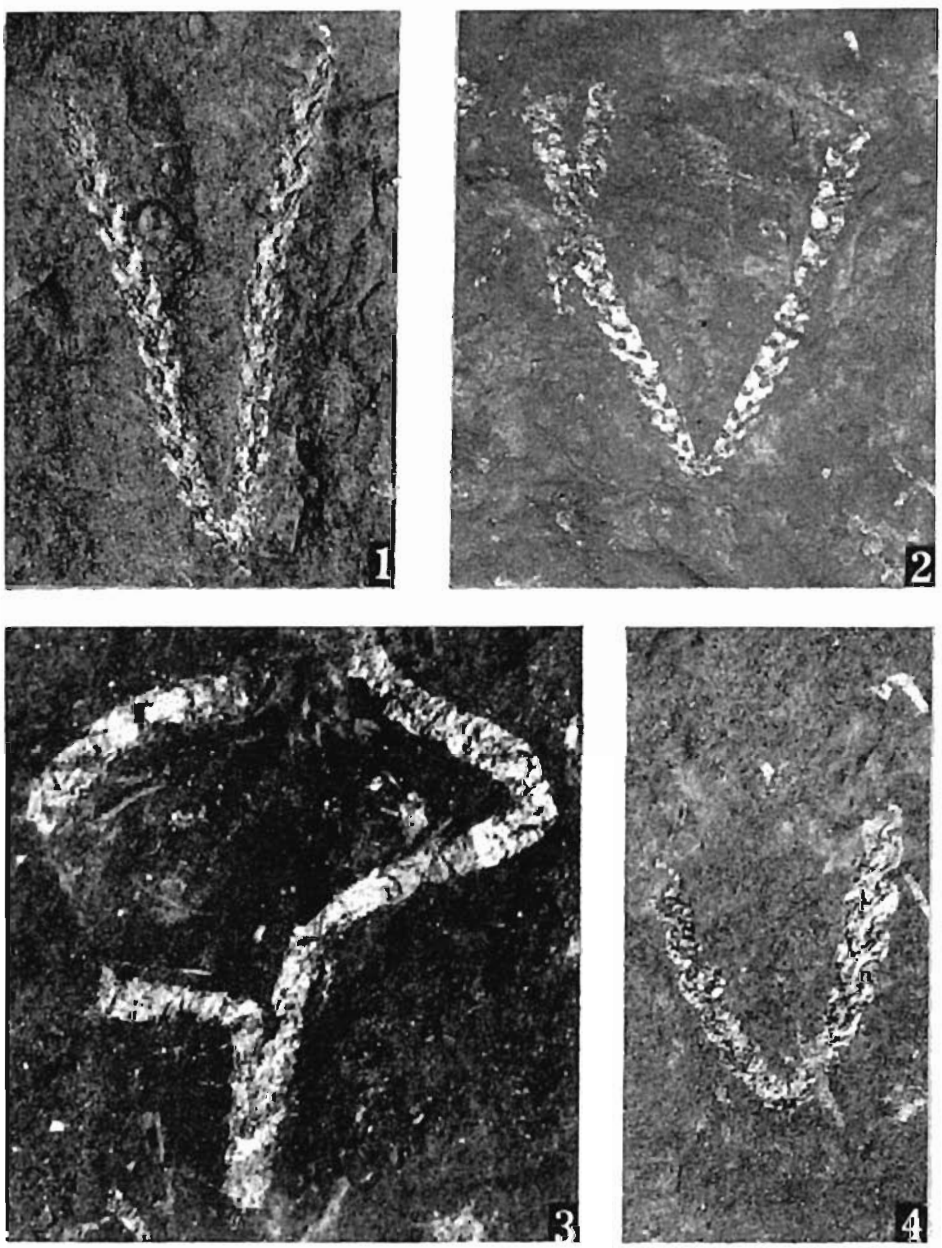
1 — ?*Leptograptus* sp.; Dębki *2*, 2596.7—2595.7 m, ×4.
2 — *Nemagraptus* cf. *gracilis gracilis* (Hall); Piaśnica *2*, 2646.3—2645.3 m. ×6.
3 — Dichograptidae Lapw. (?*Didymograptus* sp.); Łeba *8*, 2709.5—2708.5 m, ×1.5.
4 — Dendrograptidae Roemer gen. et sp. indet.; Białogóra *1*, 2675.6—2674.1, ×2.



1 — *Corynoides* cf. *calicularis* Nich.; Dębki 3, 2641.8—2640.8 m, ×7.
2 — *Corynoides* cf. *calicularis* Nich.; Białogóra 2, 2626.5—2625.5 m, ×7.
3 — Dendrograptidae Roemer gen. et sp. indet.; Dębki 3, 2648.2—2647.2 m, ×6.
4 — *Dicellograptus divaricatus salopiensis* Elles & Wood, proximal part; Piaśnica 2, 2645.3—2644.3 m, ×3.
5 — *Dictyonema* sp.; Dębki 3, 2648.2—2647.2 m, ×2.
6 — *Dicellograptus vagus* Hadding; Białogóra 1, 2673.1—2672.1 m, ×6.

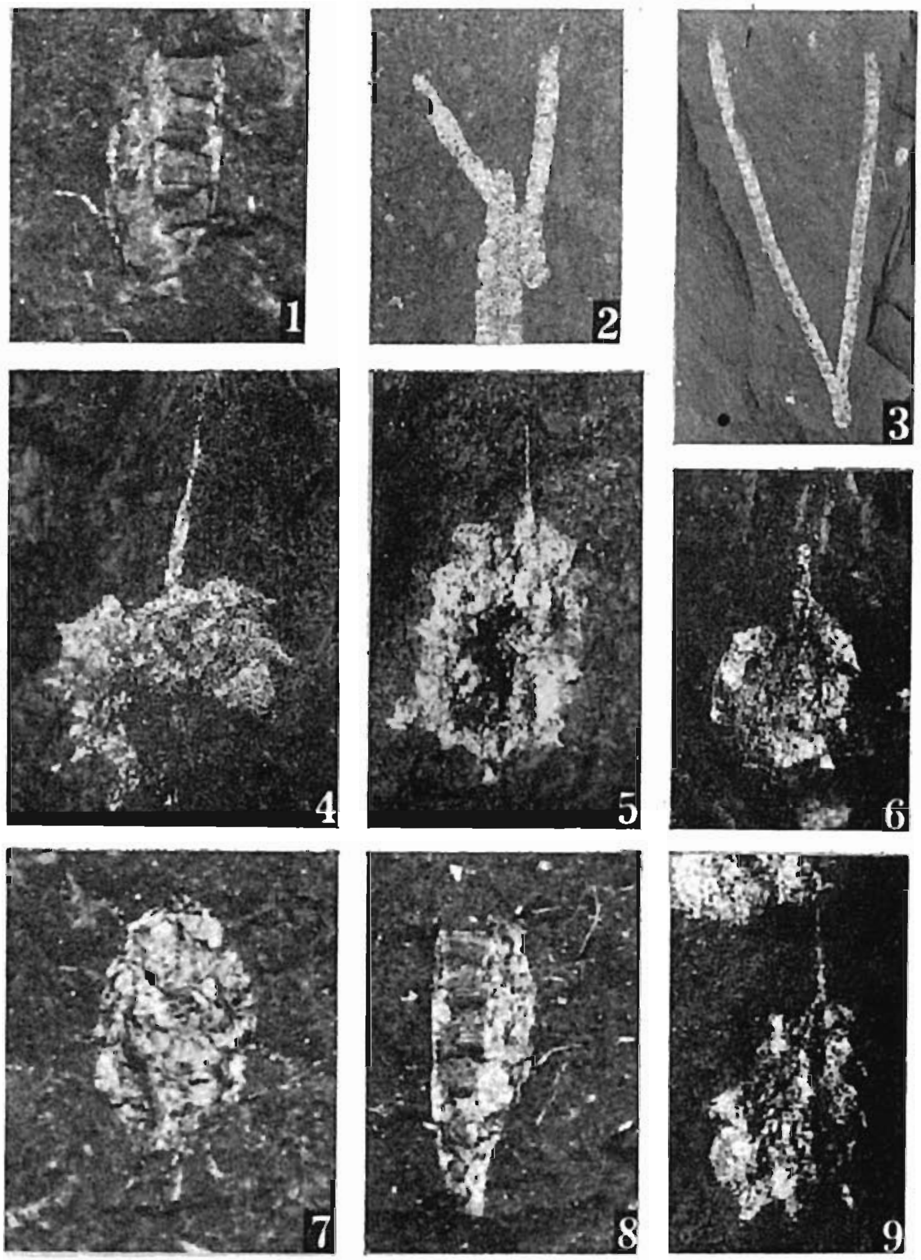


1 — *Dicellograptus pumilus* Lapw.; Łeba *8*, 2671.8—2670.8 m, ×8.
2—3 — *Dicellograptus johnstrupi* Hadding; Białogóra *2*, 2813.2—2812.2 m; *2* ×4, *3* ×10.
4 — *Dicellograptus caduceus* Lapw.; Łeba *8*, 2671.8—2670.8 m, ×8.
5 — *Dicellograptus johnstrupi* Hadding; Białogóra *2*, 2814.2—2813.2 m, ×12.
6 — *Dicranograptus ziczac* Lapw.; Mieroszyno *8*, 2813.0—2812.0 m, ×10.

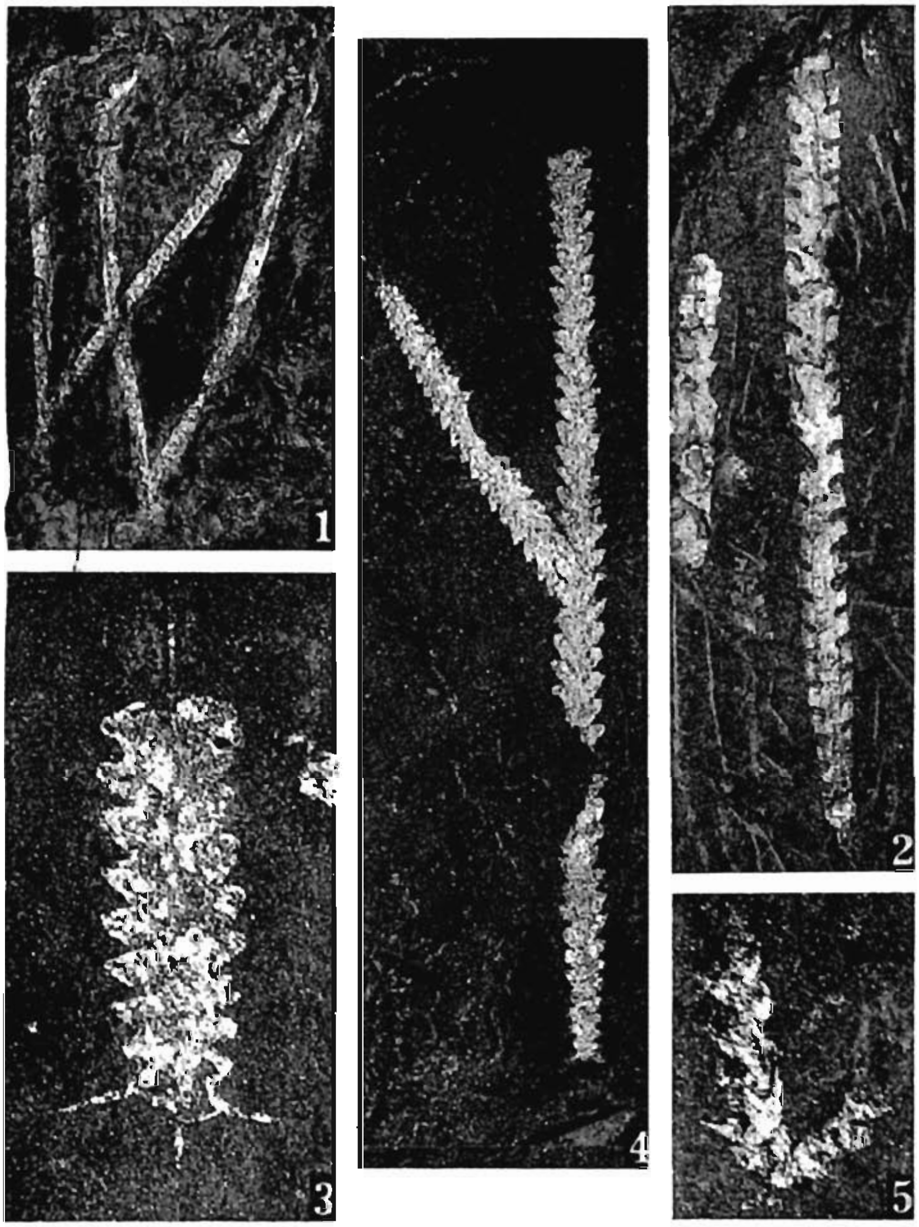


1—2, 4 — *Dicellograptus sextans* Hall; *1* — Dębki 3, 2645.0—2644.0 m, ×6; *2* — Piaśnica 2, 2647.3—2646.3 m, ×4; *4* — Łeba 8, 2708.5—2707.5 m, ×4.

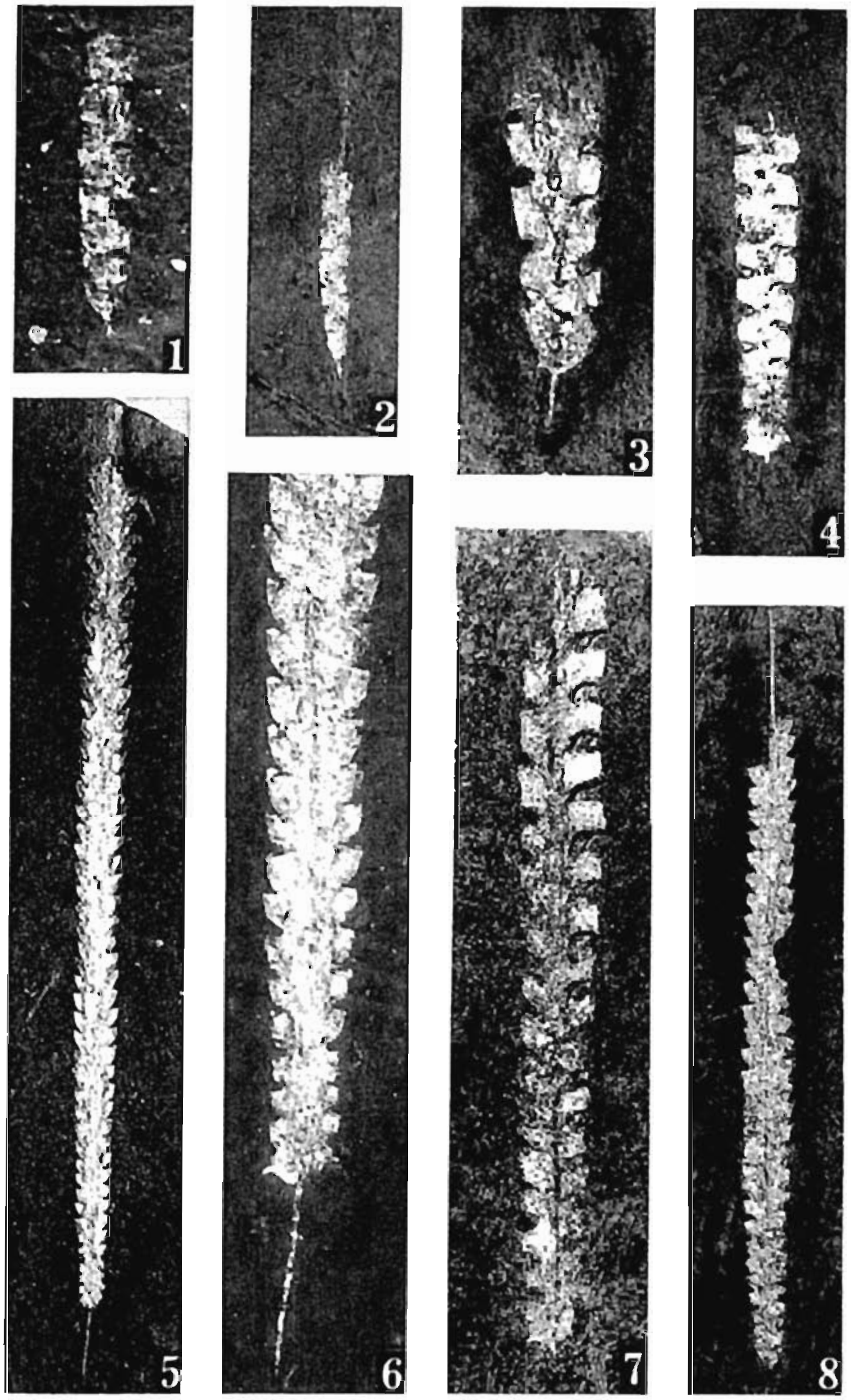
3 — *Dicranograptus ziczac* Lapw.; Mieroszyno 8, 2813.0—2812.0 m, ×10.



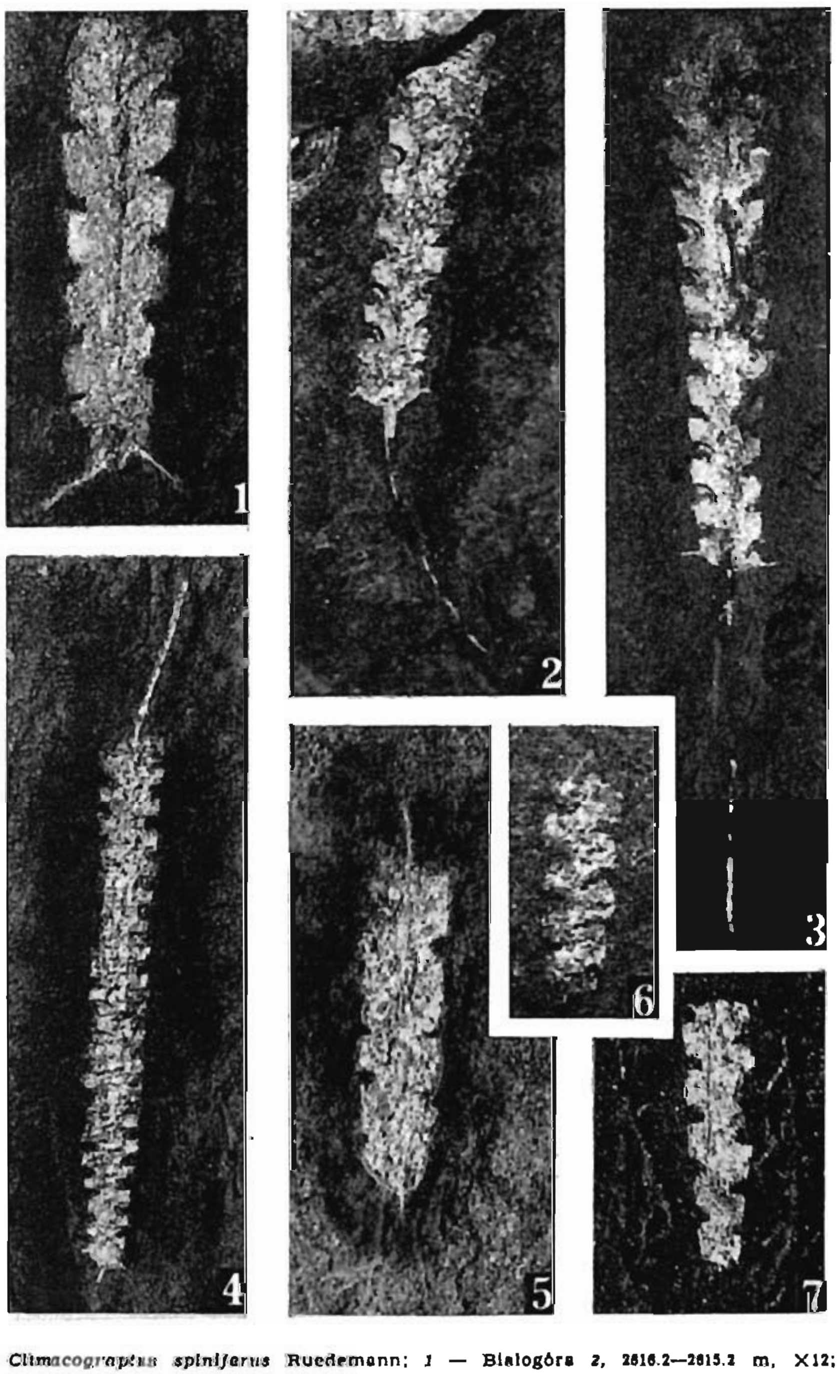
1, 7—8 — *Glossograptus* cf. *hincksii hincksii* Hopkinson; *1* — Żarnowiec *5*, 2673.0—2672.0 m, ×10; *7* — Mieroszyno *8*, 2813.0—2812.0 m, ×10; *8* — Żarnowiec 5, 2669.0—2668.0 m, ×10.
2—3 — *Dicranograptus clingani* Carruthers; *2* — Łeba *8*, 2671.8—2670.8 m, ×2.5; *3* — Białogóra *2*, 2619.3—2618.2 m, ×2.5.
4 — *Nanograptus* cf. *phylloides* (Elles & Wood); Białogóra *1*, 2675.6—2674.1 m, ×12.
5—6, 9 — *Nanograptus* cf. *lapworthi* Hadding; Białogóra *1*, 2675.6—2674.1 m, ×12; *5* — mature stage, *6* — juvenile stage, *9* — 2674.1—2673.1 m.



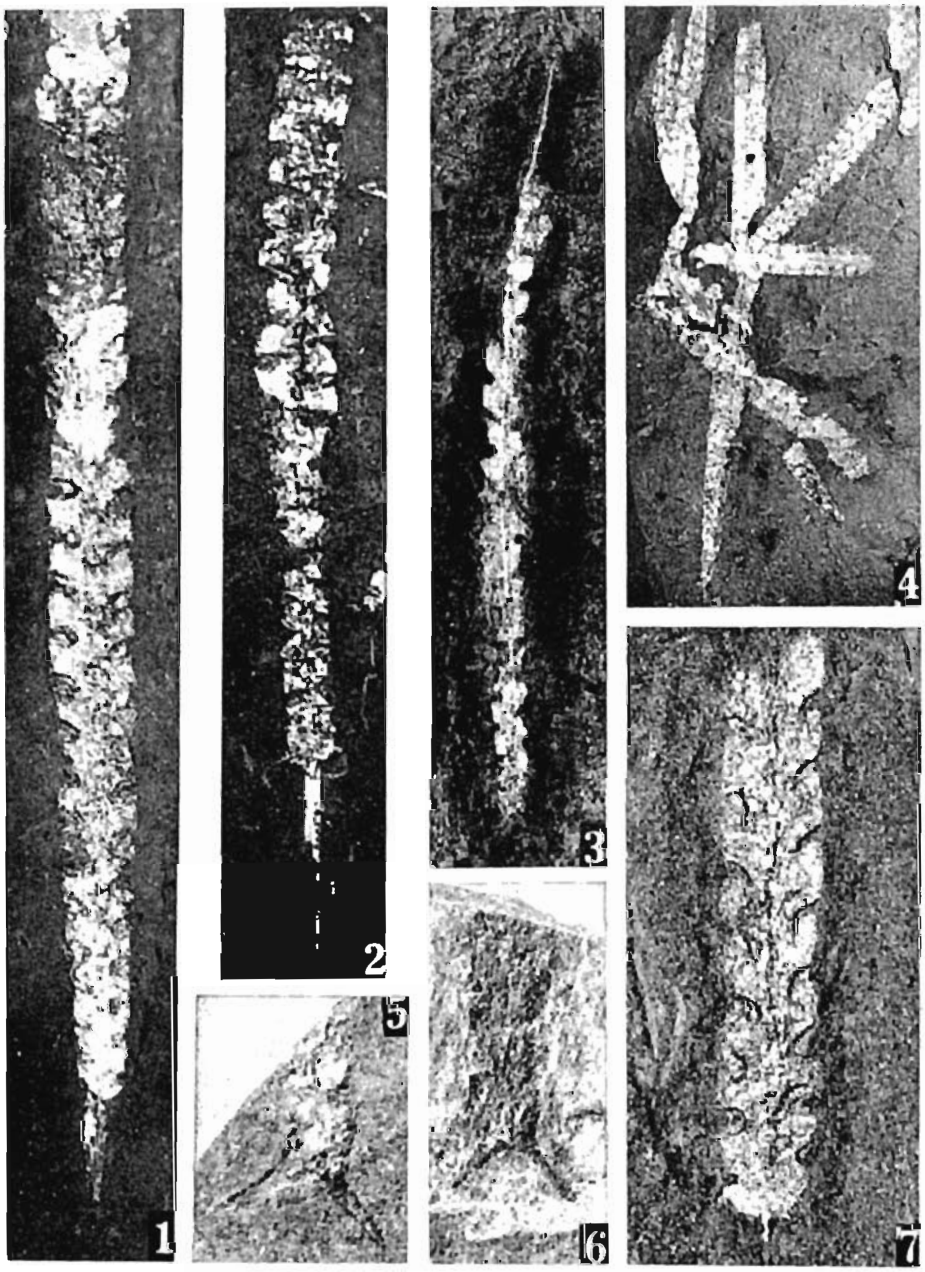
1 — *Dicranograptus brevicaulis* Elles & Wood; Piaśnica *2*, 2646.3—2645.3 m, ×2.
2 — *Climacograptus antiquus antiquus* Lapw.; Dębki *3*, 2642.8—2641.8 m, ×3.5.
3 — *Diplograptus multidens* Elles & Wood; Białogóra *2*, 2623.3—2622.3 m, ×10.
4 — *Diplograptus compactus* Elles & Wood; Białogóra *1*, 2647.6—2646.6 m, ×3.
5 — *Dicellograptus divaricatus salopiensis* Elles & Wood; proximal part, Białogóra *1*, 2673.1—2672.1 m, ×10.



1 — *Climacograptus kuckersianus* Wiman; Żarnowiec *5*, 2673.0—2672.0 m, ×10.
2 — *Climacograptus brevis* Elles & Wood; Białogóra *1*, 2674.1—2673.1 m, ×7.
3 — *Climacograptus brevis* cf. *mutabilis* Strachan; Białogóra *1*, 2639.6—2638.5 m, ×12.
4 — *Pseudoclimacograptus* (*P.*) *scharenbergi stenostoma* (Bulman); Białogóra *1*, 2674.1—2673.1 m, ×8.
5—6 — *Diplograptus* sp. *1*; Białogóra *2*, 2623.3—2622.3 m; 5 ×4, 6 — proximal part, ×7.
7 — *Amplexograptus* cf. *fallax* Bulman; Piaśnica *2*, 2644.3—2643.3 m, ×4.
8 — *Diplograptus* cf. *pristis* (Hisinger); Białogóra *1*, 2643.6—2642.6 m, ×3.



1, 7 — *Climacograptus spiniferus* Ruedemann; *1* — Białogóra *2*, 2616.2—2615.2 m, ×12; *7* — Dębki *2*, 2597.7—2596.7 m, ×8.
2—3 — *Amplexograptus arctus* Elles & Wood; Białogóra *1*, 2670.9—2669.9 m, ×8.
4 — *Amplexograptus perexcavatus* (Lapworth); Plaśnica *2*, 2645.3—2644.3 m, ×5.
5 — *Climacograptus angustus* (Perner); Białogóra *2*, 2614.2—2613.2 m, ×12.
6 — *Pseudoclimacograptus* sp.; Żarnowiec *5*, 2669.0—2668.0 m, ×10.



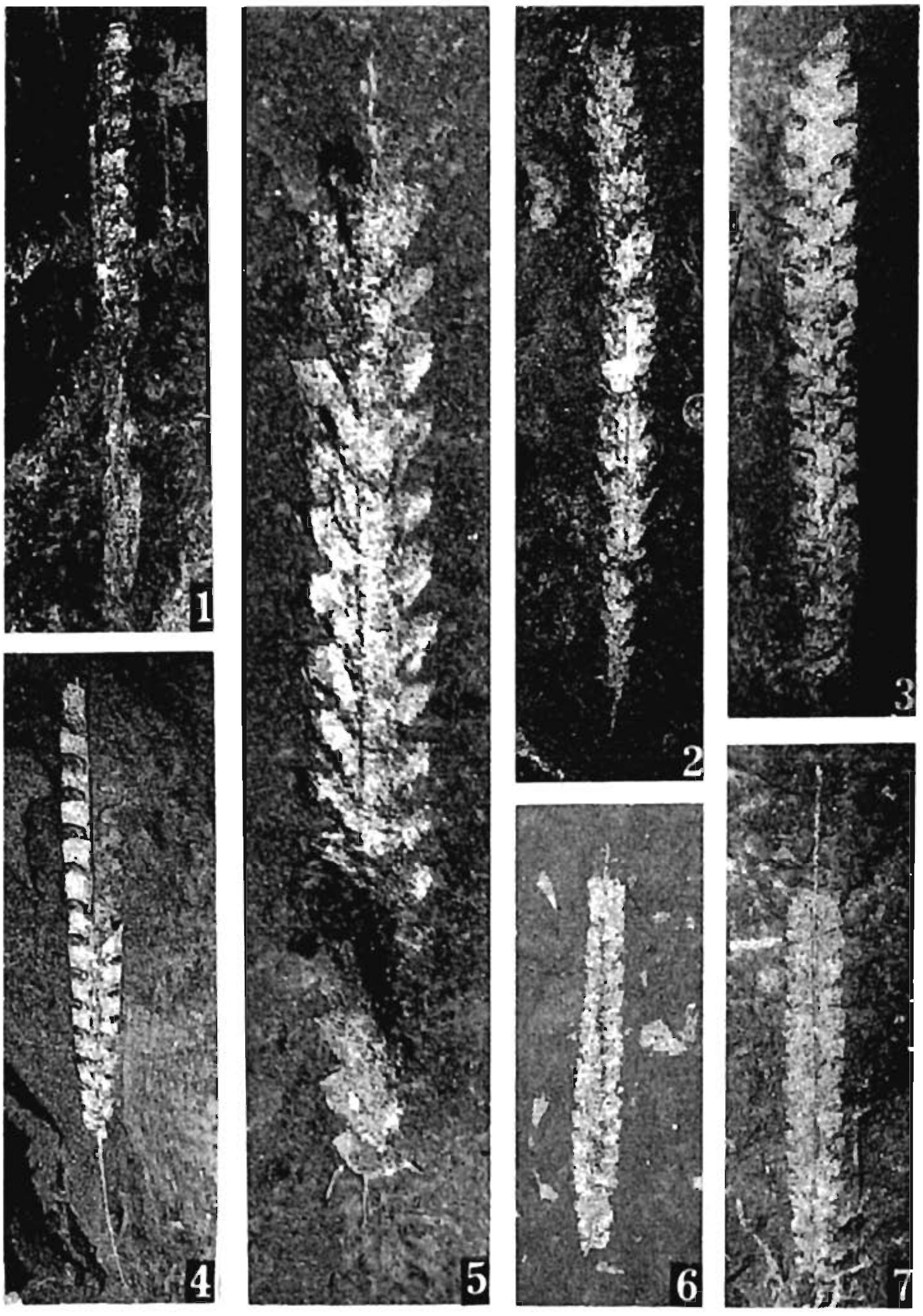
1—2 — *Climacograptus antiquus antiquus* Lapworth; *1* — Dębki 3, 2645.0—2644.0 m, ×6; *2* — Białogóra 1, 2675.6—2674.1 m, ×5.

3 — *Climacograptus brevis* Elles & Wood; Dębki 3, 2648.2—2647.2 m, ×5.

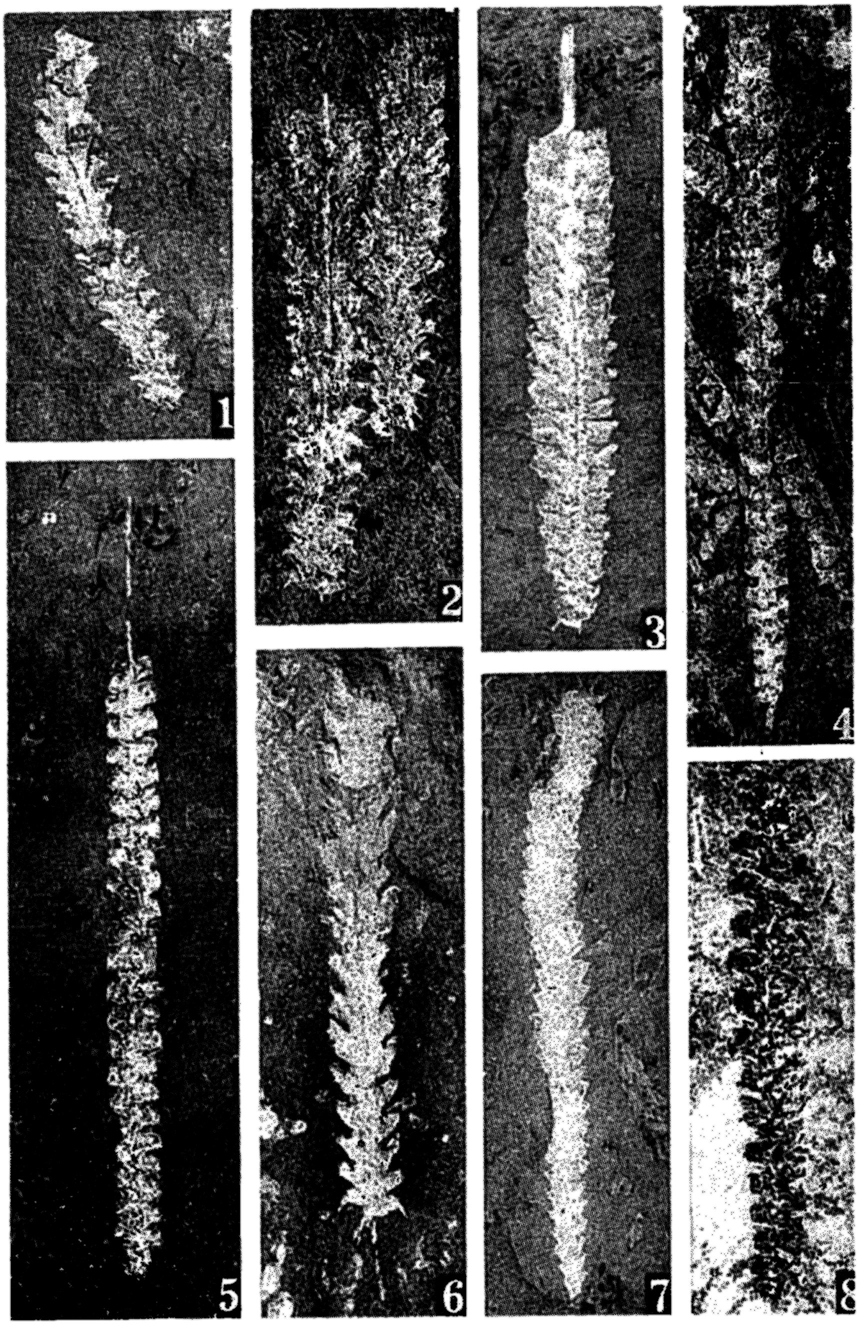
4 — *Climacograptus styloideus* Elles & Wood; Dębki 2, 2597.7—2596.7 m, ×2.

5—6 — *Climacograptus bicornis bicornis* (Hall); *5* — Białogóra 2, 2614.2—2613.2 m, ×5; *6* — Białogóra 2, 2619.3—2618.2 m, ×12.

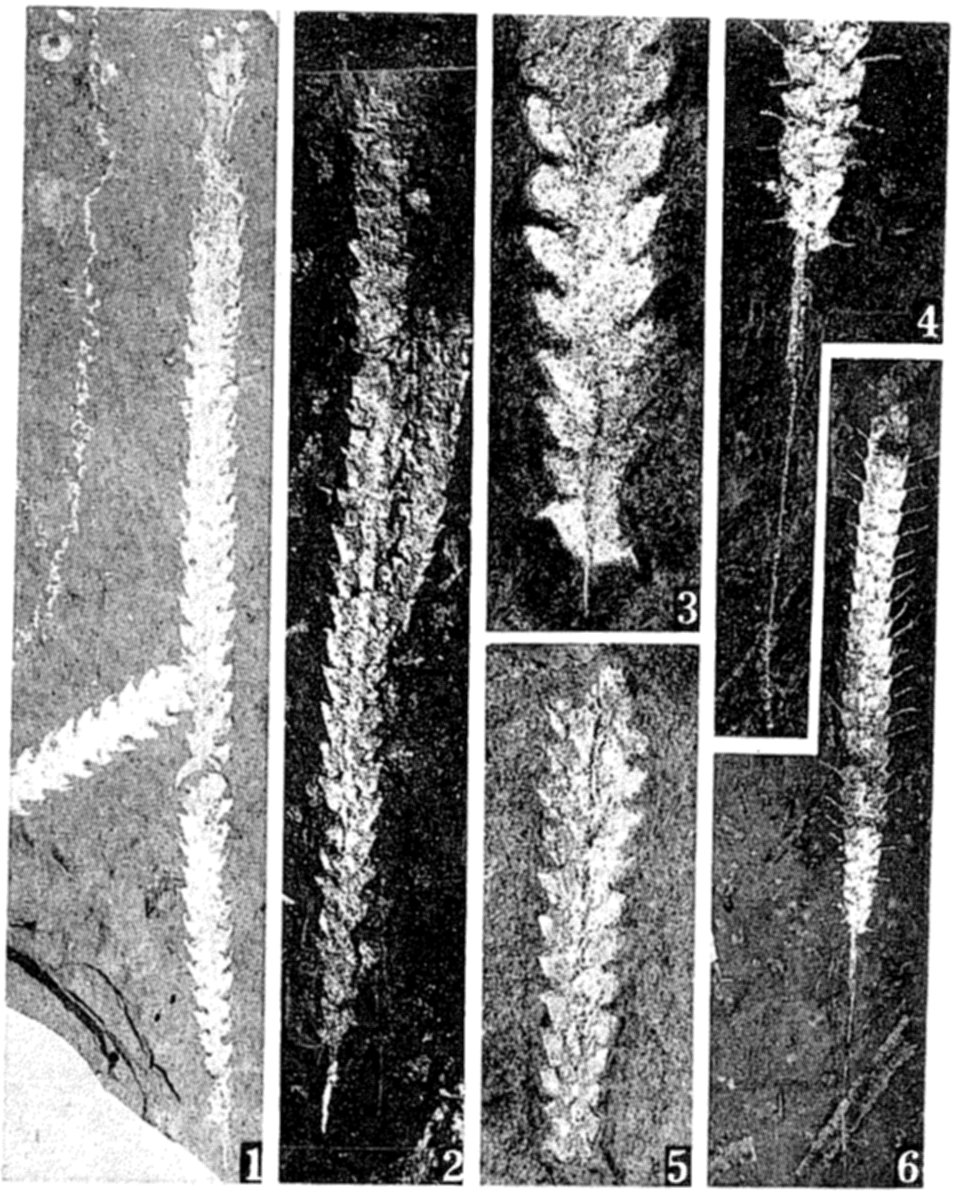
7 — *Pseudoclimacograptus* aff. *westrogothicus* Jaanusson & Skoglund; Białogóra 1, 2668.9—2667.9 m, ×10.



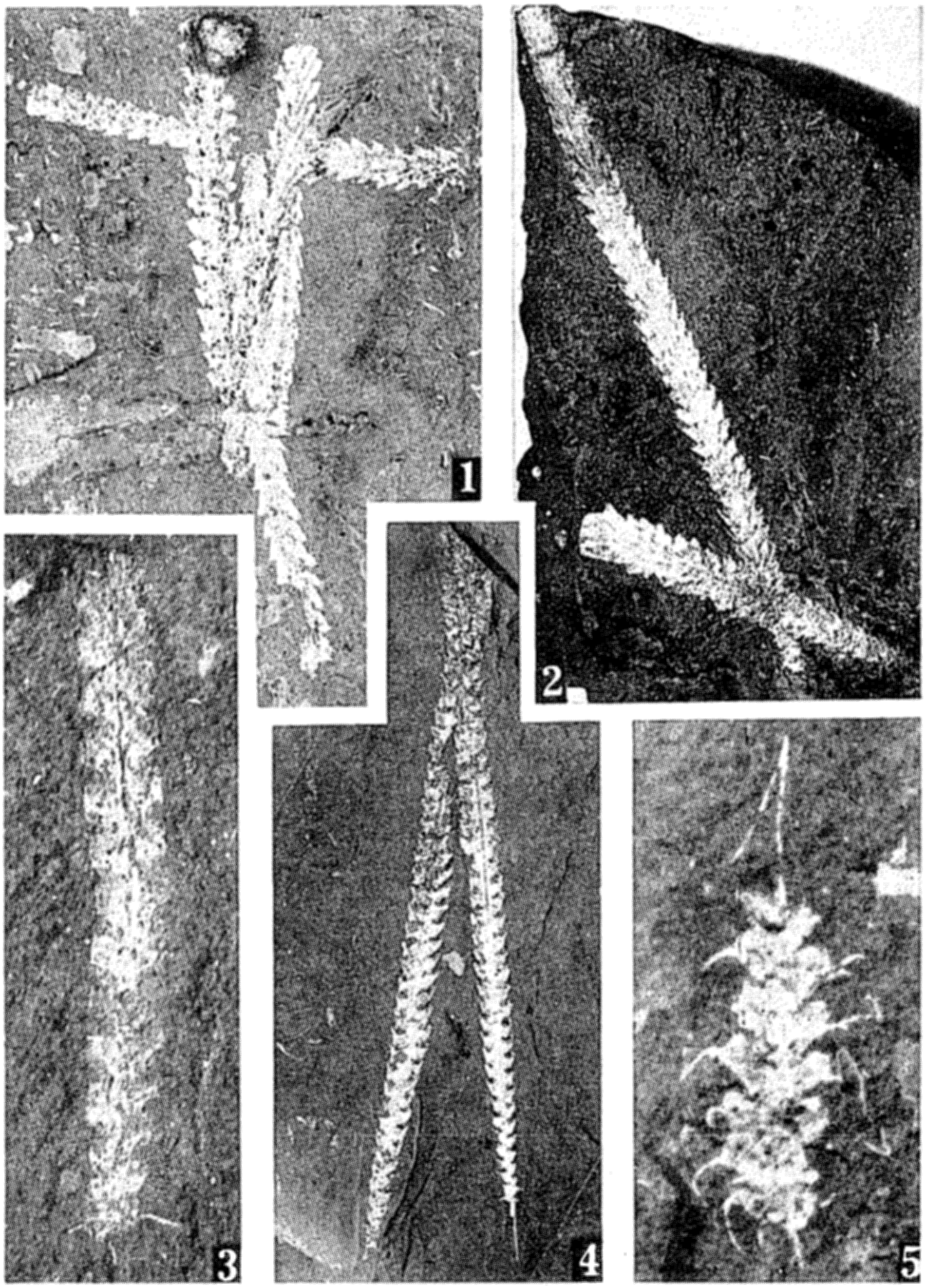
1 — *Climacograptus wilsoni* Lapworth; Białogóra *1*, 2669.9—2668.9 m, × 5.
2 — *Glyptograptus teretiusculus* (His.); Białogóra *1*, 2674.1—2673.1 m, ×4.
3 — *Climacograptus* sp. *2*; Piaśnica *2*, 2648.6—2647.3 m, ×5.
4 — *Climacograptus* cf. *caudatus* Lapw.; Białogóra *2*, 2614.2—2613.2 m, ×5.
5 — *Glyptograptus* sp. *1*; Białogóra *1*, 2657.7—2656.7 m, ×6.
6—7 — *Climacograptus minimus* Carruthers; *6* — Łeba *8*, 2671.8—2670.8 m, ×4; *7* — Łeba *8*, 2666.8—2665.8 m, ×4.



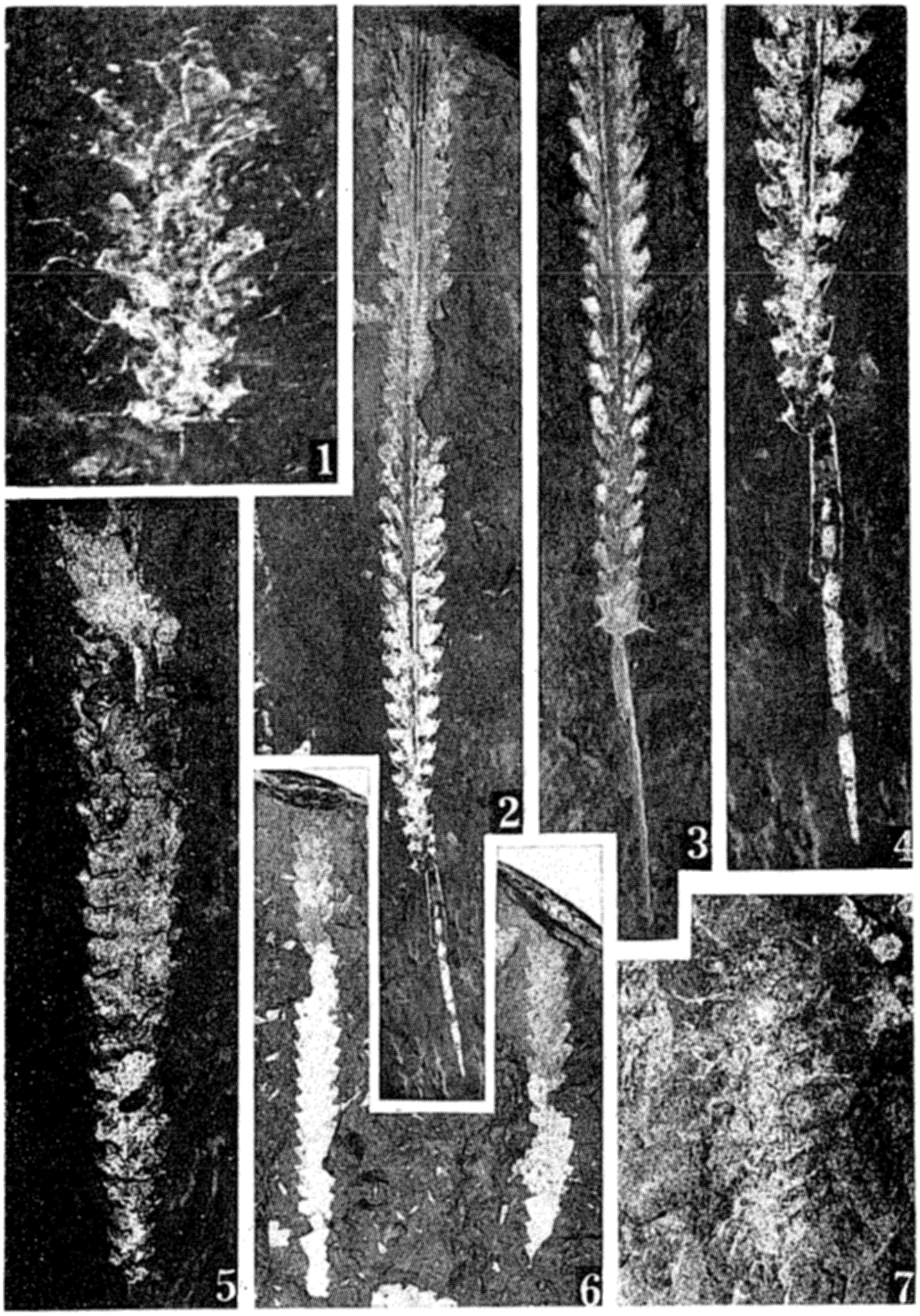
1 — *Diplograptus multidens* Elles & Wood; Łeba *8*, 2707.5—2706.5 m, ×4.
2 — *Climacograptus bekkeri* (Öpik); Białogóra *1*, 2673.1—2672.1 m, ×5.
3 — *Orthograptus calcaratus vulgatus* Elles & Wood; Białogóra *2*, 2622.3—2621.3 m, ×4.
4 — *Climacograptus antiquus antiquus* Lapw.; Białogóra *1*, 2670.1—2669.9 m, ×3.5.
5, 8 — *Pseudoclimacograptus (P.) scharenbergi scharenbergi* (Lapw.); *5* — Piaśnica *2*, 2646.3—2645.3 m, ×3; *8* — Białogóra *1*, 2674.1—2673.1 m, ×7.
6 — *Glyptograptus* sp. *2*; Piaśnica *2*, 2645.3—2644.3 m, ×4.
7 — *Orthograptus truncatus truncatus* (Lapw.); mature stage, 2597.7—2596.7 m, ×3.



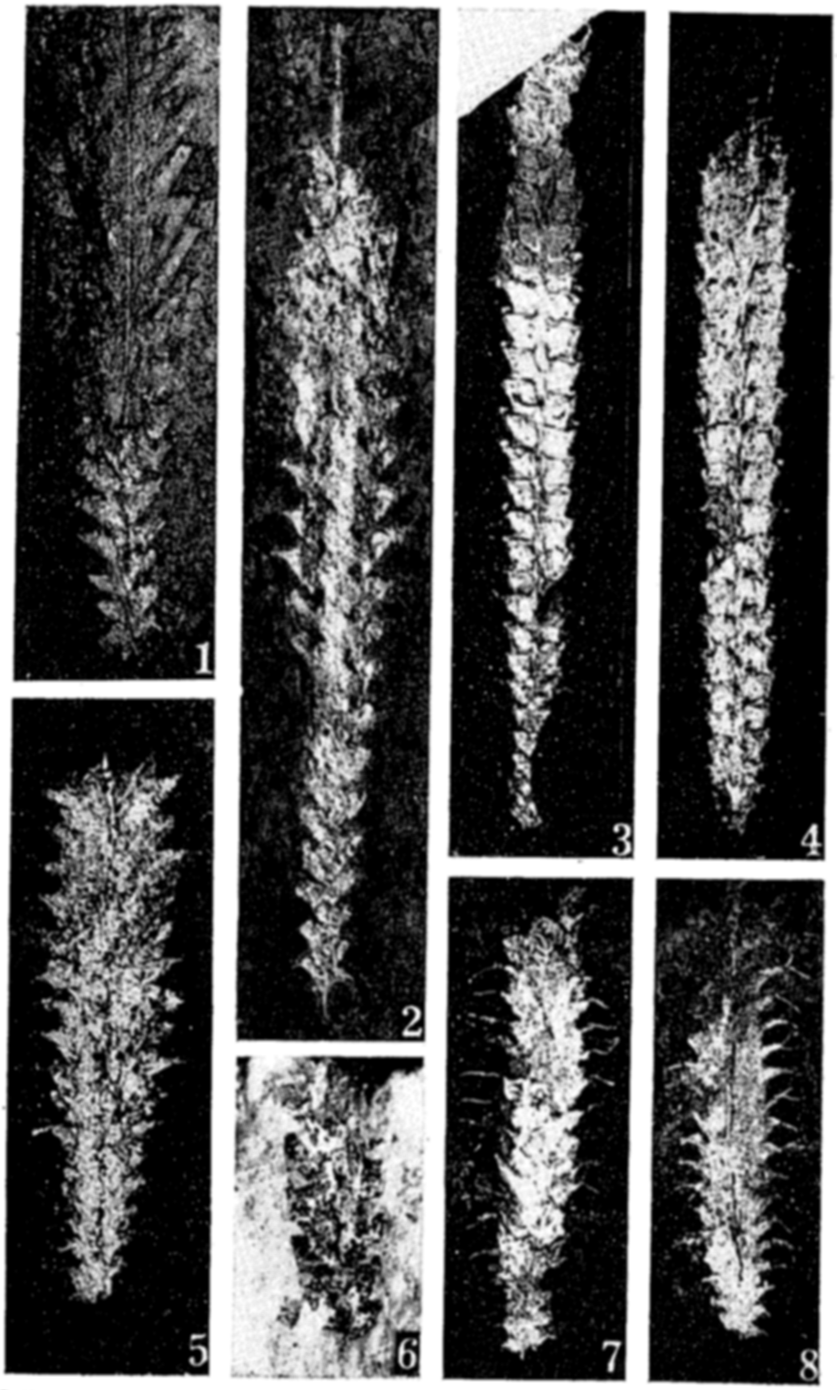
1—2 — *Glyptograptus teretiusculus* (His.); Piaśnica *2*, 2646.3—2645.3 m; *1* ×3; *2* ×4.
3 — *Glyptograptus cernuus* Jaanusson; Piaśnica *2*, 2647.3—2646.3 m, ×10.
4, 6 — *Orthograptus whitfieldi* (Hall); Białogóra *1*, 2674.1—2673.1 m; *4* — proximal part, ×6; *6* ×2.5.
5 — *Orthograptus truncatus truncatus* (Lapw.); juvenile stage, Białogóra *2*, 2614.2—2613.2 m, ×7.



1 — *Orthograptus truncatus pauperatus* Elles & Wood; Łeba *8*, 2669.8—2668.8 m, ×3.
2 — *Orthograptus calcaratus vulgatus* Elles & Wood; Białogóra *2*, 2617.2—2616.2 m, ×2.
3 — *Climacograptus* sp. *1*; Białogóra *1*, 2668.9—2667.9 m, ×10.
4 — *Glyptograptus teretiusculus* (His.); Białogóra *1*, 2674.1—2673.1 m, ×2.
5 — *Lasiograptus harknessi* (Nich.); Białogóra *2*, 2621.3—2620.3 m, ×10.



1 — *Lasiograptus costatus* Lapw.; Mieroszyno *8*, 2813.0—2812.0 m, ×10.
2—4 — *Orthograptus calcaratus calcaratus* (Lapw.); *2, 4* — Białogóra *2*, 2622.3—2621.3 m, *2* ×3, *4* — proximal part, ×6; *3* — Białogóra *1*, 2647.6—2646.6 m, ×4.
5 — *Orthograptus calcaratus acutus* Elles & Wood; Białogóra *1*, 2668.9—2667.9 m, ×4.
6 — *Orthograptus truncatus intermedius* Elles & Wood; Łeba *8*, 2669.8—2668.8 m, ×3.
7 — *Lasiograptus* cf. *costatus* Lapw.; Dębki *3*, 2642.8—2641.8 m, ×7.



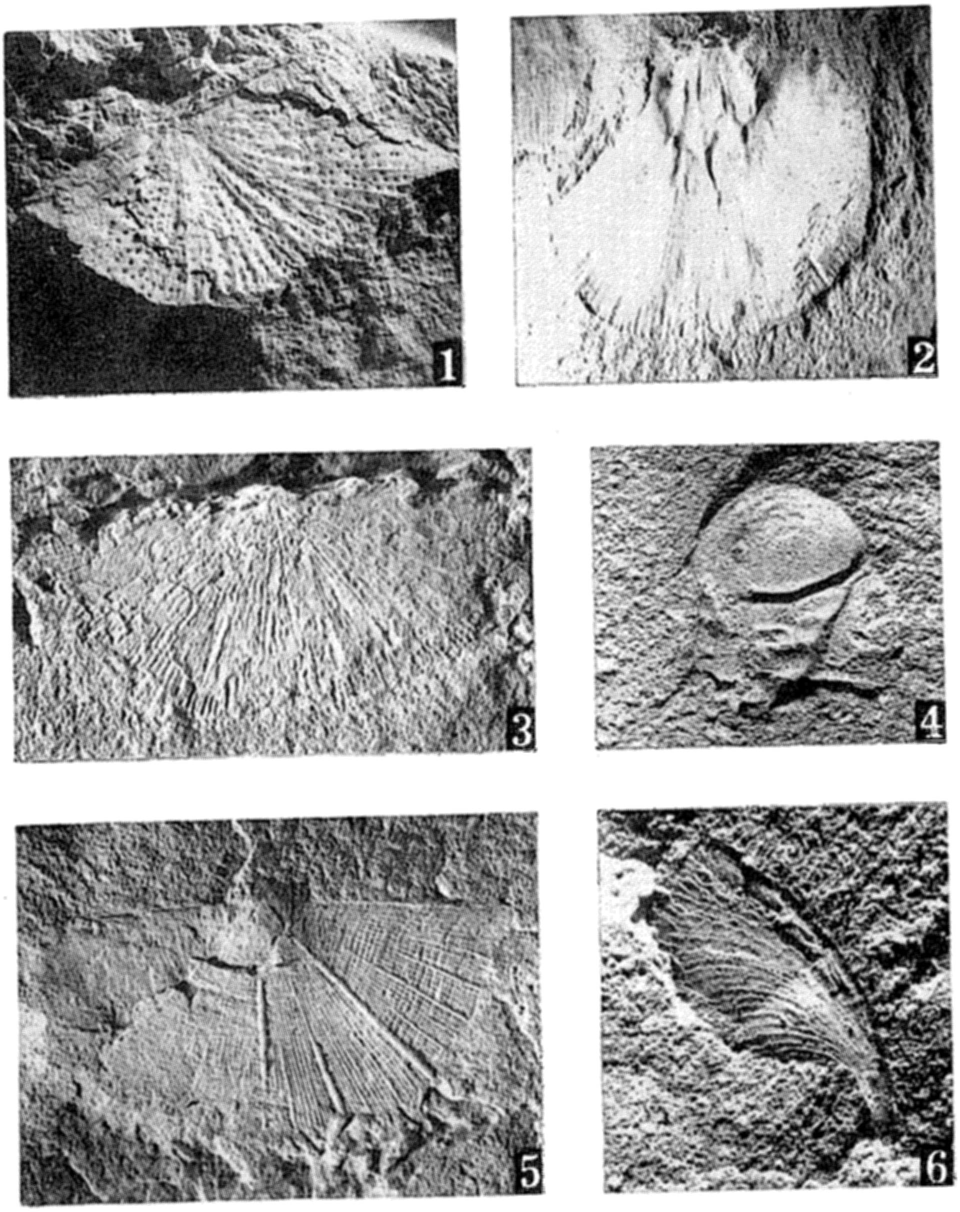
1—2 — *Orthograptus apiculatus* (Elles & Wood); *1* — Piaśnica *2*, 2646.3—2645.3 m, ×6; *2* — Łeba *8*, 2709.5—2708.5 m, ×6.

3—4 — *Orthograptus quadrimucronatus quadrimucronatus* (Hall); *3* — Dębki *2*, 2597.7—2596.7 m, ×4, *4* — Białogóra *2*, 2614.2—2613.2 m, ×5.

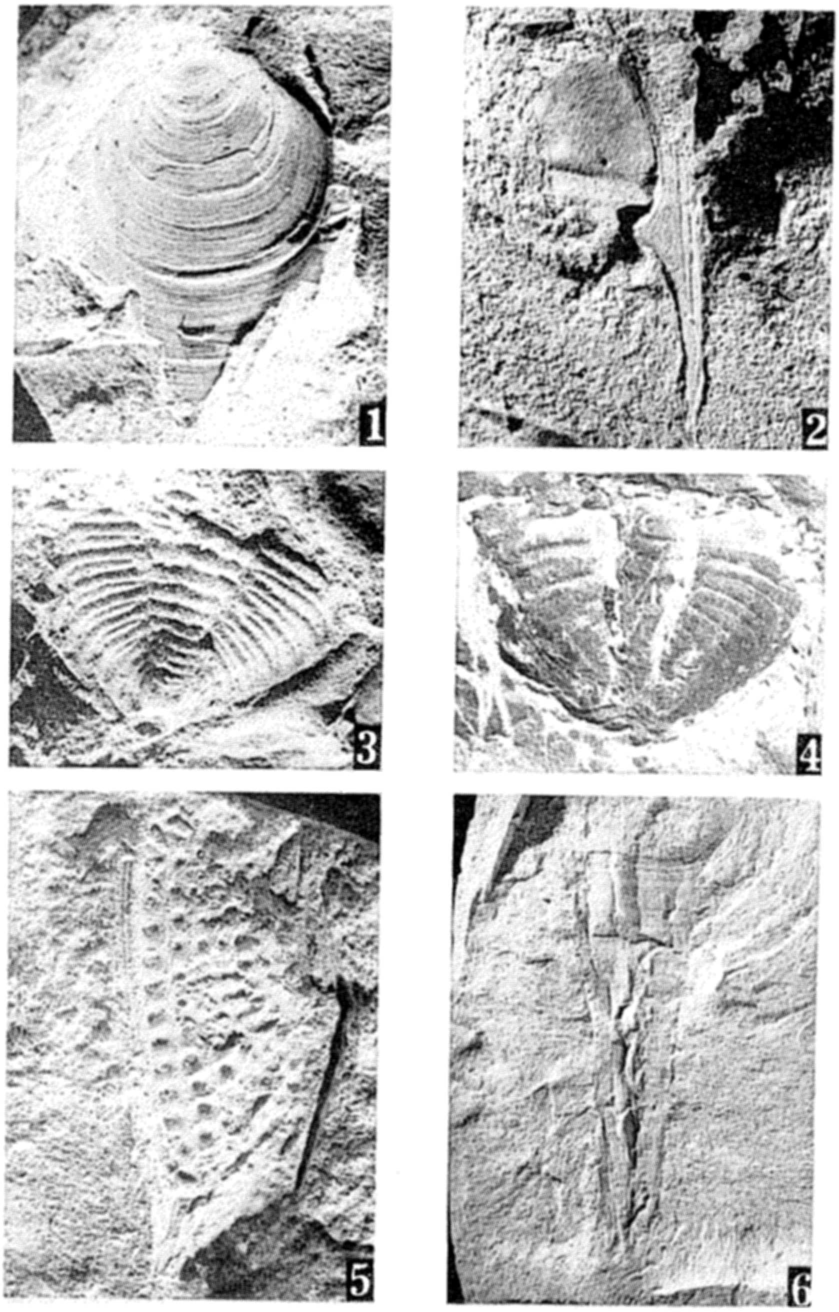
5 — *Hallograptus* sp.; Piaśnica *2*, 2646.3—2645.3 m, ×5.

6 — *Pseudoclimacograptus (P.) clevensis* Skoglund; Dębki *2*, 2596.7—2595.7 m, ×10.

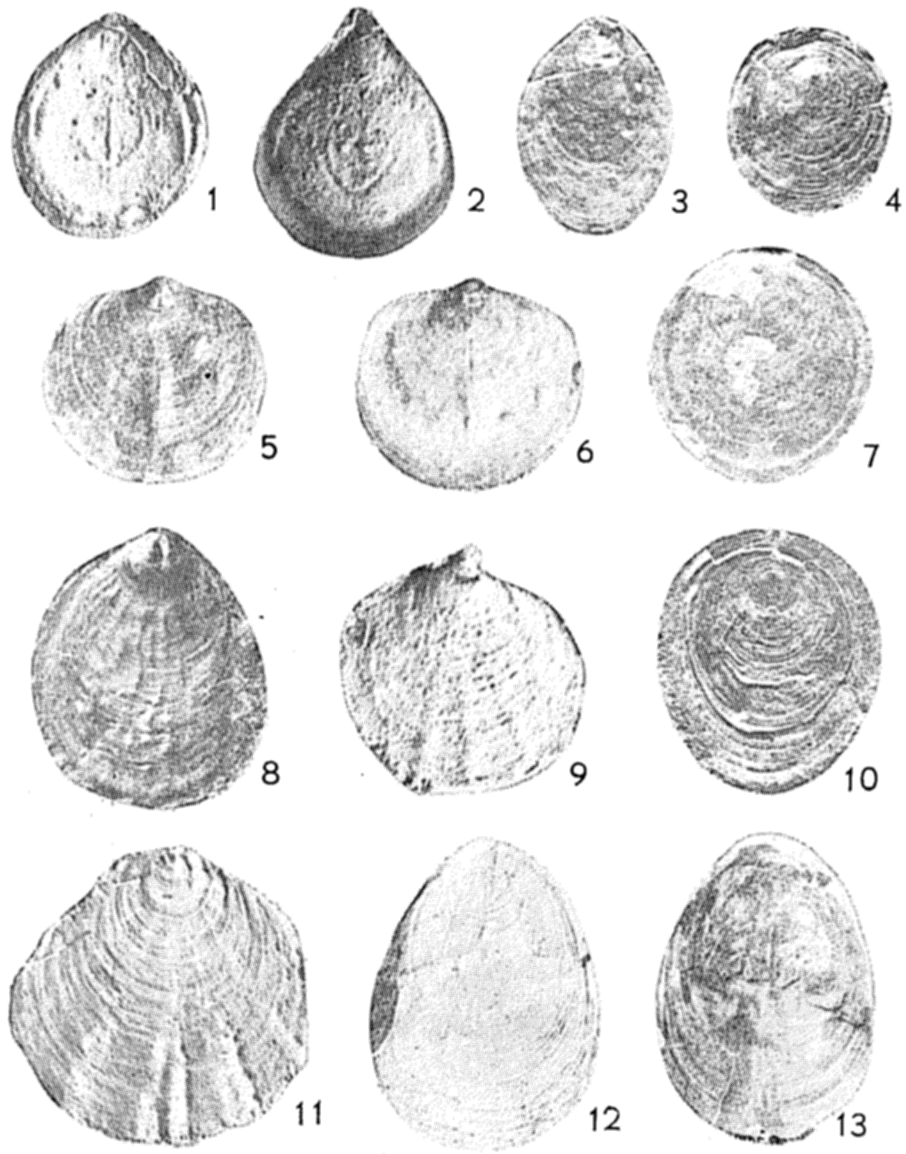
7—8 — *Hallograptus mucronatus mucronatus* (Hall); Piaśnica *2*, 2646.3—2645.3 m, *7* ×4, *8* ×4.



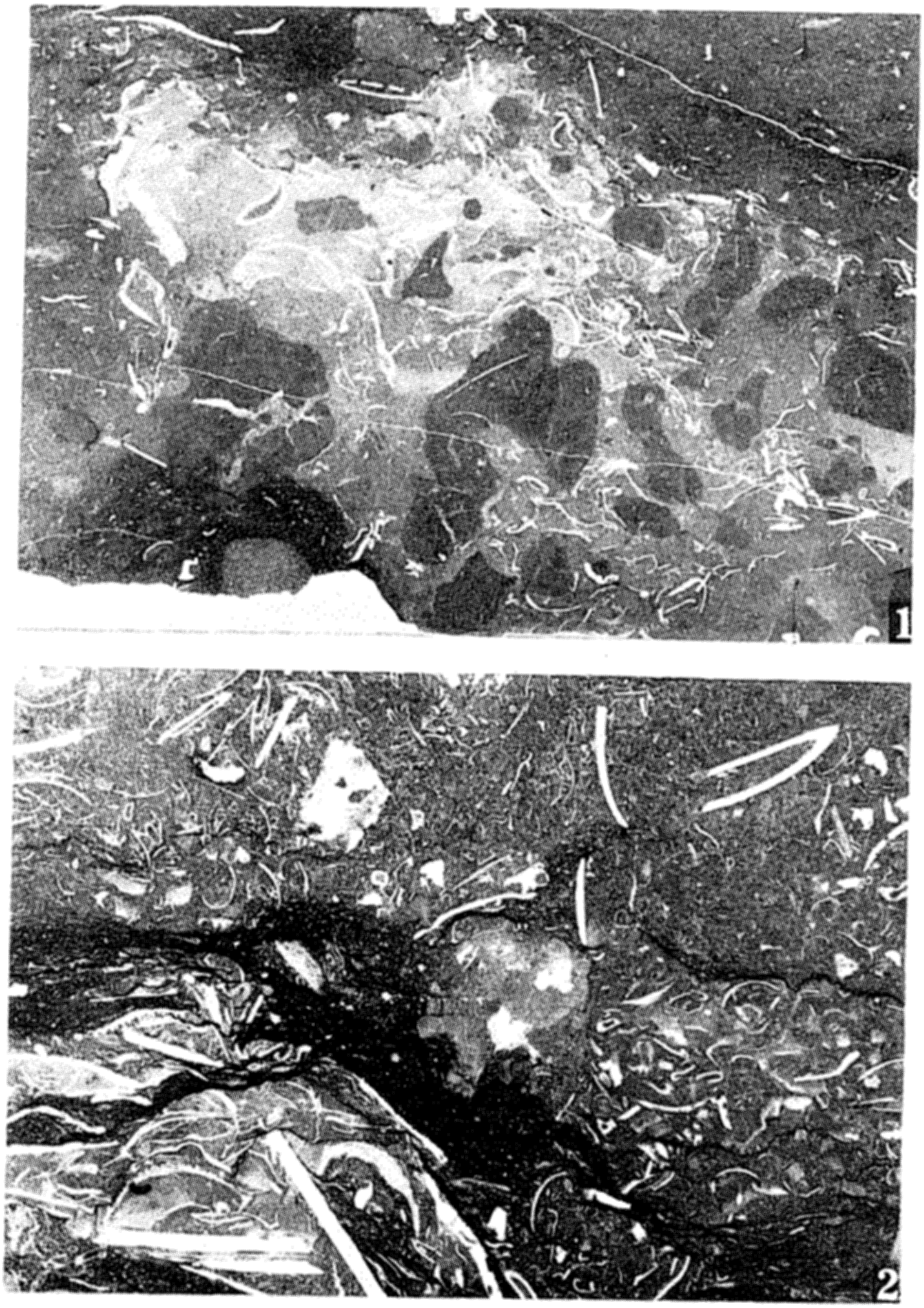
1 — *Eostropheodonta hirnantensis* (M'Coy); Białogóra *1*, 2630.3—2629.0, ×3.
2 — *Hirnantia sagittifera* (M'Coy); Białogóra *2*, 2605.5—2604.5 m, ×2.
3 — ?*Sowerbyella sericea* (Sowerby); Białogóra *1*, 2658.7—2657.7 m, ×8.
4 — *Mucronaspis* cf. *mucronata* (Brongniart); cephalon, Białogóra *2*, 2608.5—2607.5 m, ×6.
5 — *Sowerbyella rosetana* Henningsmoen; Piaśnica *2*, 2648.3—2647.3 m, ×7.
6 — ?*Opsimasaphus* sp.; Dębki *2*, 2595.7—2594.7 m, ×12.



1 — *Lingula* sp.; Piaśnica *2*, 2645.3—2644.3 m, ×8.
2 — ?*Phillipsinella parabola* (Barrande); Białogóra *2*, 2608.5—2607.5 m, ×6.
3 — *Mucronaspis mucronata* (Brongniart); Białogóra *2*, 2606.5—2605.5 m, ×6.
4 — *Calliops* sp. cf. *callicephalus* (Had); Dębki *2*, 2596.7—2595.7 m, ×5.
5 — *Tretaspis* sp.; Dębki *2*, 2595.7—2594.7 m, ×6.
6 — *Orthoceras* sp.; Białogóra *1*, 2662.9—2661.9 m, ×3.



1 — *Obolus elatus* Hadd.; Dębki *3*, 2645.0—2644.0 m, ×10.
2 — *Obolus* sp.; Białogóra *1*, 2675.6—2674.1 m, ×10.
3 — *Lingulella dicellograptorum* Hadd.; Dębki *2*, 2597.7—2596.2 m, ×10.
4, 10 — *Paterula portlocki* (Geinitz); Dębki *2*, 2597.7—2596.7 m, ×10.
5—6 — *Hisingerella nitens* (His.); Piaśnica *2*, ×15; *5* — 2645.3—2644.3 m; *6* — 2648.6—2647.3
7 — *Paterula bohemica* Barrande; Piaśnica *2*, 2646.3—2645.3 m, ×10.
8 — *Obolus ornatus* Hadd.; Dębki *2*, 2597.7—2596.7 m, ×10.
9, 11 — *Obolus kiaeri* Hadd.; ×10; *9* — Dębki *3*, 2646.2—2645.0 m; *11* — Białogóra *1*, 2669, 2668.9 m.
12—13 — *Lingula* sp.; *12* — Białogóra *2*, 2634.0—2633.0 m, ×4; *13* — Piaśnica *2*, 2645.3—2644.3 ×3.



Organodetrital Limestone Formation

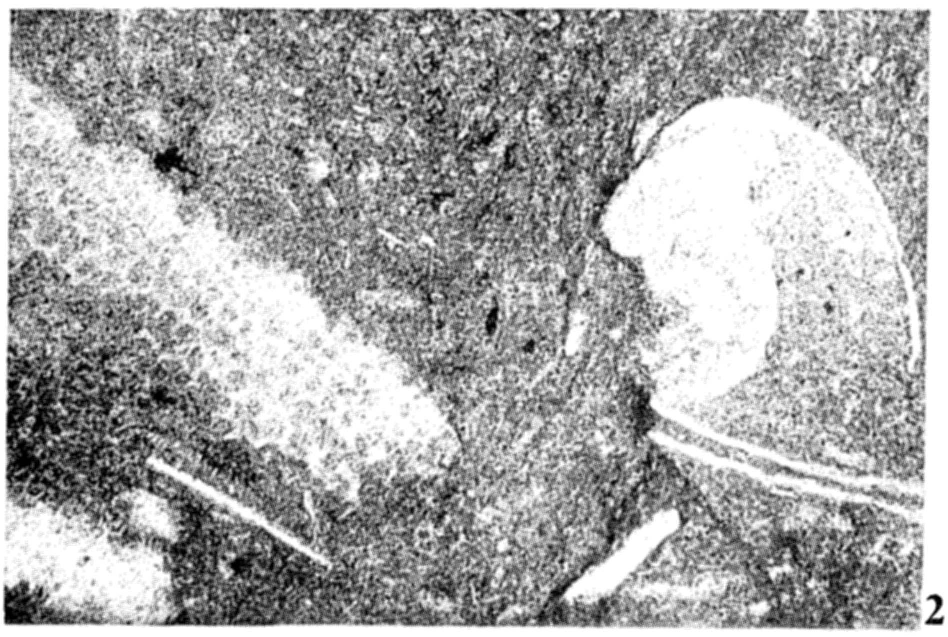
1 — Marly-micritic organodetrital limestone with nodular structure; fragmental carapaces of trilobites and ostracods, and shells of brachiopods visible among the bioclasts; Dębki 3, 2657.4—2656.4 m, ×4.5.

2 — Marly-micritic organodetrital limestone showing streaks enriched in claystone substance; Piaśnica 2, 2651.3—2650.3 m, ×6.5.

Organodetrital Limestone Formation

1 — Marly-micritic organodetrital limestone showing corrosion of organic fossil remains on the boundary of strongly marly streaks; Dębki 3, 2654.4—2653.4 m, ×10.5.

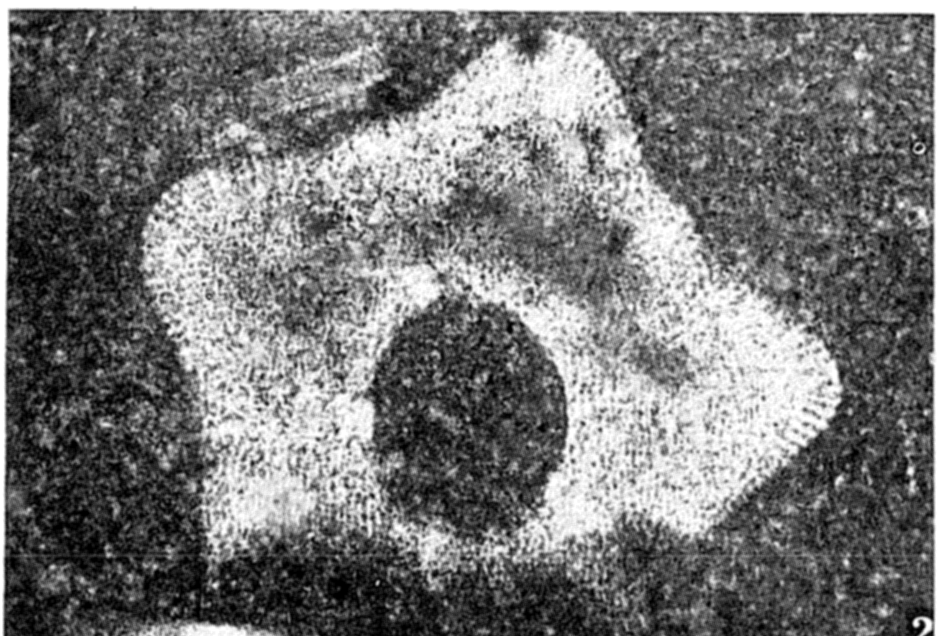
2 — Accumulation of badly crushed bioclasts: trilobite, brachiopod, bryozoan and crinoid remains; Dębki 2, 2636.1—2635.1 m, ×12.



Organodetrital Limestone Formation

1 — Marly-micritic organodetrital limestone showing a nodular structure; Dębki 3, 2655.4—2655.0 m, ×4.5.

2 — Section through a gastropod and a bryozoan colony; marly -micritic organodetrital limestone; Dębki 2, 2636.1—2635.1 m, ×60.

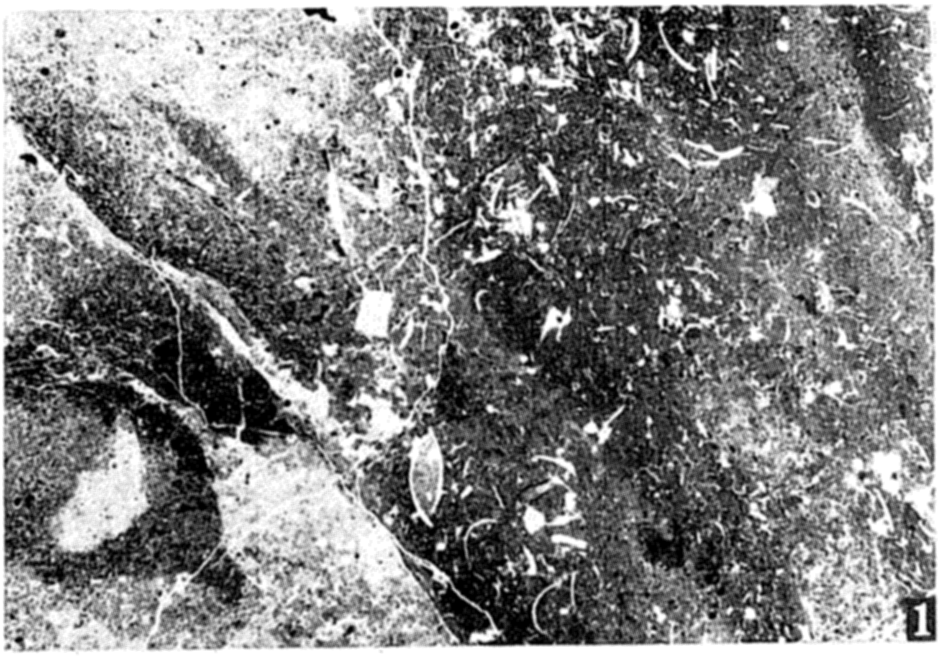


Organodetrital Limestone Formation

1 — Organic fossil remains in marly-micritic limestone; note burrowings in a trilobite carapace; Dębki 3, 2657.4—2656.4 m, ×80.

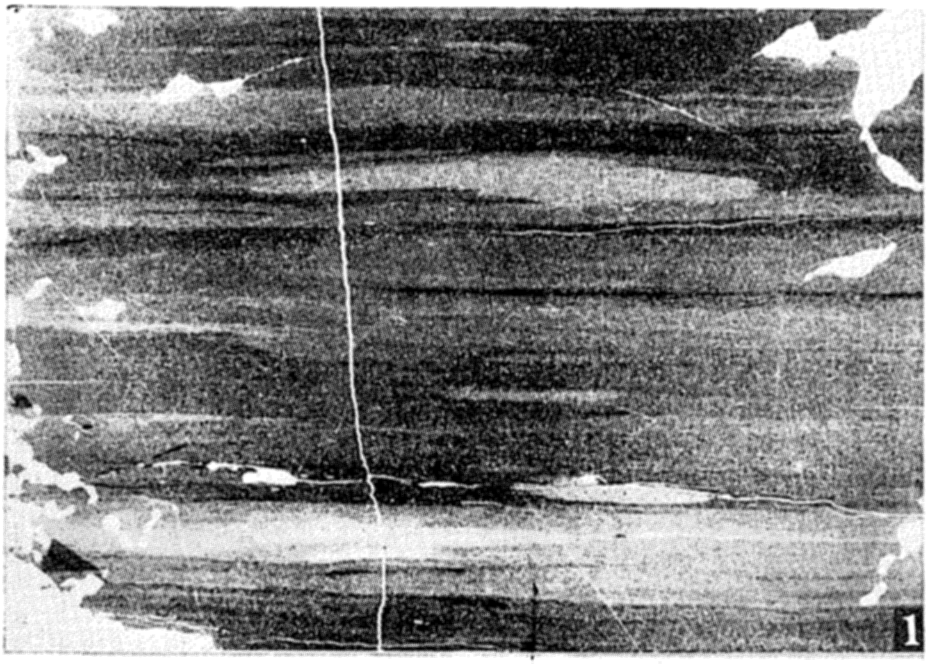
2 — Cross section of a crinoidal trochite; Piaśnica 2, 2651.3—2650.3 m, ×90.

1—2 — Graptolitic Claystone Formation; Marly Claystone Member; phosphorite concretions, Dębki *3*, 2649.2—2648.2 m, ×4.5



Graptolitic Claystone Formation, Marly Claystone Member

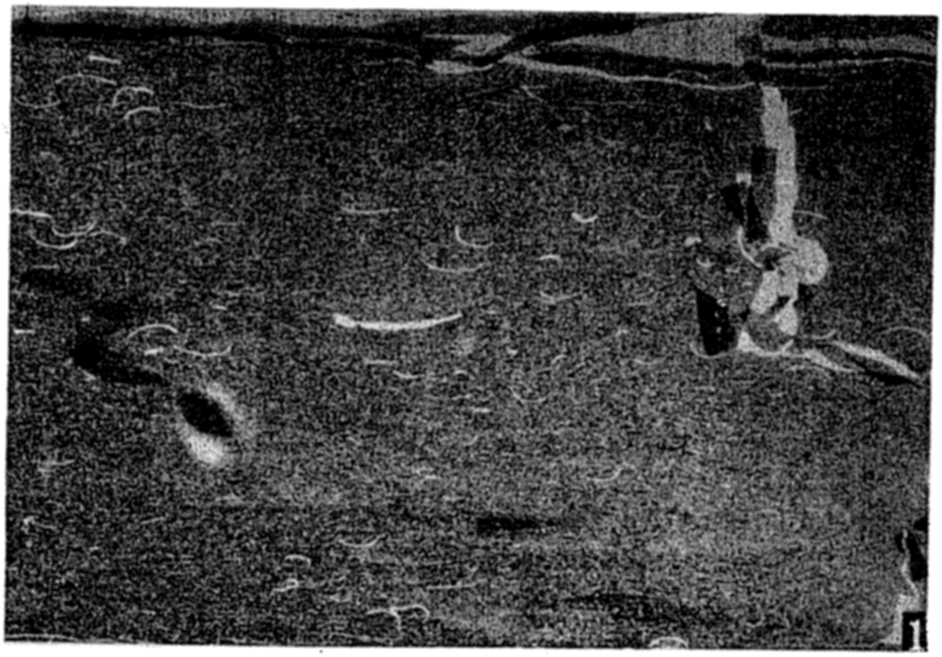
1 — Fragmental organic remains in a phosphorite concretion; Dębki 3, 2649.2—2648.2 m, ×16.
2 — Lamiae with ferrous ocoids, lower down phosphorite concretion; Łeba 8, 2712.3—2712.0 m, ×6.5.

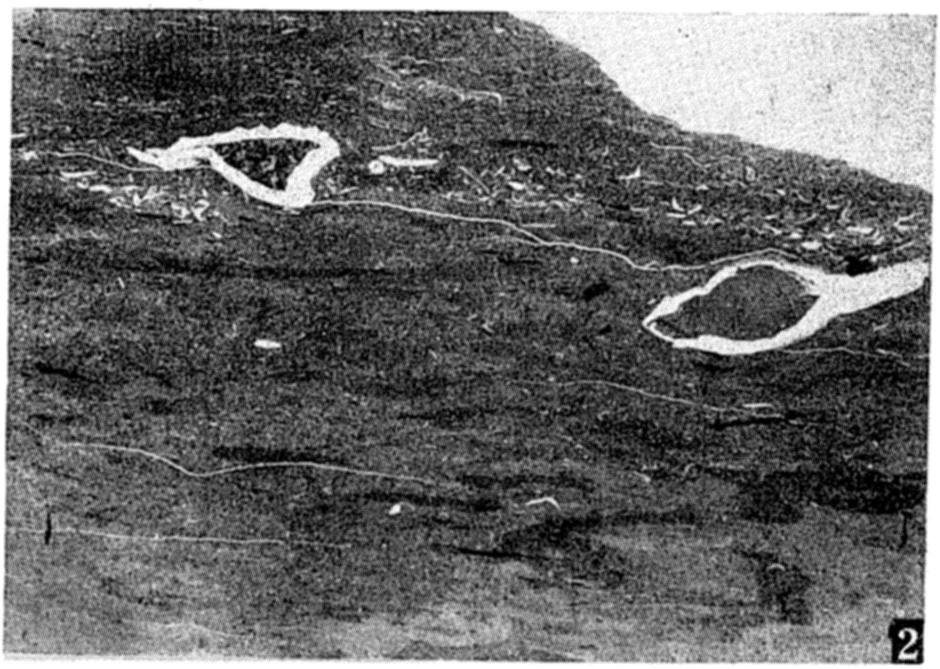


Graptolitic Claystone Formation

1 — Parallel flat lamination in claystone with occasionally detectable streaking; Dębki *2*, 2597.7—2596.7 m, ×4.5.

2 — Spotted claystone with variable bituminuous substance content; Białogóra *1*, 2656.7—2655.7 m, ×4.5.

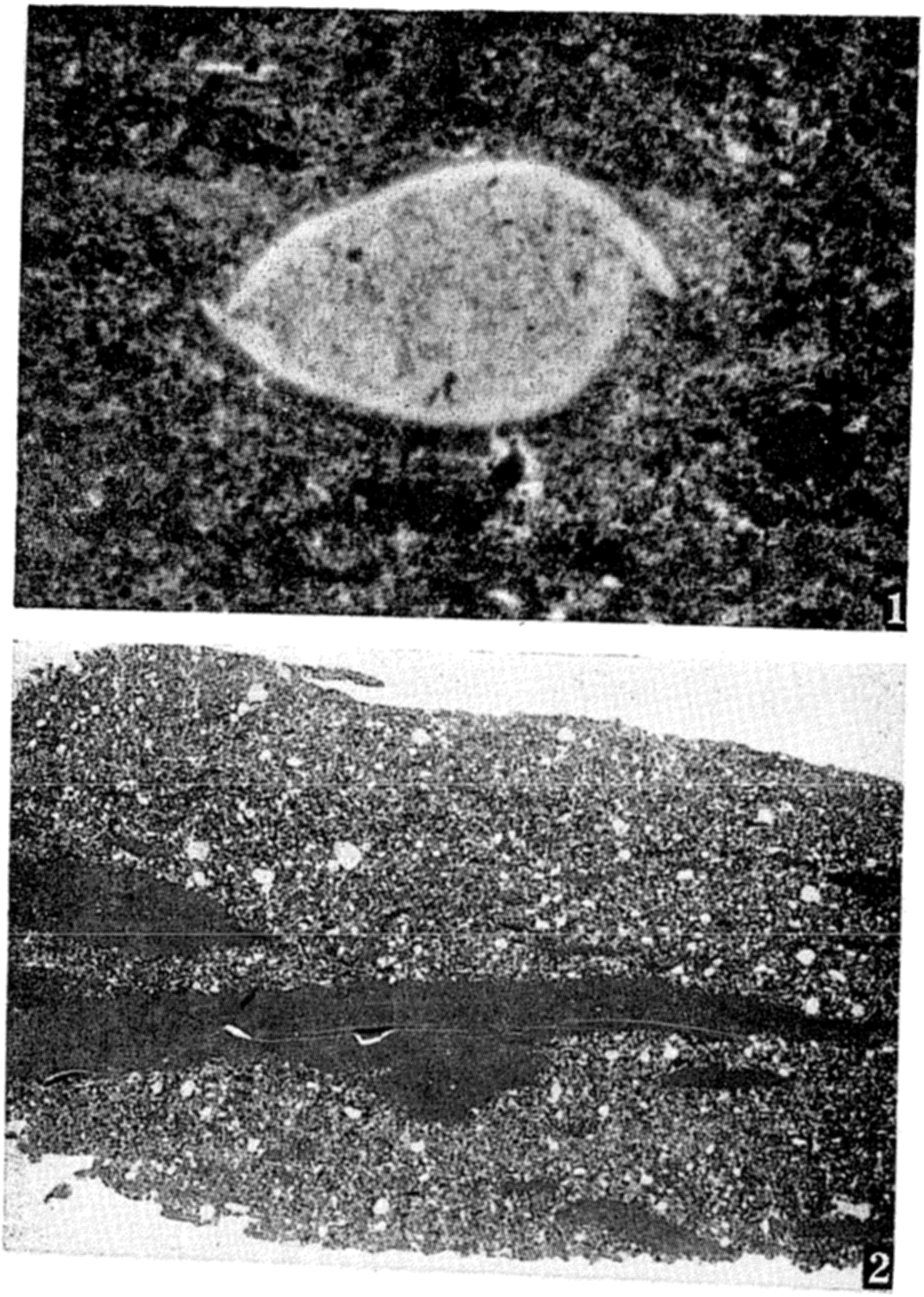




Graptolitic Claystone Formation

1 — Non-laminated marly claystone with rare ostracod remains; Dębki 3, 2642.8—2641.8 m, ×6.5.

2 — Claystone with probably re-deposited organic remains; absence of abrasion in the brachiopod shells indicates near transport; Białogóra 2, 2633.0—2632.0 m, ×4.5.



1 — Graptolitic Claystone Formation; marly claystone, section through complete ostracod carapace; Dębki 3, 2645.0 m—2644.0 m, × 130.

2 — Marly Formation; alternating laminae of sandy and marly-micritic limestone; Dębki 2, 2595.7—2594.7 m, ×4.5.