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The Ordovician lithostratigraphy of the Peribaltic Depression (NE Poland)

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Proposal of the lithostratigraphical division of the Ordovician, epicontinental, clastic-carbonate deposits in Polish part of the Peribaltic Depression is presented. It is based entirely on the sections of deep boreholes. 15 lithostratigraphical units have been distinguished and defined within the Ordovician sequence, including 10 formations and 5 members. 5 formations have been created in the eastern and 5 in the western part of the depression. The lithology, stratigraphical position and palaeontological data of particular units are presented. Their boundaries have been established and stratotypical sections are proposed. Controversial aspects of the bio- and chronostratigraphy of the proposed division were pointed out.

INTRODUCTION

Lithostratigraphical problems of the Ordovician in the Peribaltic Depression have not been widely discussed so far. E. Tomczykowa (1962, 1964) was the first to make an attempt of the preparation of lithostratigraphical scheme and — for the western part of the depression — Z. Modliński and T. Topulos (1974). Later papers on the topic are by W. Bednarczyk and M. Turnau-Morawska (1975), T. Podhalańska (1980) and recently W. Bednarczyk (1996). As yet, all proposed divisions were informal and they concerned either selected areas of the depression or particular stratigraphical units of the Ordovician system.

The present study is based on 108 fully or partly cored borehole sections drilled in the studied area for various purposes, between 1991 and 1996, by the Polish Geological Institute, Polish Oil and Gas Company — Geological Bureaus: "Geonafta" in Wołomin and in Piła, and "Petrobaltic" — Oil and Gas Exploration and Production Company in Gdańsk. 67 boreholes were drilled in the eastern part of the depression, remaining 41 in its western part, including 14 in the Polish sector of the Baltic Sea. The total analysed interval of the Ordovician sections is 8200 m, including 2909 m of the core.

Data obtained from core analysis were completed and corrected by interpretations of resisitivity and neutron-gamma logs. 16 fully cored boreholes (13 drilled in the eastern and 3 in the western part of the area) served as a model for geophysical interpretations. Own observations and data were completed by published and unpublished materials of other authors, especially lithological, petrographical and concerning facies problems (A. Langier-Kuźniarowa, 1974, 1976). Unpublished results of own petrographical and biostratigraphical investigations (graptolites, trilobites and brachiopods) were also taken into consideration.

The formal criteria included in the "Polish Stratigraphical Code" (*Zasady...*, 1975) were accepted as a base for selection, classification and terminology of lithostratigraphical units created here. Formation is the principal lithostratigraphical unit in the scheme. Set of distinguished formations serves as a basic, regional lithostratigraphical division. Only in some cases formations have been subdivided into lower order units (i.e. members). Stratotypes and hypostratotypes were selected in sections where the critical interval was fully cored, what allows to recognize the development of sediments and character of boundaries of particular units.

Only macroscopical lithological features of sedimentary origin served as principal criteria for the unit definition. Influence of secondary processes, such as dolomitization, recrystallization and homogenization, very common in the Ordovician carbonate sequences, were intentionally omitted.

Names of the created or redefined units have extended their lithological parts, what is caused by a wish of essential

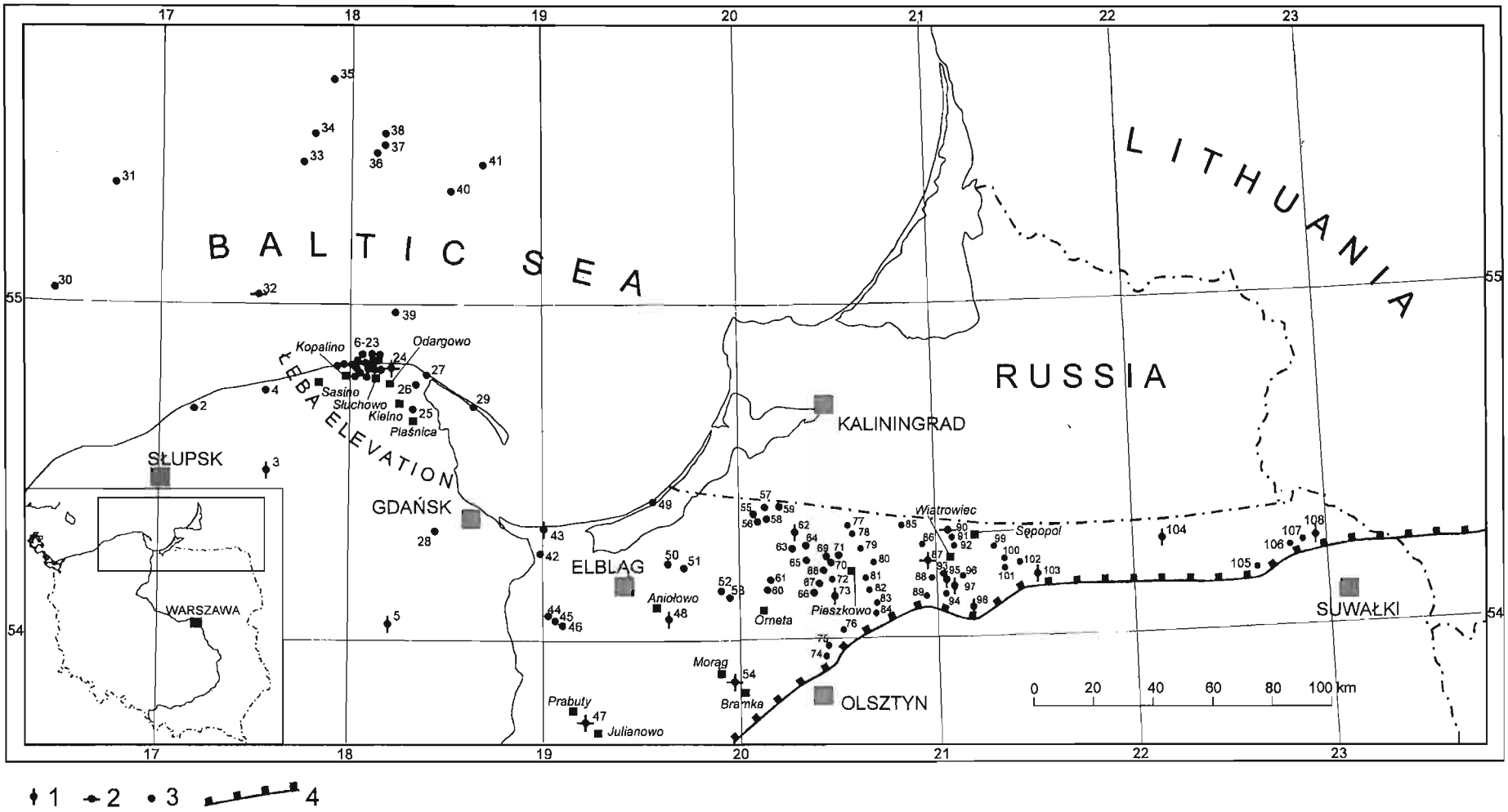


Fig. 1. Locality of the boreholes drilled in the Polish part of the Peribaltic Depression
1 — boreholes where the Ordovician rocks were fully cored; 2 — stratotypical borehole sections for the formations; 3 — other boreholes; 4 — present extent of the Ordovician deposits; boreholes: *1* — Słupsk IG 1, *2* — Smołdzino 1, *3* — Lębork IG 1, *4* — Łeba 8, *5* — Kościerzyna IG 1, *6* — Białogóra 1, *7* — Białogóra 6, *8* — Białogóra 2, *9* — Białogóra 3, *10* — Białogóra 4k, *11* — Żarnowiec 7, *12* — Żarnowiec 9k, *13* — Żarnowiec 8k, *14* — Żarnowiec 5, *15* — Dębki 3, *16* — Dębki 7, *17* — Dębki 2, *18* — Piaśnica 2, *19* — Dębki 4, *20* — Dębki 6, *21* — Dębki 6a, *22* —Żarnowiec IG 4, *23* — Żarnowiec IG 1a, *24* — Żarnowiec IG 1, *25* — Darżlubie IG 1, *26* — Mieroszyno 8, *27* — Władysławowo 4, *28* — Niestępowo 1, *29* — Hel IG 1, *30–41* — boreholes of P.P. „Petrobaltic", *42* — Nowa Kościelnica 1, *43* — Gdańsk IG 1, *44* — Malbork 2, *45* — Malbork IG 1, *46* — Malbork 3, *47* — Prabuty IG 1, *48* — Pasłęk IG 1, *49* — Krynica Morska 2, *50* — Młynary 3, *51* — Młynary 1, *52* — Gładysze 1, *53* — Gładysze 2, *54* — Olsztyn IG 2, *55* — Żelazna Góra 4, *56* — Żelazna Góra 5, *57* — Żelazna Góra 3, *58* — Żelazna Góra 1, *59* — Głębock 1, *60* — Henrykowo 5, *61* — Henrykowo 1, *62* — Dębowiec Warmiński 2, *63* — Dębowiec Warmiński 4, *64* — Dębowiec Warmiński 1, *65* — Dębowiec Warmiński 3, *66* — Zaręby 1, *67* — Zaręby 3, *68* — Glądy 3, *69* — Glądy 4, *70* — Zaręby 2, *71* — Glądy 1, *72* — Pieszkowo 1, *73* — Łaniewo 1, *74* — Dobre Miasto 3, *75* — Dobre Miasto 1, *76* — Dobre Miasto 2, *77* — Gałajny 2, *78* — Gałajny 1, *79* — Piasek 1, *80* — Wyręba 2, *81* — Rodnowo 1, *82* — Lidzbark Warmiński 3, *83* — Lidzbark Warmiński 1, *84* — Lidzbark Warmiński 2, *85* — Basze 1, *86* — Liski 1, *87* — Bartoszyce IG 1, *88* — Sokolica 1, *89* — Paluzy 1, *90* — Sępopol 3, *91* — Sępopol 2, *92* — Sępopol 1, *93* — Zawada 1, *94* — Łankiejmy 2, *95* — Kętrzyn IG 1, *96* — Korsze 1, *97* — Łankiejmy 1, *98* — Klewno 1, *99* — Barciany 3, *100* — Barciany 1, *101* — Barciany 2, *102* — Barciany 4, *103* — Lesieniec 1, *104* — Gołdap IG 1, *105* — Filipów IG 1, *106* — Łopuchowo IG 1, *107* — Jezioro Okrągłe IG 2, *108* — Jezioro Okrągłe IG 1
Mapa lokalizacji otworów wiertniczych w polskiej części obniżenia perybałtyckiego
1 — otwory wiertnicze, w których osady ordowiku przewiercono z pełnym poborem próbek rdzeniowych; 2 — otwory wiertnicze z profilami stratotypowymi formacji; 3 — inne otwory wiertnicze; 4 — obecna granica zasięgu osadów ordowiku

information about lithology. Environmental interpretation was omitted: indeed, sedimentary environments are identified but there are no detailed studies on this topic. Some units are limited by sedimentary unconformities and these are rather allostratigraphical units. Because of lack of any formal criteria in the Polish literature, such units were not treated separately (H. D. Hedberg, 1972; R. Dadlez, 1987).

There are three main applications of the present division. It enables to distinguish particular units in the cored sections, and to make an unquestionable identification and correlation based on logging (resistivity and neutron-gamma logs), and makes possible to link the created units with standard, international chronostratigraphical division. It also helps to precise unit correlation between the eastern and western parts of the studied area and to define relations between particular lithofacies and lithofacies associations.

Archival lithological samples, fauna specimens and thin sections are stored in the Department of the Regional and Petroleum Geology of the Polish Geological Institute in Warsaw.

DESCRIPTION OF LITHOLOGICAL UNITS

The Ordovician system of the Polish part of the Peribaltic Depression is composed of a thin sequence — not homogenous laterally — of three, mixed, main lithological types: conglomerates and sandstones, shales and shales with glauconite, and carbonates. Pyroclastics (bentonites) and chemically originated rocks (including glauconitites and ferruginous oolites) are significantly less important. These lithotypes occur in various superposition and quantity proportions in particular sections (Figs. 2, 3).

Genetically, the analysed sequence of epicontinental deposits represents two transgressive-regressive sedimentary cycles. The lower, Tremadoc is composed of clastics. The Ordovician part of the upper, Arenig–Silurian cycle is composed of shaley-carbonate deposits. These cycles are separated from each other by a regional, heterochronous unconformity (R. M. Mjannil, 1966). Due to lateral facies changes, two main groups of sections which differ in lithological composition, fauna assemblages and thickness may be distinguished in the Podlasie Depression Ordovician. The first (eastern part of the area) is more variable in lithological composition and contains more carbonates. The second (western part) is monotonnous, enriched in clastics — mainly shales. Deposits of the first group represent probably the proximal shelf facies and those of the second group — distal shelf environments. Both types of sequences are complete stratigraphically and represent full spectrum of Ordovician series — from Tremadoc to Ashgill (Tab. 1).

Because of vertical lithological variability of the analysed sections, 10 lithostratigraphical formations in the west and 5 in the east were possible to be distinguished. Table 1 presents the summary of created formations, their lateral relations, subdivision, thicness and their position within the standard, international chronostratigraphical division.

WESTERN PART OF THE DEPRESSION

Five formations have been distinguished in the Ordovician sections of the western part of the Peribaltic Depression. They are, in ascending order: the Piaśnica Black Bituminous Shale Formation (A_0), the Słuchowo Shale with Glauconite Formation (A_1), the Kopalino Limestone Formation (A_2), the Sasino Shale Formation (A_3) and the Prabuty Marl and Shale Formation (A_4). Within two formations, lithostratigraphical members have been distinguished. There are the Odargowo Limestone Member (A_{1a}) in the Słuchowo Shale with Glauconite Formation and the Bramka Limestone Member (A_{3a}) in the Sasino Shale Formation (Tab. 1).

Figure 2 presents generalised typical sections, representative for particular lithostratigraphical units.

THE PIAŚNICA BLACK BITUMINOUS SHALE FORMATION (A_0) (TAB. 1, FIG. 2)

N a m e a n d h i s t o r y . The name comes from the Piaśnica village near the Baltic coast (Fig. 1). For the first time W. Bednarczyk has distinguished this formation as a separate lithostratigraphical unit (W. Bednarczyk, M. Turnau-Morawska, 1975; W. Bednarczyk, 1996). Deposits of the Tremadoc part of the unit are recognized only in the borehole sections drilled in the Polish sector of the Baltic Sea (Fig. 1).

S u b d i v i s i o n . Not made.

T y p e s e c t i o n . The formation stradales the Cambrian/Ordovician boundary. The stratotype of the Tremadoc part of the formation is taken from the B16-1/85 borehole, at 1831.5–1840.0 m. Hypostratotypes come from thin, secondary reduced sections of the A23-1/88 (1304.5–1305.5 m) and A8-1/83 (1927.0–1931.0 m) boreholes.

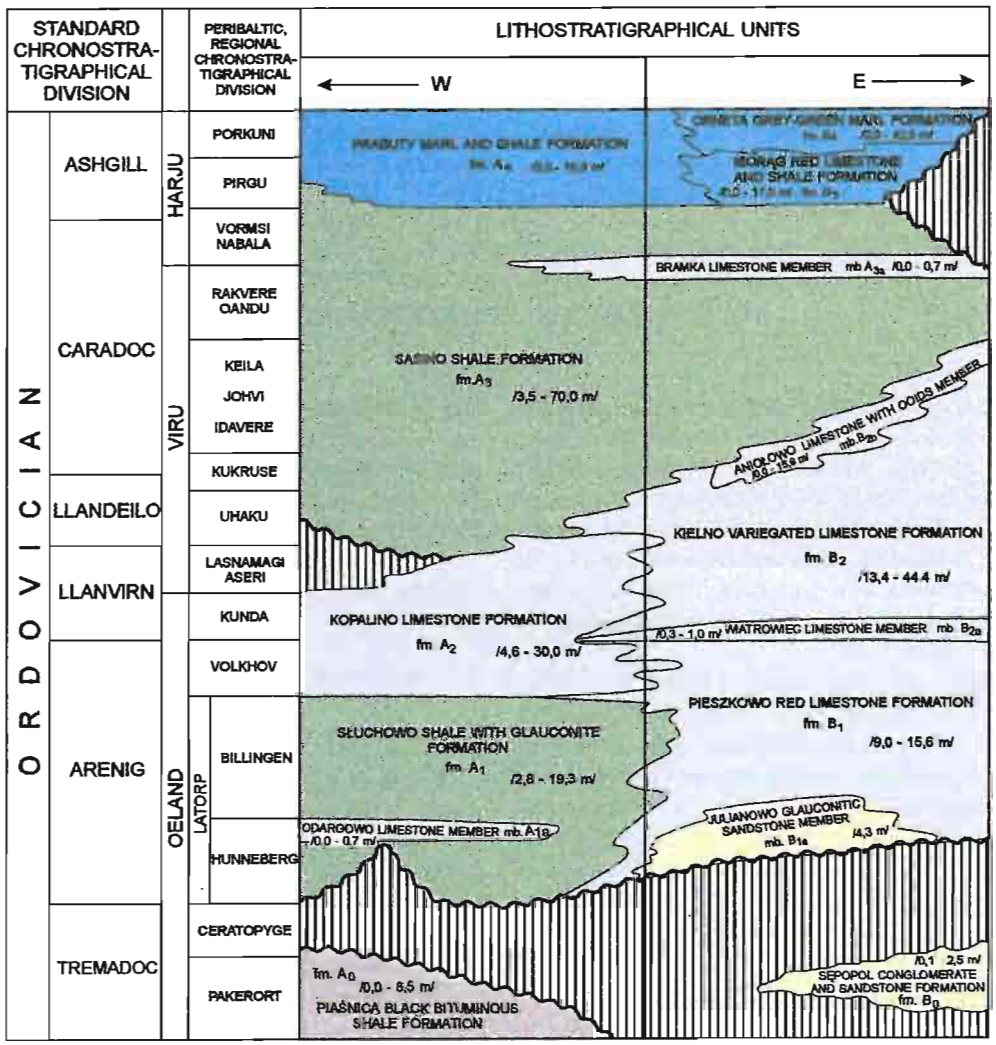
O t h e r s e c t i o n s . Typical rocks of the Tremadoc part of the formation are also recognized in the complete or fragmentary borehole sections, among others: B7-1/91 (2323.0–2329.0 m), B6-2/85 (1432.5–1441.0 m), B6-1/82 (1410.0–1416.5 m), B4-1/81 (1097.5–1109.5 m) and B3-1/81 (1382.55–1382.58)[1].

B o u n d a r i e s . The Tremadoc part of the Piaśnica Black Bituminous Shale Formation concordantly overlies the facially identical Upper Cambrian shaley deposits. It is covered, with unconformity, by transgressive, conglomerate unit of the Słuchowo Shale with Glauconite Formation. The Cambrian–Ordovician boundary may be univocally marked only on the base of fossils; in some cases only it can be

[1] In this case as well as further in the paper, the depths of unit boundaries in partly cored borehole sections refer to cored interval only.

Table 1

Ordovician lithostratigraphy of the Peribaltic Depression



Yellow — clastic deposits (conglomerates, medium- to fine-grained sandstones); green-grey — shaley and shaley-glauconitic deposits; black — bituminous, shaley deposits; dark blue — shaley-calcareous deposits (shales, marls, marly limestones); light blue — calcareous and calcareous-dolomitic deposits

interpreted on geophysical logs (Fig. 2). The upper boundary runs along a significant unconformity at the transition into the Arenig shaley-glauconitic deposits of the Słuchowo Shale with Glauconite Formation (A_1).

L i t h o l o g y . Black, bituminous shales, intercalated in places with thin laminae of dark grey, calcareous shales. Significant amount of scattered bituminous matter (kerogen) and concretion-like concentrations of antraconite are indicative for this unit. Pyrite is abundant in shales and occurs in small, irregular concretion-like concentrations or thin lenses. In some sections, very rarely, thin intercalations of black, marly, skeletal limestones (biosparites, biomicrites) appear within the shaley rocks.

O r g a n i c r e m a i n s a n d a g e . The fauna assemblage is composed of *Dictyonema flabelliforme flabelliforme* (Eichwald), *D. flabelliforme norvegicum* (Kjerulf), *D. flabelliforme rossicum* Obut, *D. flabelliforme s.l.*, *Clonograptus tenellus* (Linarsson), *C.* sp., *Anisograptus* cf. *norvegicum* Bulman, *A.* sp., *Bryograptus kjerulfi* Lapworth and *B.* sp. Among other groups of organisms inarticulate brachiopods, represented by *Lingulella lepis* (Salter), *Obolus* cf. *apollinis* Eichwald, *O.* sp. and *Acrotreta* sp., also Phyllocarida crustaceans and conodonts, represented by the genera *Oneotodus* and *Cordylodus* (Z. Modliński, 1988) occur.

The fauna assemblage univocally evidences the upper part of the Lower Tremadoc (Pakerort) subseries containing the *Adelograptus hunnebergensis* and *Dictyonema flabelliforme norvegicum* Zones (J. E. Hede, 1951; J. Bergström, 1982). In consideration of concordant transition between the uppermost Upper Cambrian and Tremadoc, it should be accepted that the lower part of Tremadoc shales corresponds with lower part of the Lower Tremadoc, comprising the Graptolite Zones, beginning with *Dictyonema flabelliforme desmograptoides* to *D. flabelliforme flabelliforme* (Z. Modliński, 1988).

Extent and thickness. The present lateral extent of the Tremadoc part of the formation is limited by erosion to the Polish part of the Baltic Sea area. The thickness is variable, it attains 8.5 m.

Equivalents. The lithostratigraphical and partly lithofacies equivalent of the Tremadoc part of the formation is the bituminous shale unit of the Lower Tremadoc (Pakerort) sections of, among others, Scania and Öland Island in Sweden. This unit has been described in Sweden as the informal "*Dictyonema* Shale" (J. E. Hede, 1951; J. Bergström, 1982; I. Puura, L. E. Holmer, 1993).

Record disposer. The "Petrobaltic" — Oil and Gas Exploration and Production Company in Gdańsk.

THE SŁUCHOWO SHALE WITH GLAUCONITE FORMATION (A_1) (TAB. 1, FIG. 2)

Name and history. The name comes from the Słuchowo village near the Baltic coast (Fig. 1). For the first time this name has been used by W. Bednarczyk (1996).

Subdivision. The locally developed Odargowo Limestone Member (A_{1a}) has been distinguished in the lower part of the formation.

Type section. The stratotype of the formation is taken from the Żarnowiec IG 1 borehole (2707.8–2726.4 m). The hypostratotype comes from the Kościerzyna IG 1 borehole (4395.9–4398.7 m).

Other sections. This unit is also recognized in the fully or partly cored boreholes: Hel IG 1 (3032.0–3047.0 m), Darżlubie IG 1 (2997.5–3011.5 m), Dębki 2 (2649.0–2660.3 m), Białogóra 2 (2667.43–2671.0 m), Piaśnica 2 (2675.0–2692.5 m), Niestępowo 1 (3493.5–3498.5 m) and B3-3/81 (1375.55–1382.55 m) (Fig. 1).

Boundaries. Both boundaries are distinct and well visible. The base of the unit commonly discordantly overlies and onlaps the Lower Tremadoc or Upper Cambrian strata — either shaley deposits with rare limestone intercalations in the west and north-west or sandy-carbonate-shaley deposits in the east and south-east. The top of the unit is covered in all sections by lithologically contrasting limestones of the Kopalino Limestone Formation (A_2).

Lithology. Sequence of the formation begins with a transgressive layer of basal conglomerate, 7 to 30 cm thick, composed of poorly-rounded Upper Cambrian clasts and dark brown phosphatic rocks bound either with carbonate-shaley or quartz-glauconite silty/sandy matrix. Dark grey and black shales intercalated with grey-green shales occur above. In the lowermost part they contain abundant, various admixture of silt. In the lower part of the shaley unit, thin beds enriched in glauconite and also dark grey, crystalline limestones may be noticed. The carbonates occur as laminae or are arranged in the bed plane nodules, they contain organic grains and relicts of recrystallized biogenical structures. In some sections, a few millimetres thick layer of olive-green bentonite occurs at the transition between basal conglomerate and shale.

Organic remains and age. Deposits are rich in various fossils, such as graptolites, inarticulate brachiopods, conodonts and — close to the base — *Caryocaris* sp. crustaceans. Among graptolites, numerous index taxa were determined which serve to distinguish four standard Lower Arenig (Latorp) zones — *Tetragraptus phyllograptoides, Didymograptus balticus, Phyllograptus densus* and *P. angustilius elongatus* (Z. Modliński, 1973, 1976; W. Bednarczyk, 1979).

Extent and thickness. The formation occurs in the onshore and offshore parts of the Peribaltic Depression, westwards of the River Vistula meridian. The thickness of the formation varies from 2.8 to 19.3 m.

Equivalents. The lower and middle parts of the so-called. Lower *Didymograptus* Shale or according to recent literature — the Töyen Shale, distinguished in Swedish provinces of Scania and Jämtland (J. E. Hede, 1951; G. Regnéll, J. E. Hede, 1960; T. Tjernvik, 1956, 1960; J. Bergström, 1982; V. Jaanusson, 1982*a*) are the lithological and partly lithofacies equivalents of the formation.

Record disposer. The Polish Geological Institute in Warsaw. Core of the stratotypical Żarnowiec IG 1 and hypostratotypical Kościerzyna IG 1 boreholes are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw.

THE ODARGOWO LIMESTONE MEMBER (A_{1a}) (TAB. 1, FIG. 2)

Name and history. The name comes from the Odargowo village near Żarnowiec at the Baltic coast.

Subdivision. Not made.

Type section. The proposed stratotype is in the Białogóra 1 borehole (2700.1–2700.55 m). The hypostratotypical section is located in the B3-3/81 borehole (1430.4–1431.13 m).

Other sections. Reduced in thickness relicts of this member were noticed in the Hel IG 1 borehole (3041.65–3041.7 m), Żarnowiec IG 1 borehole (2719.7–2719.8 m) and others (Fig. 1).

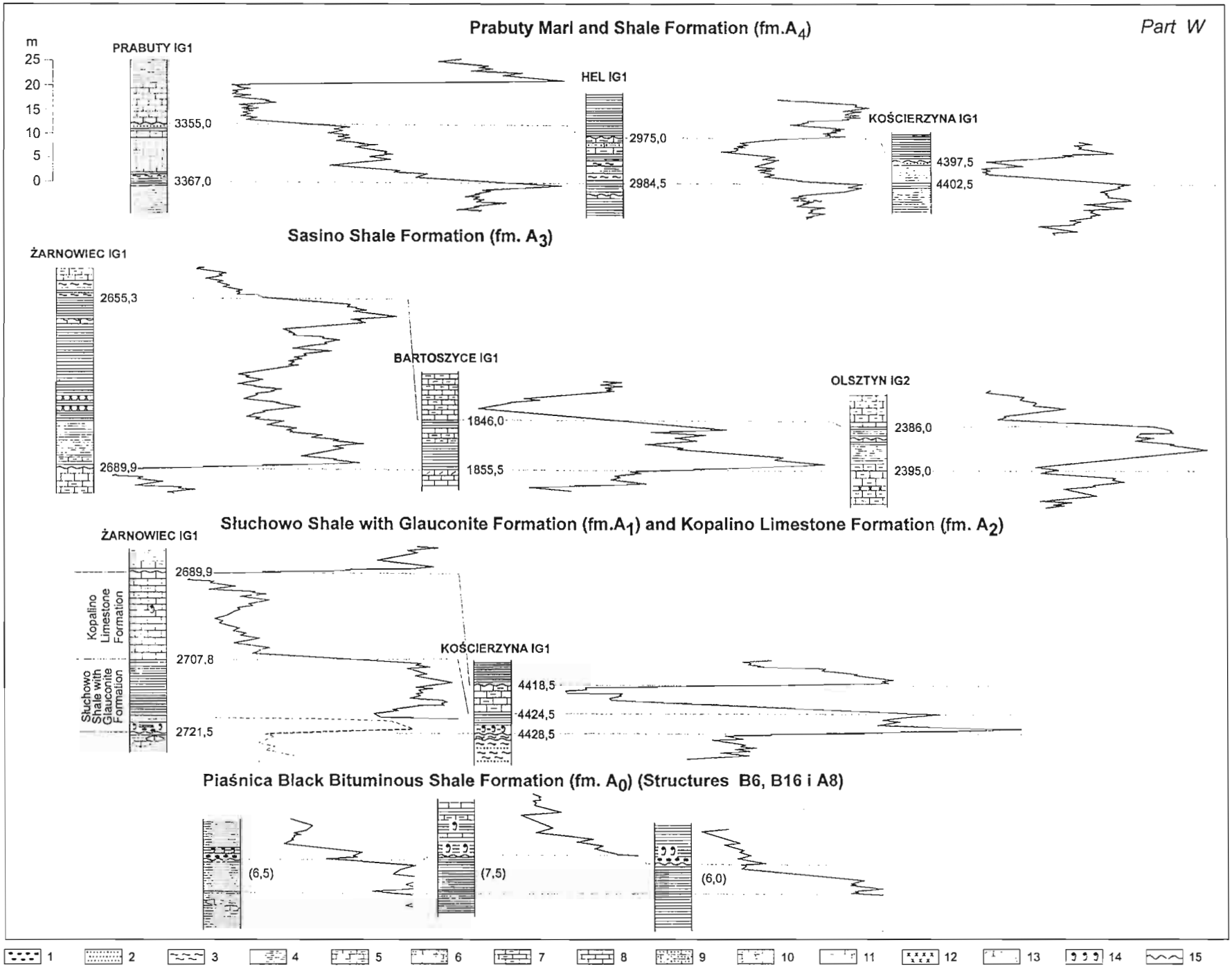
Boundaries. The base and top of the member run along significant unconformities, clearly separating the carbonates from remaining deposits of the Słuchowo Shale with Glauconite Formation (A_1).

Lithology. Grey and light grey, marly limestones with numerous, scattered glauconite grains. In some sections they are intercalated with thin grey shales and dark grey glauconitite.

Organic remains and age. Fossils are represented here by graptolite fragments of *Tetragraptus* sp., by *Bröggeria* sp. and *Spondylotreta* sp. brachiopods and by rare Phyllocarida crustaceans. The member lies within the well documented faunistically Słuchowo Shale with Glauconite Formation and it falls within the Lower Arenig subseries, more precisely — the lower part of the Latorp Peribaltic stage.

Extent and thickness. The member occurs in the Łeba Elevation and adjacent part of the Baltic Sea. The thickness may reach about 0.7 m.

Equivalents. The carbonates represent a relict of the "*Planilimbata* Limestone" distinguished within the shaley unit in the Lower Arenig of Scania (T. Tjernvik, 1960).


Prabuty Marl and Shale Formation (fm.A4)
Part W
m
25
20
15
10
5
0
PRABUTY IG1
3355,0
3367,0
HEL IG1
2975,0
2984,5
KOŚCIERZYNA IG1
4397,5
4402,5
Sasino Shale Formation (fm. A3)
ŻARNOWIEC IG1
2655,3
2689,9
BARTOSZYCE IG1
1846,0
1855,5
OLSZTYN IG2
2386,0
2395,0
Słuchowo Shale with Glauconite Formation (fm.A1) and Kopalino Limestone Formation (fm. A2)
ŻARNOWIEC IG1
2689,9
Kopalino Limestone Formation
2707,8
Słuchowo Shale with Glauconite Formation
2721,5
KOŚCIERZYNA IG1
4418,5
4424,5
4428,5
Piaśnica Black Bituminous Shale Formation (fm. A0) (Structures B6, B16 i A8)
(6,5)
(7,5)
(6,0)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Record disposer. The Polish Oil and Gas Company — Geological Bureau "Geonafta" in Piła administers materials from the stratotypical Białogóra 1 borehole section and the "Petrobaltic" — Oil and Gas Exploration and Production Company in Gdańsk — from the hypostratotypical section.

THE KOPALINO LIMESTONE FORMATION (A_2) (TAB. I, FIG. 2)

Name and history. The name comes from the Kopalino village near the Baltic coast (Fig. 1). The geographical part of the name for the first time has been used by W. Bednarczyk (1996) as the Kopalino Member.

Subdivision. Not made.

Type section. The stratotype is taken from the Żarnowiec IG 1 borehole (2689.2–2707.8 m). The hypostratotypical section is located in the Kościerzyna IG 1 borehole (4414.7–4420.3 m).

Other sections. This unit was also recognized in many other boreholes where the formation interval was either fully or partly cored. They are a.o. the Lębork IG 1 (3303.9–3310.0 m), Darżlubie IG 1 (2975.2–2977.5 m), Hel IG 1 (3020.0–3028.1 m), Piaśnica 2 (2648.6–2668.0 m) and Białogóra 2 (2660.0–2667.1 m).

Boundaries. The lower boundary of the Kopalino Limestone Formation coincides with the upper boundary of the Słuchowo Shale with Glauconite Formation (A_1). The upper runs along a distinct unconformity, below the overlying Sasino Shale Formation (A_3).

Lithology. Mainly marly limestones rich in bioclasts; also pure limestones and skeletal limestones. They are grey, dark grey and grey-greenish in colour, sometimes with brownish tint. Limestones are intercalated with thin, dark grey and grey-greenish, marly and shaley-marly layers and nodules. Some limestone beds contain scattered glauconite grains. Sedimentary unconformities are abundant here. In places, nodular structures are noticed.

Organic remains and age. The faunal assemblage is composed of trilobites: *Megistaspis limbata* (Boeck), *Symphysurus dorsatus* Poulsen, *S. palpebrosus* Dalman, *Neoasaphus* cf. *platyurus latisegmentatus* (Nieszkowski), *Asaphus* sp., *Pseudoasaphus* sp., *Nileus armadillo* Dalman, *Ptychopyge broggeri* Schmidt, *P.* sp., *Niobe* sp., *Illaenus* sp., *Cyrtometopus* cf. *clavifrons* (Dalman), *Raymondaspis* sp., *Ampyx* sp., *Trinodus* sp. and ?*Greagnostus* sp. Also brachiopods have been found: *Nicollela* cf. *moneta* (Eichwald), *N.* sp., *Myotreta* sp., *Scaphelasma* sp., *Tornyelasma* sp., *Lingulella* sp. and *Acrotreta* sp., *Endoceras* sp. as well as *Orthoceras* sp. cephalopods, and the Upper Arenig and Llanvirn conodonts with taxa indicative for the Llanvirn Conodont Zone *Eoplacognatus suecicus* Bergström (T. Podhalańska, 1980). These fossils evidence the Upper Arenig to the lower part of the Upper Llanvirn interval in the west and to the upper part of the Upper Llanvirn in the east. These intervals correspond with the Peribaltic stages from Volkhov to, respectively, Aseri and Lasnamagi.

Extent and thickness. The formation occurs in the onshore part of the Peribaltic Depression, westwards of the River Vistula. In the Polish sector of the Baltic Sea it is known from the area located northwards of the Łeba Elevation. The thickness of the formation varies from 4.6 to 20.5 m onshore and from less than 1.0 to about 30.0 m in the offshore sections.

Equivalents. In Bornholm (Denmark) and Scania (Sweden) the Komstad Limestone Formation (J. Bergström, 1982) corresponds with the Kopalino Limestone Formation.

Record disposer. The Polish Geological Institute in Warsaw. Cores coming from both stratotypical and hypostratotypical boreholes are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw.

THE SASINO SHALE FORMATION (A_3) (TAB. I, FIG. 2)

Name and history. The name comes from the Sasino village near the Baltic coast (Fig. 1). This unit was previously being distinguished as the informal Upper Pomerania Beds (E. Tomczykowa, 1964), Complex III — Zones 6 to 14 (Z. Modliński, T. Topulos, 1974), Graptolite Shale Formation (T. Podhalańska, 1980) and recently the Sasino Formation (W. Bednarczyk, 1996).

Subdivision. The Bramka Limestone Member (A_{3a}) has been distinguished in the upper part of the formation.

Type section. The stratotype of the formation comes from the Żarnowiec IG 1 borehole section (2655.3–2689.2 m). The hypostratotypes are the Olsztyn IG 2 (2392.4–2401.9 m) and Bartoszyce IG 1 (1846.1–1855.7 m) boreholes. Both hypostratotypical sections show regional lithotype and thickness variability of the unit.

Other sections. The formation was also encountered in the following borehole sections, where the critical interval was fully cored: Kościerzyna IG 1

Fig. 2. Lithostratigraphical correlation of the Ordovician deposits from the western part of the Peribaltic Depression

1 — conglomerates; 2 — sandstones; 3 — siltstones, shaley-siltstones; 4 — shales; 5 — marls; 6 — sandy marls; 7 — marly limestones; 8 — limestones; 9 — sandy limestones; 10 — skeletal limestones; 11 — limestones with ferruginous ooids; 12 — bentonites; 13 — limestone lenses; 14 — glauconite; 15 — main washout surfaces; note that the depth values of the lithostratigraphical unit boundaries presented on Figs. 2 and 3 are interpreted from geophysical logs

Korelacja litostratygraficzna osadów ordowiku zachodniej części obniżenia perybałtyckiego

1 — zlepieńce; 2 — piaskowce; 3 — mułowce, mułowce ilaste; 4 — iłowce; 5 — margle; 6 — margle piaszczyste; 7 — wapienie margliste; 8 — wapienie; 9 — wapienie piaszczyste; 10 — wapienie organodetrytyczne; 11 — wapienie z ooidami żelazistymi; 12 — bentonity; 13 — soczewki wapienne; 14 — glaukonit; 15 — ważniejsze powierzchnie rozmyć; głębokości granic poszczególnych jednostek litostratygraficznych na fig. 2 i 3 ustalono na podstwie interpretacji danych karotażu geofizycznego

(4398.7–4414.7 m), Gdańsk IG 1 (3095.7–3109.0 m), Prabuty IG 1 (3368.0–3382.4 m), Kętrzyn IG 1 (1558.6–1569.6 m), Klewno 1 (1501.4–1509.7 m) and in other partly cored boreholes.

Boundaries. The lower boundary is clearly diachronous and runs within the Upper Llanvirn, Llandeilo and Lower Caradoc series. West of the River Vistula and on the Baltic Sea the formation overlies the Kopalino Limestone Formation (A_2) and to the east of the River Vistula it lies on the Kielno Variegated Limestone Formation (B_2), including the Aniołowo Limestone with Ooids Member (B_{2b}). In most sections a significant unconformity may be observed at the base of the unit. In the western part of the Peribaltic Depression the upper boundary of the Sasino Shale Formation coincides with the lower boundary of the overlying Prabuty Marl and Shale Formation (A_4). In the eastern part it is concordantly, in places with an erosional gap, overlain by the Morąg Red Limestone and Shale Formation (B_3) or directly by the Orneta Grey-green Marl Formation (B_4).

Lithology. Shales black, dark grey and grey-greenish in colour, often bituminous, limy and silicified in places. Abundant bentonite intercalations. In some sections, intercalations of dark grey, grey and grey-greenish marly limestones and marls.

Organic remains and age. Graptolites are the principal group determining the age. Their rich assemblage indicate the *Didymograptus murchinsoni* (only in the Kościerzyna IG 1 borehole section), *Glyptograptus teretiusculus*, *Nemagraptus gracilis*, *Diplograptus multidens*, *Dicranograptus clingani* and *Climacograptus styloides* Graptolite Zones. The *Diplograptus multidens* Zone (T. Podhalańska, 1980) is subdivided here into the *Diplograptus molestus* and *Climacograptus wilsoni* Zones (for example Z. Modliński, 1973). *Paterula portlocki* (Geinitz), *P. bohemica* Barrande and *Hisingerella nitens* (Hisinger) inarticulate brachiopods were found here as well as trilobites, gastropods, cephalopods and ostracods. The identified fossils indicate the lowermost Llanvirn to uppermost Caradoc series for the western part of the studied area. In the east it evidences the Caradoc *Dicranograptus clingani* and *Climacograptus styloides* Graptolite Zones, corresponding with the Peribaltic stages from Oandu to Vormsi.

Extent and thickness. The formation deposits occur in the western and eastern (as far as the vicinities of Lesieniec) parts of the Peribaltic Depression. The thickness varies from 3.5 to 37.0 m onshore and 26.5–70.0 m offshore (Fig. 2).

Equivalents. The lithostratigraphical equivalent of the unit in Scania and Bornholm are the *Dicellograptus* Shales (J. Bergström, 1982) and in Västergötland the Mossen Shale Formation and Fjäcka Shale Formation (V. Jaanusson, 1982*b*).

Record disposer. The Polish Geological Institute in Warsaw. Core samples coming from the stratotypical Żarnowiec IG 1 borehole section and hypostratotypical Olsztyn IG 2 and Bartoszyce IG 1 borehole sections are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw.

THE BRAMKA LIMESTONE MEMBER (A_{3a})
(TAB. 1, FIG. 2)

Name and history. The name of the member comes from the Bramka village near Morąg in the Mazury Lakelands (Fig. 1). This name has not been used yet to describe a formal lithostratigraphical unit.

Subdivision. Not made.

Type section. The stratotype comes from the Olsztyn IG 2 borehole (2394.8–2395.1 m). The hypostratotype is in the Żarnowiec IG 1 borehole (2659.9–2660.1 m).

Other sections. The member deposits are also recognized in many other borehole sections, among others: Bartoszyce IG 1 (1847.9–1848.2 m), Kętrzyn IG 1 (1562.3–1562.85 m), Łankiejmy 1 (1507.6–1508.3 m) and Klewno 1 (1504.2–1504.4 m).

Boundaries. The lower and upper boundaries are distinct, because of contrasting lithology between the limestones and the Sasino Shale Formation (A_3). The member top is additionally emphasised by a distinct, irregular, sedimentary unconformity, often pyritized (K. Jaworowski, Z. Modliński, 1972, pl. 2, fig. 4).

Lithology. Compact, grey-green, rarely dark grey or grey limestones and marly limestones, often with abundant, scattered glauconite grains, pyritized in places. In some sections limestones contain small lithoclasts of phosphatic rocks and grey-green marl intercalations.

Organic remains and age. Only fragments of trilobites and brachiopods without any stratigraphical importance were found in these deposits. However, it is possible to correlate the member with the *Dicranograptus clingani* Graptolite Zone or the Rakvere Peribaltic stage, because of its position within the well palaeontologically documented Sasino Shale Formation.

Extent and thickness. The lateral extent of the member is limited to the eastern part of the Peribaltic Depression and to some borehole sections of the western part. The thickness varies from 0.0 to 0.7 m.

Equivalents. The Standrom Limestone is the equivalent in Sweden (V. Jaanusson, 1982*b*).

Record disposer. The Polish Geological Institute in Warsaw.

THE PRABUTY MARL AND SHALE FORMATION (A_4)
(TAB. 1, FIG. 2)

Name and history. The name of the formation comes from the town of Prabuty in the Mazury Lakelands (Fig. 1). Earlier, this unit was included to the Mazury Beds (E. Tomczykowa, 1964) and recently to the Kaszuby Formation (W. Bednarczyk, 1996).

Subdivision. Not made.

Type section. The stratotype comes from the Prabuty IG 1 borehole (3356.6–3368.0 m). The hypostratotypes occur in the Hel IG 1 (2971.5–2981.1 m) and Kościerzyna IG 1 (4394.0–4398.7 m) borehole sections.

Other sections. Typical rocks for the formation are also recognized in the following borehole sections: Gdańsk IG 1 (3089.0–3095.7 m), Lębork IG 1 (3273.0–3281.0 m), Białogóra 1 (2629.0–2638.3 m) Łeba 8 (2659.5–2668.8 m) and others.

Boundaries. The Prabuty Marl and Shale Formation concordantly overlies the bituminous deposits of the Sasino Shale Formation (A_3). It is covered, with a distinct sedimentary unconformity, by the Lower Llandovery black, bituminous graptolite shales or nodular limestones.

Lithology. The unit is composed of grey, dark grey and rarely black marls, argillaceous and silty marls, silty and limy shales. They may be intercalated with grey marly limestones. Fine-grained sandstone, sometimes sandy siltstone or poorly-sorted sandstone bed of variable thickness (maximum 0.8 m) may appear in the upper part of some sections. This sandy bed sometimes contains abundant glauconite grains and conglomerate intercalations composed of poorly-rounded limy and shaley clasts. Its top is washed away and often pyritized. In the westernmost sections (Słupsk IG 1 and Lębork IG 1) in the lower part of the formation, silty shales contain admixture of quartz sand or even gravel (grains up to 8 mm in diameter).

Organic remains and age. In the lower part of the formation the following taxa occur which evidence the Lower Ashgill age: *Nankinolithus granulata* (Wahlenberg), *Tretaspis seticornis* (Hisinger), *T.* sp., *Microparia speciosa* Hawle et Corda, *Lonchodomas portlocki* (Barrande), *Philipsinella parabola* (Barrande), *Panderia megalophthalma* Linnarsson, *Illaenus* sp., *"Illaenus" angelini* Holm, *Climacograptus* cf. *angustatus* (Perner), *Dicellograptus* sp., *Orbiculoidea radiata* Troedsson, *Anisopleurella* sp. and others. In the upper part *Mucronaspis mucronata* (Brongniart), *Ogmocnemis irregularis* Kielan, *Microparia speciosa* Hawle et Corda, *Eostropheodonta hirnatensis* (M'Coy), *Hirnantia sagittifera* (M'Coy) and other fossils indicate the Upper Ashgill age.

Extent and thickness. The formation occurs in the onshore and offshore parts of the western Peribaltic Depression (westwards of the Gdańsk IG 1 and Prabuty IG 1 boreholes). The thickness varies onshore from 3.0 to 10.3 m and offshore — from 4.0 to 19.5 m.

Equivalents. The lower part of the formation may be correlated with the Jerrstad Siltstones and the upper — with the Tommarp Siltstones of Scania (Sweden) and Bornholm (Denmark) (J. Bergström, 1982).

Record disposer. The Polish Geological Institute in Warsaw. Core samples coming from the stratotypical Prabuty IG 1 and hypostratotypical Hel IG 1 and Kościerzyna IG1 borehole sections are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw.

EASTERN PART OF THE DEPRESSION

Five formations have been distinguished in the Ordovician sections of the eastern part of the Peribaltic Depression. There are, in ascending order: the Sępopol Conglomerate and Sandstone Formation (B_0), the Pieszkowo Red Limestone Formation (B_1), the Kielno Variegated Limestone Formation (B_2), the Morąg Red Limestone and Shale Formation (B_3) and the Orneta Grey-green Marl Formation (B_4). Within two formations, lithostratigraphical members have been distinguished. These are the Julianowo Glauconitic Sandstone Member (B_{1a}) belonging to the Pieszkowo Red Limestone Formation and the Wiatrowiec Limestone Member (B_{2a}) in the lower and the Aniołowo Limestone with Ooids Member (B_{2b}) — in the upper parts of the Kielno Variegated Limestone Formation (Tab. 1). Figure 3 presents generalised, typical sections, representative for particular lithostratigraphical units.

THE SĘPOPOL CONGLOMERATE AND SANDSTONE FORMATION (B_0) (TAB. I, FIG. 3)

Name and history. The name comes from the Sępopol village in the Warmia Lakelands (Fig. 1). The proposed name has not been used yet in the Polish stratigraphical terminology.

Subdivision. Not made, however, if better preserved sections would be obtained in the future the formation could be subdivided into three members: the lower — conglomeratic, middle — sandy and upper — sandy-shaley (B. Szymański, 1974, 1984).

Type section. The stratotype comes from the most completely preserved Sępopol 3 borehole section (1993.2–1995.7 m). The hypostratotypes come from the reduced sections of Zaręby 2 (2229.0–2231.0 m) and Młynary 1 (2791.9–2792.0 m) boreholes.

Other sections. The formation was recognized also in the reduced sections of Zaręby 3 (2188.0–2190.0 m), Glądy 4 (2366.5–2368.0 m) and Pieszkowo 1 (2059.2–2061.5 m) boreholes (Z. Modliński, B. Szymański, 1972; B. Szymański, 1974).

Boundaries. The formation lies above marked unconformity and onlaps the various Cambrian units — Middle Cambrian in the east and Upper Cambrian in the west. The formation is covered, with unconformity, by the Lower Arenig, transgressive, conglomeratic-glauconitic deposits. Because of its erosive boundaries the formation represents allostratigraphical unit.

Lithology. Mainly medium to fine-grained, oligomictic sandstones (quartz arenites), grey and light grey in colour, characterized by the occurrence of well-rounded and well-sorted grains. Transgressive, polymictic conglomerate bed commonly occurs in the lowermost part of the unit. It is composed of the Cambrian rock clasts represented by quartz

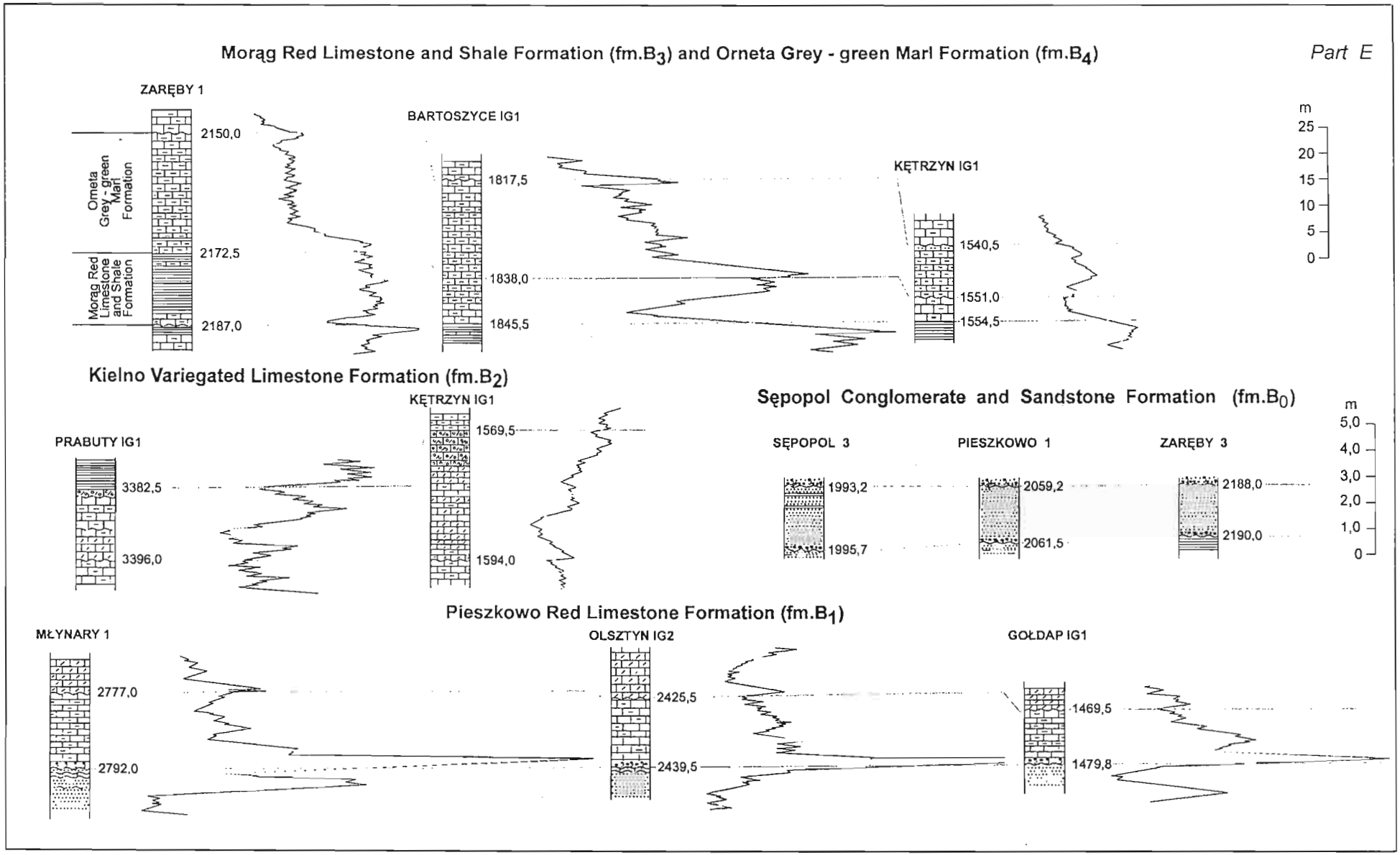


Fig. 3. Lithostratigraphical correlation of the Ordovician deposits from the eastern part of the Peribaltic Depression
Explanations as in Fig. 3
Korelacja litostratygraficzna osadów ordowiku wschodniej części obniżenia perybałtyckiego
Objaśnienia jak na fig. 2

sandstones, siltstones, crystalline limestones, and also phosphatic rocks, quartz grains and brachiopod shells composed of chitin and phosphate. In the upper parts of the Zaręby 2 and Sępopol 3 borehole sections the sandstone unit is intercalated with thin, non-calcareous, *Dictyonema* Shale-like, black, bituminous shales. This layer is 0.5 to 2.5 cm thick, usually slightly thicker than 1.0 cm (Z. Modliński, B. Szymański, 1972; B. Szymański, 1974, 1984).

Organic remains and age. In the sandy-conglomeratic part of the unit *Obolus apollinis* Eichwald, *O.* sp. and *Lingulella* sp. occur. In dark, bituminous shales only sicules and rhabdosom fragments of not identified taxonomically graptolites were recorded. The fauna assemblage generally indicate the Lower Tremadoc (Pakerort) subseries.

Extent and thickness. The formation is restricted to the eastern part of the depression. Deposits occur there in patches limited by erosive or tectonical-erosive boundaries. The thickness varies from 0.1 to 2.5 m.

Equivalents. The lithostratigraphical and partly lithofacies equivalent of the formation are the Kallavere Formation in Estonia (D. Kaljo *et al.*, 1984, 1988), the "*Obolus* Beds" or "*Obolus* Sandstones" in Sweden (Öland Island, Finngrunder borehole in the Gulf of Bothnia and Östergötland — P. Thorslund, S. Axberg, 1980; J. Bergström, 1982; I. Puura, E. Holmer, 1993) and Salontu and Paluknes Suites in Lithuania (J. Jacyna, 1993; J. Laskovas, A. Vazonis, 1996).

Record disposer. Polish Oil and Gas Company, Wołomin Branch. Core is not preserved. Archival lithological samples, fauna specimens and thin sections are stored in the Department of the Regional and Petroleum Geology of the Polish Geological Institute in Warsaw.

THE PIESZKOWO RED LIMESTONE FORMATION (B_1) (TAB. 1, FIG. 3)

Name and history. The name comes from the Pieszkowo village in the Warmia Lakelands (Fig. 1). The unit contains the informally created Pieszkowo Formation (W. Bednarczyk, 1996).

Subdivision. The locally developed Julianowo Glauconitic Sandstone Member (B_{1a}) has been distinguished in the lowermost part of the formation. The conglomeratic-glauconitic part of the formation could be distinguished in the future as a separate lithological unit.

Type section. The stratotype of the formation comes from the Olsztyn IG 2 borehole section (2431.5–2444.3 m). The hypostratotypical are in the Gołdap IG 1 (1470.3–1479.8 m), and Młynary 1 (2776.6–2791.0 m) borehole sections.

Other sections. Deposits of the formation were also recognized in the following borehole sections: Prabuty IG 1 (3407.3–3422.9), Żelazna Góra 4 (2655.0–2666.5 m), Klewno 1 (1530.4–1540.0 m), Dębowiec Warmiński 2 (2569.0–2581.0 m), Niestępowo 1 (3481.0–3490.0 m) and others (Fig. 1).

Boundaries. In all sections, the lower an upper boundaries are distinct. They are commonly emphasized by sedimentary unconformities and a significant lithological contrast with under- and overlying units. The formation covers with unconformity and onlaps either clastics of the Sępopol Conglomerate and Sandstone Formation (B_0) or various Cambrian units — Upper Cambrian in the west and Middle Cambrian in the east. The upper boundary of the unit coincides with the lower boundary of the Wiatrowiec Limestone Member (Tab. 1).

Lithology. The Pieszkowo Red Limestone Formation is bipartite. In the lower part it is composed of conglomerates, glauconitites and shales and in the upper part — of limestones (Fig 3).

Polymictic, basal conglomerates begin the unit from the base. They are composed of clasts of the underlying rocks: quartz sandstones, siltstones, phosphatic rocks, shales and locally crystalline limestones. The clasts are poorly-sorted and poorly-rounded. Matrix is shaley-carbonate or shaley-silty. The thickness is small and varies from 0.1 to 0.3 m.

Glauconitites occur above. Locally they directly overlie the Cambrian sandstones. This lithotype is composed of glauconite or glauconite and quartz. The rocks are significantly diagenetically altered. They are green, grey-green in colour, sometimes with red-brown patches. Matrix is carbonate or carbonate-phosphatic, with various admixture of clay in places. The glauconitites may be intercalated with dark grey shales, often rich in glauconite. The thickness of the glauconitite unit is 0.2–2.5 m.

The main, middle and upper parts of the formation are composed of carbonates, represented by poorly-sorted limestones, dolomitic limestones, also skeletal limestones and marly limestones with skeletal debris. There are mainly biomicrites and micrites less or more argillaceous. They contain, especially in the lower part, abundant glauconite. Nodular structures and subaqual sedimentary unconformities of various origin with traces of organic activity are typical for this unit. The unconformity horizons are often emphasized by stromatolite layers and ferruginous minerals. The carbonates are variegated in colour, red, grey-green in places. The thickness of the carbonate unit varies from 6.6 to 14.0 m.

Organic remains and age. Various fossils occur mainly in carbonate and shaley deposits of the formation. They are represented by trilobites, brachiopods, graptolites, cephalopods, ostracods and conodonts. Among trilobites the following species were identified: *Symphysurus angustatus* (Sars et Boeck), *S. dorsatus* Poulsen, *S. palpebrosus* (Dalman), *Nileus* cf. *exarmatus* Tjernvik, *N. armadillo* Dalman, *N. exarmatus* Tjernvik, *Niobe* cf. *incerta* Tjernvik, *N. laevigata* (Dalman), *Megistaspis* (*Megistaspis*) *planilimbata* (Angelin), *M.* (*M.*) *limbata* (Boeck), *M.* (*M.*) aff. *gibba* (Schmidt), *M.* (*M.*) *hyorrhina* (Leuchtenberg), *M.* (*M.*) cf. *heroides* (Brögger), *Plesiomegalaspis* sp., *Asaphus* (*Asaphus*) cf. *lepidurus* Nieszkowski, *Ampyx obtusus* Moberg et Segerberg, *A.* cf. *pater* Holm, *Raymondaspis brevicauda* Tjernvik, *R. limbatus* (Angelin) and others. Remaining fossils are represented by *Didymograptus extensus* (Hall), *D.* sp. and *Tetragraptus* sp. graptolites and various conodonts (W. Bednarczyk, 1968; M. Nehring, 1969).

These fossils indicate the Arenig series: in the lower part of the unit — the Latorp B_1, composed of the *Symphysurus angustatus* and *Megistaspis* (*Megistaspis*) *planilimbata* Tri-

lobite Zones and in the middle and upper parts — the Volkhov B_{II} stage comprising the *Megistaspis* (*Megistaspis*) *limbata* and *Asaphus* (*Asaphus*) *lepidurus* Trilobite Zones.

Extent and thickness. Eastern part of the Peribaltic Depression — eastwards of the River Vistula meridian to the state border. The thickness varies from 9.0 to 15.6 m (Fig. 3).

Equivalents. The Skelbro Limestone and lower part of the Komstad Limestone from Bornholm (Denmark) (V. Poulsen, 1965, 1966) and the *Orthoceras* Limestones, without their uppermost part (in southern Sweden) (J. Bergström, 1982) are the lithostratigraphical equivalents of the formation. In Lithuania and the Kaliningrad District, within comparable deposits, a few regional lithostratigraphical units have been distinguished (*Reshenya...*, 1978, 1987; J. Laskovas, A. Vazonis, 1996).

Record disposer. The Polish Geological Institute in Warsaw. Core samples from the stratotypical Olsztyn IG 2, and hypostratotype Gołdap IG 1 boreholes are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw.

THE JULIANOWO GLAUCONITIC SANDSTONE MEMBER (B_{1a}) (TAB. I, FIG. 3)

Name and history. The name of the unit comes from the Julianowo village near Prabuty in the Mazury Lakelands (Fig. 1) This unit has not been distinguished yet.

Subdivision. Not made.

Type section. The stratotype of the formation is in the Prabuty IG 1 borehole section (3407.3–3411.6 m).

Boundaries. The boundaries are distinctive macroscopically. The lower runs along irregular surface occurring on the sedimentary unconformity above the ?Upper Cambrian sandstones. The upper boundary runs along unconformity, below the remaining part of the Pieszkowo Red Limestone Formation (B_1).

Lithology. Compact, silicified, glauconitic-quartz sandstones, in places quartz sandstones with glauconite. They are grey-green, grey-yellow, dark grey in colour with red patches. Transgressive, polimictic conglomerate bed, 0.1 m thick, occurs at the base of the member. The latter is composed of clasts of poorly-rounded quartz sandstone and phosphatic rocks. Matrix is composed of quartz-glauconitic sand. Thin intercalations of non-calcareous, black shales may occur in the upper part of the unit.

Organic remains and age. Only *Didymograptus* sp. graptolites are identified here. The Lower Arenig (Latorp) age is estimated for the member, because of its position in the Ordovician section.

Extent and thickness. These deposits were noticed only in the Prabuty IG 1 borehole section, where they are 4.3 m thick.

Equivalents. Not recognized.

Record disposer. The Polish Geological Institute in Warsaw. Core samples from the stratotypical Prabuty IG 1 borehole section are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw.

THE KIELNO VARIEGATED LIMESTONE FORMATION (B_2) (TAB. I, FIG. 3)

Name and history. The name comes from the Kielno village in the Mazury Lakelands (Fig. 1). Previously, this unit was distinguished as the informal Middle and Upper Pomerania Beds (E. Tomczykowa, 1964) or as the Kielno and Aniołowo Members, suggested recently by W. Bednarczyk (1996).

Subdivision. Two members have been distinguished within the formation — in the lower part — the Wiatrowiec Limestone Member (B_{2a}) and in the upper — the Aniołowo Limestone with Ooids Member (B_{2b}).

Type section. The stratotype of the formation comes from the Kętrzyn IG 1 borehole section (1572.1–1598.0 m). The hypostratotype is in the Prabuty IG 1 borehole (3382.4–3396.0 m).

Other sections. Cored intervals of the formation occur also in the Lesieniec 1 (1370.0–1401.0 m), Zaręby 1 (2188.5–2214.0 m), Pasłęk IG 1 (2681.1–2725.5 m) (Fig. 1).

Boundaries. The lower boundary coincides with the lower boundary of the Wiatrowiec Limestone Member (B_{2a}). The upper boundary coincides with the upper boundary of the Aniołowo Limestone with Ooids Member (B_{2b}) or the lower boundary of the Sasino Shale Formation (A_3).

Lithology. The formation is composed of various carbonates represented by skeletal limestones, marly limestones and — in the upper part of the unit — by limestones with ferruginous ooids (the Aniołowo Limestone with Ooids Member). In the lower part of the unit limestones are grey and dark grey in colour (the Wiatrowiec Limestone Member). In the upper part they are variegated, brown-red, red, grey-brown and grey-greenish. Abundant, thin, irregular marl and shale intercalations as well distinct, subaqual, sedimentary unconformities occur within the unit.

Organic remains and age. Abundant and various fossils occur in the unit. They are: trilobites, graptolites, brachiopods, cystoids, cephalopods, gastropods and others (W. Bednarczyk, 1968; Z. Modliński, 1966, 1973). The faunal assemblage indicates the Lower Llanvirn to Lower Caradoc age of the unit. Its upper boundary is heterochronous and runs within various zones of the Llandeilo and Caradoc series (Tab. 1).

Extent and thickness. The formation occurs in the entire eastern party of the Peribaltic Depression, from the vicinities of Gdańsk and Prabuty in the west to the vicinities of Suwałki in the east. The thickness varies from 13.4 to 44.4 m (Fig. 3).

Equivalents. Several, regional lithostratigraphical units, described as formation or suites, which are comparable with the Kielno Variegated Limestone Formation, are known from central Sweden, Lithuania and the Kaliningrad District (V. Jaanusson, 1982*a*; *Reshenya...*, 1978, 1987; J. Laskovas, A. Vazonis, 1996).

Record disposer. The Polish Geological Institute in Warsaw. Core samples from the stratotypical Kętrzyn IG 1 and hypostratotypical Prabuty IG 1 borehole sections are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw.

THE WIATROWIEC LIMESTONE MEMBER (B_{2a}) (TAB. 1, FIG. 3)

Name and history. The name comes from the Wiatrowiec village near Bartoszyce in the Mazury Lakelands (Fig. 1).

Subdivision. Not made.

Type section. The stratotypical section is taken from the Bartoszyce IG 1 borehole (1879.1–1879.4 m). The hypostratotype comes from the Gdańsk IG 1 borehole (3118.4–3119.3 m).

Other sections. The member was also recognized in the following borehole sections: Prabuty IG 1 (3395.5–3396.0 m), Pasłęk IG 1 (2724.4–2725.4 m), Gołdap IG 1 (1469.4–1470.3 m) and others.

Boundaries. This grey carbonate unit contrasts significantly with the underlying deposits of the Pieszkowo Red Limestone Formation (B_1) as well as with the covering, remainig part of the Kielno Variegated Limestone Formation (B_2). The lower boundary of the member is everywhere emphasized by a distinct sedimentary unconformity (K. Jaworowski, Z. Modliński, 1972, pl. 1, fig. 2).

Lithology. Grey, dark grey, with greenish tint in places, compact, skeletal limestones (biosparites). They usually contain scattered glauconite grains and sometimes, in the lower part of the unit, ferruginous ooids. Abundant, irregular, dark grey, enriched in fine skeletal debris, shaley and marly intercalations appear within the limestones.

Organic remains and age. The following trilobite taxa are identified in the deposits: *Illaenus incisus* Jaanusson, *Asaphus raniceps* Dalman, *Ampyx* cf. *nasutus* Dalman, *Nileus* sp. and *Megistaspis* sp. as well as cephalopod fragments *"Orthoceras"* sp. These fossils indicate the Lower Llanvirn age, comparable with the middle part of the Kunda Peribaltic stage.

Extent and thickness. The member occurs in the entire eastern part of the Peribaltic Depression. The thickness varies from 0.3 to 1.0 m.

Equivalents. The Bitchunsk Suite is the equivalent in Lithuania and the Kaliningrad District (*Reshenya...*, 1978, 1987).

Record disposer. The Polish Geological Institute in Warsaw. Core samples coming from the stratotypical Bartoszyce IG1 and hypostratotypical Gdańsk IG 1 borehole sections are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw.

THE ANIOŁOWO LIMESTONE WITH OOIDS MEMBER (B_{2b}) (TAB. 1, FIG. 3)

Name and history. The name comes from the Aniołowo village near Pasłęk in the Mazury Lakelands (Fig. 1). W Bednarczyk (1996) suggested to distinguish this unit.

Subdivision. Not made.

Type section. The stratotypical section comes from the Pasłęk IG 1 borehole (2681.1–2697.0 m). The hypostratotype is in the Łankiejmy IG 1 borehole section (1512.3–1515.9 m).

Other sections. The member is also recognized in the Prabuty IG 1 (3382.4–3383.8 m), Olsztyn IG 2 (2403.9–2413.1 m), Kętrzyn IG 1 (1572.1–1580.0 m) and in many other borehole sections (Fig. 3).

Boundaries. Both boundaries of the unit are significantly heterochronous. The lower boundary is located in the upper part of the Kielno Variegated Limestone Formation (B_2) where the first intercalations, significantly enriched in ferruginous ooids, appear. It may occur in various zones of the Llanvirn and Llandeilo series.The upper boundary runs in the Llandeilo and Lower Caradoc deposits along a distinct unconformity, below the Sasino Shale Formation (A_3).

Lithology. The unit is composed of skeletal limestones grey, dark grey, grey-greenish, sometimes variegated in colour, marly in places, with characteristic intercalations rich in brown ferruginous ooids. The limestones are also intercalated with thin, irregular marls and shales.

Organic remains and age. The faunal assemblage is composed of trilobites, graptolites, brachiopods and cystoids. The trilobites are represented by *Neoasaphus ludibundus* Törnquist, *Illaenus* cf. *crassicauda* (Wahlenberg), *Nileus armadillo* Dalman, *Lonchodomas rostratus* (Sars) and others. The important graptolite taxa are represented by *Glyptograptus* cf. *teretiusculus* (Hisinger) and *Climacograptus* cf. *antiquus* Lapworth and cystoids by *Echinosphaerites* sp. and *Heliocrinites* sp. (W. Bednarczyk, 1968; Z. Modliński, 1973).

The stratigraphical range of the member varies but generally extends from the lowermost Llanvirn to Lower Caradoc subseries (Tab. 1).

Extent and thickness. The unit occurs in the eastern part of the Peribaltic Depression. The thickness varies from 0.0 to 15.9 m.

Equivalents. Several lithostratigraphical units, of various order (suites) in Lithuania and the Kaliningrad District (*Reshenya...*, 1978, 1987) are the equivalents of the Aniołowo Limestone with Ooids Member.

Record disposer. The stratotypical Pasłęk IG 1 borehole is administered by the Polish Geological Institute in Warsaw. Core samples coming from this borehole are stored in the Polish Geological Institute core depository in Hołowno near Włodawa. The hypostratotypical Łankiejmy 1 borehole is administered by the Polish Oil and Gas Company — Geological Bureau "Geonafta" in Piła.

THE MORĄG RED LIMESTONE AND SHALE FORMATION (B_3) (TAB. 1, FIG. 3)

Name and history. The name of the formation comes from the town of Morąg in the Mazury Lakelands (Fig. 1). This unit was previously, informally described either as the Mazury Beds (E. Tomczykowa, 1964) or the lower part of the Kaszuby Formation (W. Bednarczyk, 1996).

Subdivision. Not made.

Type section. The stratotypical section is located in the Bartoszyce IG 1 borehole (1838.0–1846.1 m). The hypostratotype comes from the Zaręby 1 (2172.3–2186.5 m) and Pasłęk IG 1 (2672.6–2677.7 m) borehole sections.

Other sections. The formation was recognized also in the Olsztyn IG 2 (2388.5–2392.4 m), Kętrzyn IG 1

(1554.9–1558.6 m), Łankiejmy 1 (1492.4–1499.1 m) and other borehole sections.

B o u n d a r i e s . The formation deposits either concordantly or erosionally overlie the Sasino Shale Formation (A_3). Usually, the unit is concordantly covered by the Orneta Grey-green Marl Formation (B_4), however, a sedimentary unconformity or an erosive gap may be observed in some sections. In the Klewno 1 section the unit is overlain directly by the Lower Llandovery nodular limestones.

L i t h o l o g y . The unit is composed of various rock types, such as marly limestones, marls, calcareous shales and shales, brown-red, red, grey-red, grey-green and grey in colour. Common occurrence of red (various tints) intercalations is distinctive for the formation.

O r g a n i c r e m a i n s a n d a g e . Trilobites are the most important fossils found in this unit: *Tretaspis seticornis* (Hisinger), *Panderia megalophthalma* Linnarsson, *Stenopareia* cf. *linnarssoni* (Holm), *Staurocephalus* sp., *Illaenus* cf. *roemeri* Volborth and others, which well document the Lower Ashgill age. Brachiopods, cephalopods, echinoderms and rare graptolite remains were also noticed.

E x t e n t a n d t h i c k n e s s . The formation occurs in the eastern part of the Peribaltic Depression from the vicinities of Prabuty in the west to Barciany in the east. The thickness varies from 0.0 to 17.0 m.

E q u i v a l e n t s . The Jonstrop Formation (V. Jaanusson, 1963) of central Sweden (Västergötland, Östergötland and Siljan) is the lithostratigraphical equivalent of the unit.

R e c o r d d i s p o s e r . The Polish Geological Institute administers documentation of the lithostratotypical Bartoszyce IG 1 and hypostratotypical Pasłęk IG 1 boreholes. Core samples coming from the first one are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw, and from the second one — in the Polish Geological Institute core depository in Hołowno near Włodawa. The second hypostratotypical Zaręby 1 borehole is administared by the Polish Oil and Gas Company — Geological Bureau "Geonafta" in Wołomin.

THE ORNETA GREY-GREEN MARL FORMATION (B_4) (TAB. 1, FIG. 3)

N a m e a n d h i s t o r y . The name comes from the town of Orneta in the Mazury Lakelands (Fig. 1). Previously, this unit was included into the informal Mazury Beds (E. Tomczykowa, 1964) or to the upper part of the Kaszuby Formation created recently by W. Bednarczyk (1996).

S u b d i v i s i o n . Not made.

T y p e s e c t i o n . The stratotype is taken from the Bartoszyce IG 1 borehole section (1816.7–1838.0 m). The hypostratotypes are in the Kętrzyn IG 1 (1544.5–1554.9 m) and Pasłęk IG 1 (2638.0–2672.6 m) borehole sections.

O t h e r s e c t i o n s . The formation interval was also cored in the Olsztyn IG 2 (2376.5–2388.5 m), Łankiejmy 1 (1900.7–1930.4 m), Lesieniec 1 (1359.6–1364.0 m) and other borehole sections.

B o u n d a r i e s . The unit often concordantly overlies the Morąg Red Limestone and Shale Formation (B_3). In some sections (for example the Kętrzyn IG 1 and Olsztyn IG 2 borehole) a distinct sedimentary unconformity occurs on the boundary. In the easternmost Lesieniec 1 borehole this formation erosionally, directly overlies the Sasino Shale Formation (A_3). The upper boundary is distinct and runs along unconformity, below the Lower Llandovery nodular limestones.

L i t h o l o g y . The unit is dominated by grey-green and grey marls with numerous intercalations and nodules of grey and dark grey, fine-crystalline, marly limestones. Grey or light grey, sandy limestone bed occurs in the uppermost part of some sections ((Kętrzyn IG 1 and Korsze 1 boreholes). Polymictic conglomerate (Sępopol 3 borehole) and breccia intercalations composed of limestone and marl lithoclasts and marly matrix. Olsztyn IG 2 and Sępopol 3 borehole sections occasionally appear.

O r g a n i c r e m a i n s a n d a g e . Brachiopods and trilobites are the most abundant fossils found here. First group is represented by *Eostropheodonta hirnantensis* (M'Coy), *?Platymena polonica* Temple, *Bracteoleptena polonica* (Temple) and others, and the second — by *Mucronaspis mucronata* (Brongniart), *Brongniartella platynota* (Dalman), *Liocnemis concinnus* Kielan, *Calymene* sp. and others. Cephalopods, gastropods, bivalves, crinoids, bryozoans, ostracods and rare graptolite rhabdosom fragments are also noticed here. This faunal assemblage univocally indicate the Upper Ashgill age.

E x t e n t a n d t h i c k n e s s . The unit occurs in the eastern part of the Podlasie Depression from the vicinities of Pasłęk in the west to the Lesieniec borehole in the east. The thickness varies from 0.0 to 42.5 m.

E q u i v a l e n t s . The Tommarp Formation (V. Jaanusson, 1982*b*) from central Sweden (Siljan and Västergötland) is the lithostratigraphical equivalent of this formation. In the Kaliningrad District, north-west Lithuania and Latvia — the Kuldigsk and Saldussk Suites are comparable with the uppermost part of the formation occurring in the Kętrzyn IG 1 and Korsze 1 borehole sections (*Reshenya...*, 1978, 1987).

R e c o r d d i s p o s e r . The Polish Geological Institute in Warsaw. Core samples from the stratotypical Bartoszyce IG 1 and hypostratotypical Kętrzyn IG 1 boreholes are stored in the Polish Geological Institute core depository in Iwiczna near Warsaw. Core samples coming from the hypostratotypical Pasłęk IG 1 borehole are stored in the Polish Geological Institute core depository in Hołowno near Włodawa.

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LITOSTRATYGRAFIA ORDOWIKU OBNIŻENIA PERYBAŁTYCKIEGO (NE POLSKA)

Streszczenie

Przedstawiono propozycję sformalizowanego podziału litostratygraficznego epikontynentalnych osadów klastyczno-węglanowych ordowiku polskiego fragmentu obniżenia perybałtyckiego, których nieznacznej miąższości sekwencja składa się najogólniej z dwu cyklów transgresywno-regresywnych: dolnego — tremadockiego i górnego — arenidzko-sylurskiego. W sekwencji litologicznej systemu wyróżniono — opierając się na makroskopowej zmienności pierwotnych cech sedymentacyjnych i sedymentacyjno-diastroficznych osadów — 15 jednostek litostratygraficznych, w tym: 10 o randze formacji oraz 5 rangi ogniwa. Z wyróżnionych formacji 5 ustanowiono w części zachodniej, a pozostałych 5 w części wschodniej obniżenia. Są to następujące formacje poczynając od najstarszej: w części zachodniej — formacja czarnych iłowców bitumicznych z Piaśnicy (fm. A_0), formacja iłowców z glaukonitem ze Słuchowa (fm. A_1), formacja wapieni z Kopalina (fm. A_2), formacja iłowców z Sasina (fm. A_3) i formacja margli i iłowców z Prabut (fm. A_4), natomiast w części wschodniej — formacja zlepieńców i piaskowców z Sępopola (fm. B_0), formacja czerwonych wapieni z Pieszkowa (fm. B_1), formacja pstrych wapieni z Kielna (fm. B_2), formacja czerwonych wapieni i margli z Morąga (fm. B_3) oraz formacja szarozielonych margli z Ornety (fm. B_4). W obrębie czterech wyróżnionych formacji ustanowiono jednostki niższego rzędu o randze ogniwa, a mianowicie: w części zachodniej — w formacji ze Słuchowa (fm. A_1) — ogniwo wapienia z Odargowa (og. A_{1a}) oraz w formacji iłowców z Sasina (fm. A_3) — ogniwo wapienia z Bramki (og. A_{3a}), a w części wschodniej — w formacji czerwonych wapieni z Pieszkowa (B_1) — ogniwo piaskowców glaukonitowych z Julianowa (og. B_{1a}) oraz w formacji pstrych wapieni z Kielna (B_2) — w części dolnej ogniwo wapienia z Wiatrowca (og. B_{2a}), a w części górnej ogniwo wapieni z ooidami z Aniołowa (B_{2b}). Zespoły skalne poszczególnych formacji skorelowano z litostratygraficznymi i genetycznymi ich odpowiednikami znanymi z sąsiednich obszarów regionu nadbałtyckiego, w tym z terenów Szwecji (Skania, Jämtland, Zatoka Botnicka), Danii (Bornholm), Litwy, Estonii i Obwodu Kaliningradzkiego.

Z ustanowionych jednostek część ograniczona jest regionalnymi powierzchniami nieciągłości i spełnia kryteria właściwe jednostkom o charakterze allostratygraficznym (*allostratigraphic units*).

Zbiorcze zestawienie wyróżnionych formacji i ogniw, wzajemne ich relacje przestrzenne, podział i miąższości, wreszcie pozycję w międzynarodowym standardowym schemacie chronostratygraficznym przedstawiono w tab. 1. Zgeneralizowane profile typowe i reprezentatywne dla poszczególnych jednostek oraz ich korelacje prezentuje fig. 2 i 3.