Late Eocene - Early Oligocene calcareous nannoplankton and stable isotopes ($\delta^{13}C$, $\delta^{18}O$) of the Globigerina Marls in the Magura Nappe (West Carpathians)

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Abstract: The Magura Nappe is the largest and innermost unit of the Outer Carpathians. In the Magura Basin sedimentation was completed before the Late Oligocene, whereas in the more external part of the flysch basin sedimentation persisted until the Early Miocene. In the very thick turbidite sequences of the Outer Carpathians, only two regional correlative horizons, associated with condensed pelagic deposits, were recognised. The lower horizon is related to the Cenomanian radiolarian shales and the upper one to the Globigerina Marls at the Eocene/Oligocene boundary. The litho-, biostratigraphy and isotope ($\delta^{13}C$, $\delta^{18}O$) investigations of the Late Eocene/Early Oligocene deposits of the Magura Nappe have been carried out in the following locations: Leluchów in Poland and Raslavice Vyšné - Eastern Slovakia as well as a comparison with the standard section of the Globigerina Marls in Znamirowice (Silesian Nappe, Poland). All samples from the Znamirowice, Leluchów and Raslavice sections contain a fairly abundant calcareous nannoplankton which is assigned to the combine interval zone NP 19-20 (Late Eocene) and to NP 21 (Late Eocene/ Early Oligocene). The uppermost part of the Leluchów section revealed an assemblage belonging to the NP 22 zone. On the basis of stable isotope ($\delta^{13}C$, $\delta^{18}O$) studies, it is possible to make an assumption that during the Late Eocene -Early Oligocene, the Magura Basin was partly isolated from the World Ocean what caused limited circulation of water masses. At the same time, the deposition in the Silesian Basin was still dominated by open marine conditions.

Key words: West Carpathians, Magura Nappe, Eocene-Oligocene boundary, calcareous nannoplankton, pelagic deposits, Globigerina Marls.

Introduction

In the Outer Carpathian flysch basin, with the exception of the Magura sedimentary domain, the Middle to Late Eocene time was a period of unification of the sedimentary condition. During that time hemipelagic and pelagic deep-water sedimentation dominated the Skole, Sub-Silesian, Silesian and Dukla /Fore Magura sedimentary areas (see Książkiewicz (ed.), 1962). At the beginning of Late Eocene, the deposition of the variegated shales was replaced by facies of pelagic green shales. These shales pass upward into the Globigerina Marls which is the most important chronostratigraphic horizon (Bieda et al., 1963; Koszarski, ed., 1985) of the Outer Carpathians. The age of the Globigerina Marls in the Polish Outer Carpathians was determined on the basis of foraminifers (Blaicher, 1961, 1970; Olszewska 1983, 1984; Malata in: Oszczypko *et al.*, 1990).The calcareous nannoplankton of the Globigirina Marls was studied in the Dukla (Smagowicz in: Olszewska & Smagowicz, 1977) and the Silesian Units (Aubry in: Van Couvering *et al.*, 1981).

In the Magura Basin the Early to Late Eocene was a period of a huge facial differentiation. It was manifested by the northward progradation of the fan-lobe system of the Magura Sandstone Formation (Oszczypko, 1992). The Magura Sandstone lithosome was laterally replaced by the thin-bedded Beloveza-like facies and variegated shales of the Łabowa Formation. The Magura Formation is very scarce in the microfauna assemblages which makes difficult to correlate the individual members of this formation (e.g. Poprad and Piwniczna members). These problems could be solved by calcareous nannoplankton studies, which are still at the early stages of development. It is also very important to trace the Globigerina Marls and its equivalents within Upper Eocene and Lower Oligocene lithofacies of the Magura Nappe.

In the Magura Nappe, microfauna of the Globigerina Marls were reported in the Gorlice area (Blaicher & Sikora, 1961) and regarded as an equivalent of the sub-Menilite Globigerina Marls of the Late Eocene age. At the same time the Globigerina Marls were also recognised in the East Slovakian segment of the Magura Nappe (Książkiewicz & Leško, 1959; Nemčok, 1961,

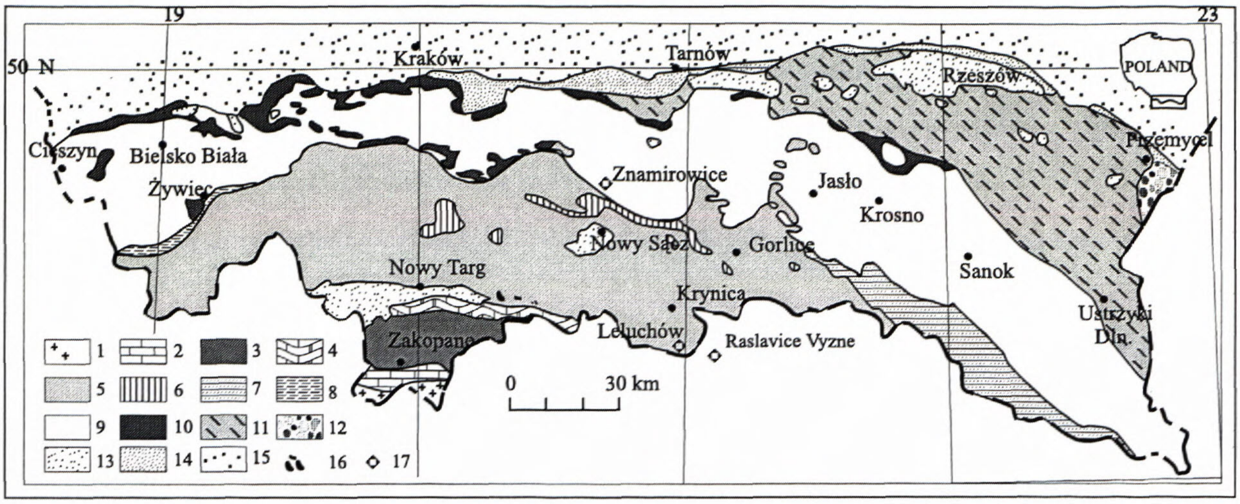


Fig. 1 Geological sketch- map of the Polish Outer Carpathians
1 crystalline core of the Tatra Mts., 2 High Tatra and sub-Tatra units, 3 Podhale flysch, 4 Pieniny Klippen Belt, 5 Magura nappe, 6 Grybów unit, 7 Dukla unit, 8 Fore-Magura unit, 9 Silesian unit, 10 Sub-Silesian unit, 11 Skole unit, 12 Sambor- Rożniatov unit, 13 Miocene deposits upon the Carpathian, 14 Zgłobice unit, 15 Miocene deposit of the Carpathian Foredeep, 16 andesite, 17 investigated area

Świdziński, 1961a). The microfauna of the Globigerina Marls in the Magura Nappe were studied by Malata (Oszczypko et al., 1990), whereas calcareous nannoplankton has been recently studied by Oszczypko M. (1996).

The aim of this work is to prepare litho- and biostratigraphic correlation of the upper Eocene/lower Oligocene deposits in the Magura Nappe from the following locations (Fig. 1): Raslavice Vyšné- East Slovakia (Bystrica Subunit) and Leluchów (Krynica Subunit) as well as a comparison with the standard section of Znamirowice (Silesian Nappe). Additionally the stabile isotope (δ^{13} C, δ^{18}O) analysis from the Leluchów and Znamirowice sections, have been carried out.

Geological setting of the sections

Leluchów. The village of Leluchów is situated in the Poprad Valley (Fig. 1) in the southernmost part of the Magura Nappe, which is close to the Pieniny Klippen Belt (PKB). The upper Eocene-Oligocene deposits are exposed in two places (A and B sections). These sections were studied by Świdziński (1961 b) and Blaicher & Sikora (1967). Recently Birkenmajer & Oszczypko (1989) and Oszczypko *et al.*, (1990) have given a detailed description of these sequences. Section A is located along a path, close to the orthodox church and section B is along a small right tributary of the Smereczek stream.This part of the nappe is represented by a broad (up to 10 km) syncline which is filled with Eocene thick-bedded sandstones of the Magura Formation (see Birkenmajer & Oszczypko, 1989; Oszczypko et al., 1990; Chrząstowski et al., 1995). The syncline is separated from the PKB by a strike-slip fault. In the Leluchów area, the Upper Eocene-Oligocene Malcov Formation overlaps the PKB.

Raslavice. The town of Raslavice (Fig. 1) is located 15 km SE from the Bardejov (E. Slovakia). The examined exposures were situated along the cart-road, about 1 km SW from the Raslavice Railway Station. The Globigerina Marls, exposed in Raslavice, are situated on the south limb of the Ralslavice syncline, which is filled with Malcov Formation (Nemčok, 1961, 1985; Swidziński, 1961 a). According to Swidziński (1961) and Nemcok (1961, 1985) the Raslavice syncline is located along the tectonic contact between Bystrica and Krynica Subunits.

Znamirowice. The Znamirowice (Fig. 1) section displays an exposure of the Globigerina Marls and associated strata of the Silesian Nappe. The examined section is located on the west bank of the Dunajec River in the Rożnów reservoir, about 11 km north from Nowy Sącz.

Lithostratigraphy

Leluchów. The lowest part of the Leluchów sections (A and B) consist of thick-bedded sandstones and conglomerates (Fig. 2). The muscovite sandstones are greybluish in colour and coarse to fine grained, with intercalations of fine-grained conglomerates. The sandstones display T_{abc} Bouma sequences. The thicknesses of the individual beds range from 40 cm to 2,5 m. The infrequent shale-mudstone intercalation are very thin (1-5 cm). Rare 2-5 m thick packets of thin-bedded turbidites are also observed. These deposits belong to the Piwniczna Sandstone Member of the Magura Formation. In both sections (A and B), the contact between the Piwniczna Sandstone Member and the overlying marly shales is not exposed (1-2 m of break in exposure). The marly shales are soft and green with numerous calcite veins with thicknesses varying from 0.5 m (profile A) to 2.5 m (profile B). They are overlain by a 4 m thick marly unit of the

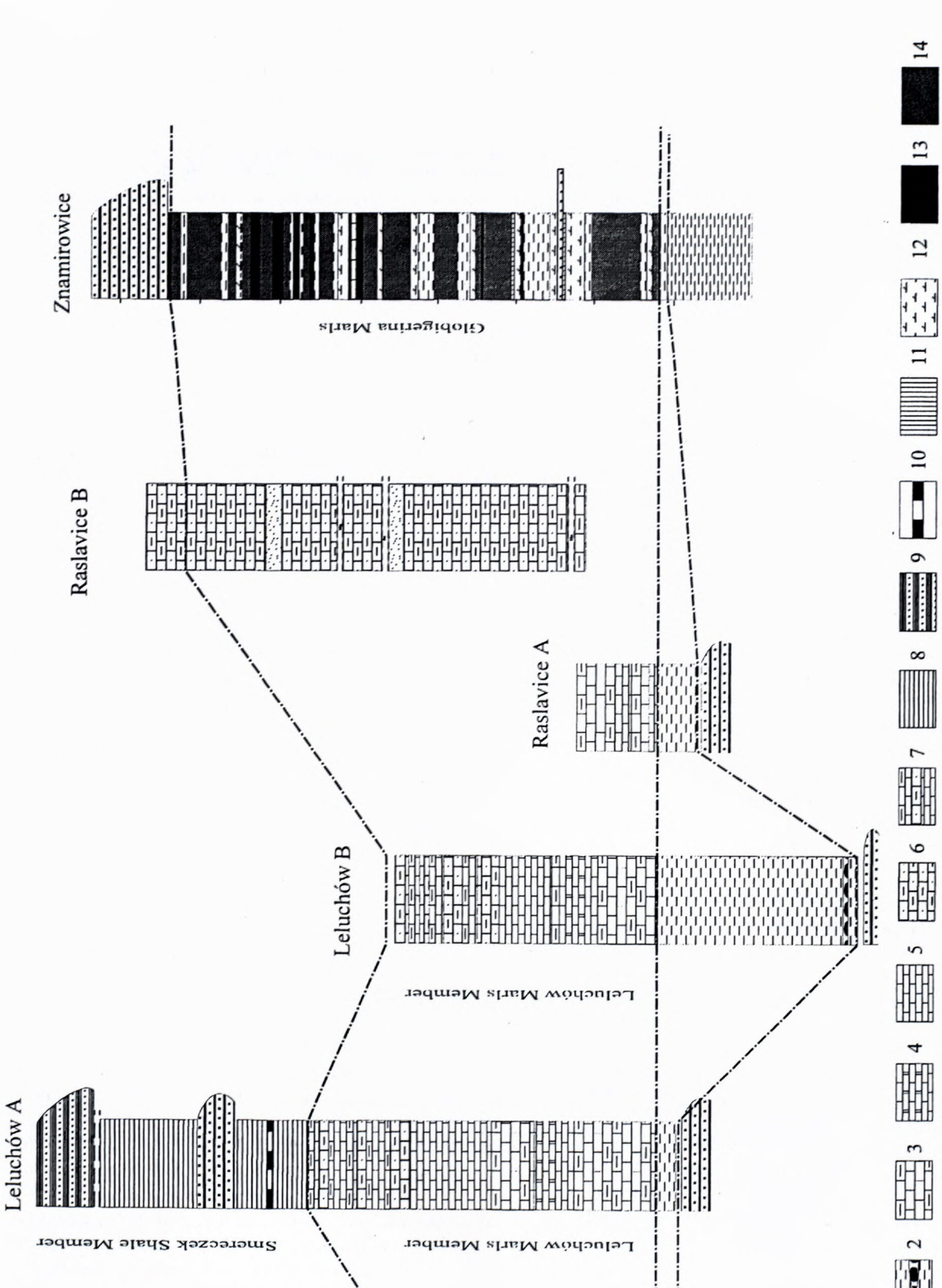


Fig. 2 Lithostratigrafic correlation of Leluchów, Raslavice and Znamirowice sections.
1 thick-bedded sandstones, 2 green calcareous shales, 3 red marls, 4 greyish-green marls, 5 greenish marls, 6 olive marls, 7 grey calcareous marls, 8 Menilite shales, 9 thin-bedded sandstones with shales intercalations, 10 hornstones, 11 limonite, 12 greyish-green non-calcareous shales, 13 dark shales and marls, 14 light-grey marls

Leluchów Marls Member. The sequence of marls is as follows:
- 1 meter of red marls,
- 0.5 meter of greyish-green marls,
- 0.5 meter red marls,
- 1 meter of greenish marls,
- 0.25 meter of olive marls,
- 1 meter of grey calcareous shales.

Just above the calcareous shales, the Smereczek Shale Member is reported (Birkenmajer & Oszczypko, 1989). This member consists of dark bituminous Menilite-like shales with thin (2-5 cm) beds of hornstones. A very thin tuffite bed ("Gąsiory" ? level) was also found in the lower part of the Smereczek Shale Member. In the uppermost part of the Leluchów section, thin-bedded turbidites of the Malcov Formation occur. These flat-laying, south dipping strata consist of Krosno-like, dark-grey marly shales with intercalations of thin bedded (10-12 cm), cross-laminated calcareous sandstones.

Raslavice. The base of section A (Fig. 2) consist of green marly shales (50 cm in thickness) which are overlain by a 85 cm thick marly unit. The sequence of marls is :10 cm of yellowish marls and 77 cm of red marls with 10 thick intercalation of yellowish marls. Section B begins with a 20 cm thick unit of red marls which is followed by 200 cm thick complex of pale marls with a sandstone intercalation at the top. In the uppermost part of the section, a complex of marls with minor sandstone intercalations is exposed. The Menilite Beds reported at this area by Nemcok (1985) have not been found in the examined sections. Going up in the section (towards the Raslavice), the exposures of the Malcov Formation are observed.

Znamirowice. The Globigerina Marls at the Znamirowice section were the subject of detailed research carried out by Van Couvering et al. (1981) and Leszczyński (1996). The section (Fig. 2) begins with a 5-m thick package of green non-calcareous clayey to muddy shales. These sediments pass upwards into a 6.3-m thick package of the Sub-Menilite Globigerina Marls. The base of the Globigerina Marls consist of cream-yellow-beige marls with an alternation of non-calcareous and calcareous green shales. In the uppermost part of Globigerina Marls, the bluish calcareous sandstone occur, which constitutes the bottom part of the Menilite Beds. Few meters above the marls, within the deposits belonging to the Menilite Beds, two thin tuffite layers belonging to the Gąsiory tuffite horizon were found. The fission-track age determination on zircons from the Gąsiory tuffites are: 28.9 +/- 1.2 my for the upper layer and 34.6 +/- 1.4 my for the lower one (Van Couvering *et al.*, 1981). These data indicate the Oligocene age of the Menilite Beds.

Lithostratigraphic correlation

Two sections (Leluchów and Raslavice) out of three described above, belong to the Magura Nappe, whereas, the third one is a part of the Silesian Nappe (see fig. 2). In the lithostratigraphic section of the Magura Nappe, the lowest position is occupied by the variegated shales, known from Raslavice, which are overlain in the Leluchów and Raslavice sections with marly shales and marls belonging to the Globigerina Marls (Leluchów Marls Member; see Birkenmajer & Oszczypko, 1989). In Leluchów just above the marls, dark bituminous shales (the Smereczek Shale Member) and thin- bedded turbidites of the Malcov Formation are reported. However, in the poorly exposed Raslavice section, the red marls are overlain by yellow-grey marls and sandstones belonging to the Malcov Formation. Despite a few differences, the Leluchów Marls Member can be litho- and biostratigraphicly correlated with the Sub- Menilite Globigerina Marls of the Silesian Nappe at Znamirowice.

Studied material and methods

The studied samples were collected by E. Malata and Prof. N. Oszczypko (Leluchów section) and M. Oszczypko-Clowes (Raslavice section). All samples were prepared with the standard smear slide technique for light microscope (LM) observations. The investigations were carried out under LM at magnification of 1024x and 1600x using phase contrast and crossed nicols. Several specimens photographed under SEM and LM are illustrated in figures 3, 4 and 5.

For the purpose of isotopic analyses 14 samples (Leluchów) and 10 samples from Znamirowice (collection belongs to Dr S. Leszczyński) have been used. To isolate the foraminifers, samples were frozen - dried, weighed and desegregated in a Calgon solution. After drying, individual planktonic and benthic foraminifers (see Table 1) were hand-picked from specific size-sorted samples. The stable isotopic analyses were conducted in the Institute of Geochemistry, Mineralogy and Ore deposits of National Academy of Sciences of Ukraine.

Calcareous nannoplankton biostratigraphy and zonation

The most common Paleogene coccolith zonations are the standard zonation of Martini (1971), and the zonation of Bukry (1973), Okada and Bukry (1980). A comparison of these two zonations (Middle Eocene through Lower Oligocene) is presented in Table 2.

The first occurrence (FO) of *Isthmolithus recurvus* DEFLANDRE has traditionally been used as a base of the Upper Eocene. However, this taxon is not a reliable marker in the lower latitudes. The FO of *Sphenolithus pseudoradians* BRAMLETTE et WILCOXON has been also used as a zonal marker for the Upper Eocene. The FO of these species seems to be controversial as the taxon has also been reported in the Middle Eocene (cfr PERCH-NIELSEN, 1985, 1986). The Upper Eocene is therefore no longer considered as two separate zones NP 19 and NP 20, but as a combined zone NP 19- 20 (AUBRY 1983), which is an equivalent to subzone CP 15b (OKADA & BUKRY, 1980). For a long time the last occurrence (LO) of *Discoaster barbadiensis* TAN SIN HOK or *Discoaster saipanensis* BRAMLETTE et RIEDEL was used as a coccolith event, marking the Eocene-Oligocene boundary

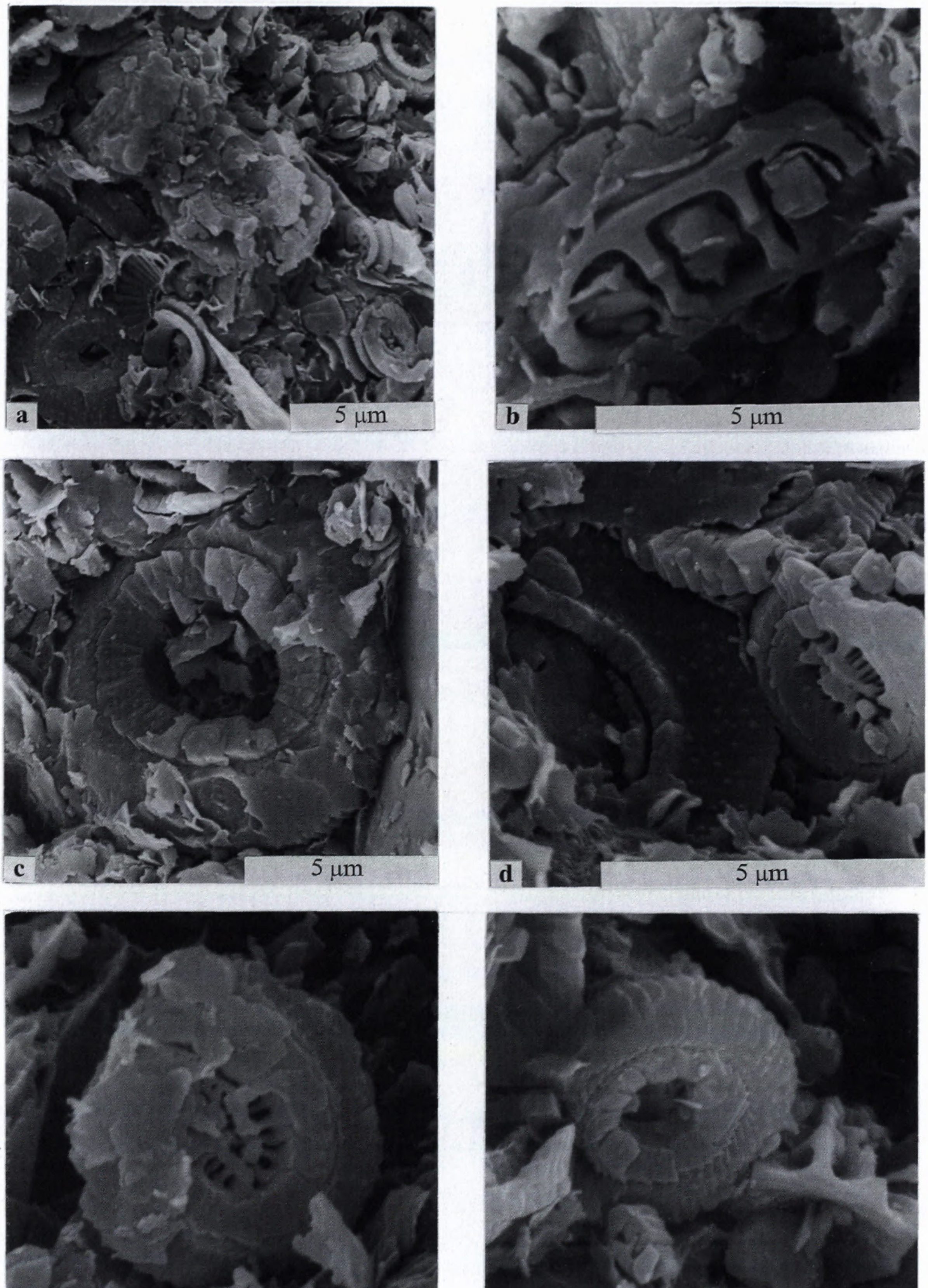
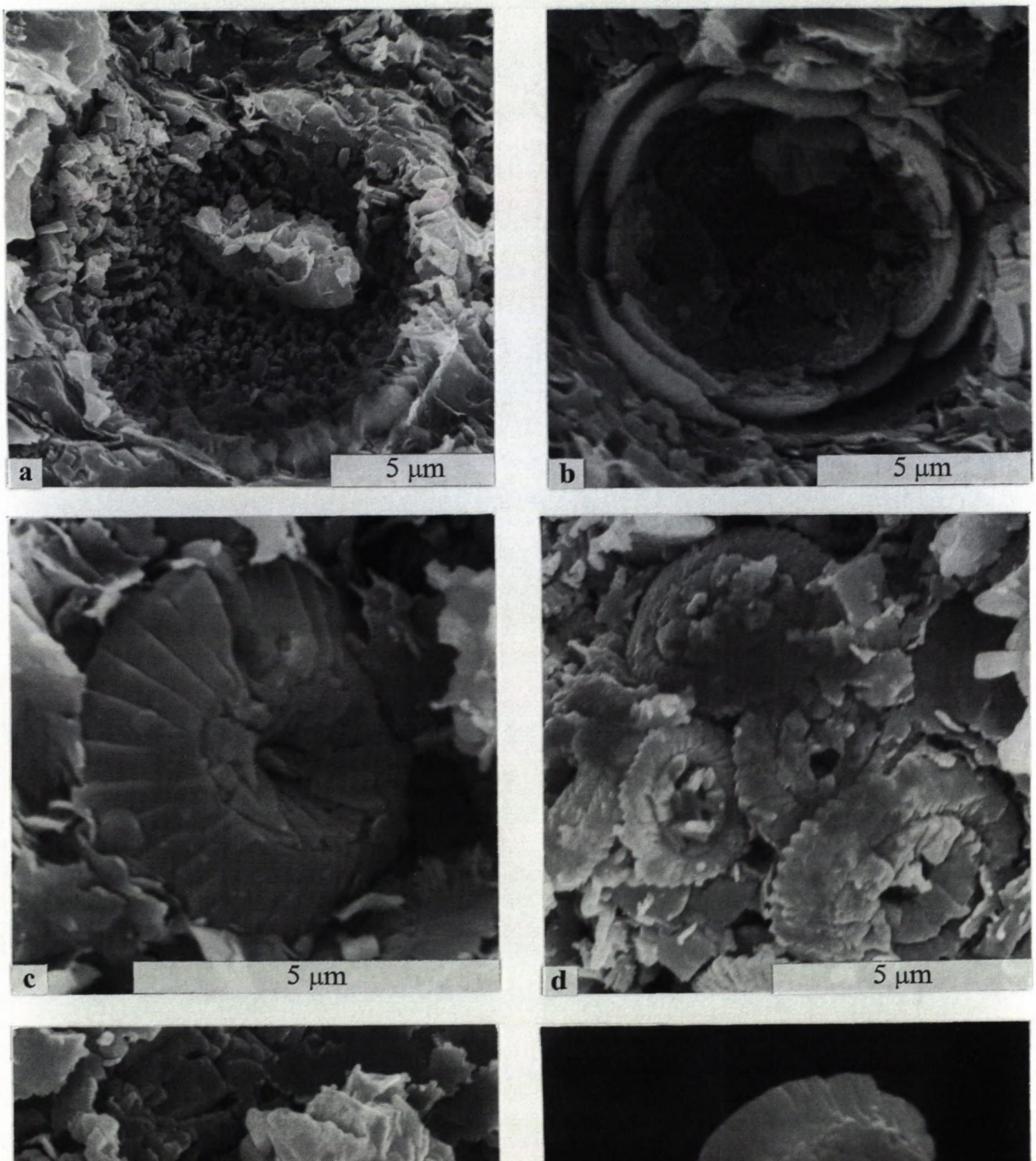


Fig. 3 SEM micrographs

a) rock surface Leluchów, section A, sample 55; b) *Isthmolithus recurvus*, Leluchów, profil A, sample 55; c) *Reticulofenestra hillae*, Leluchów, section A, sample 55; d) *Reticulofenestra umbilica*, Leluchów, section A, sample 55; e) *Dictyococcites callidus*, Leluchów, section A, sample 55; f) *Sphenolithus moriformis*, Leluchów, section A, sample 55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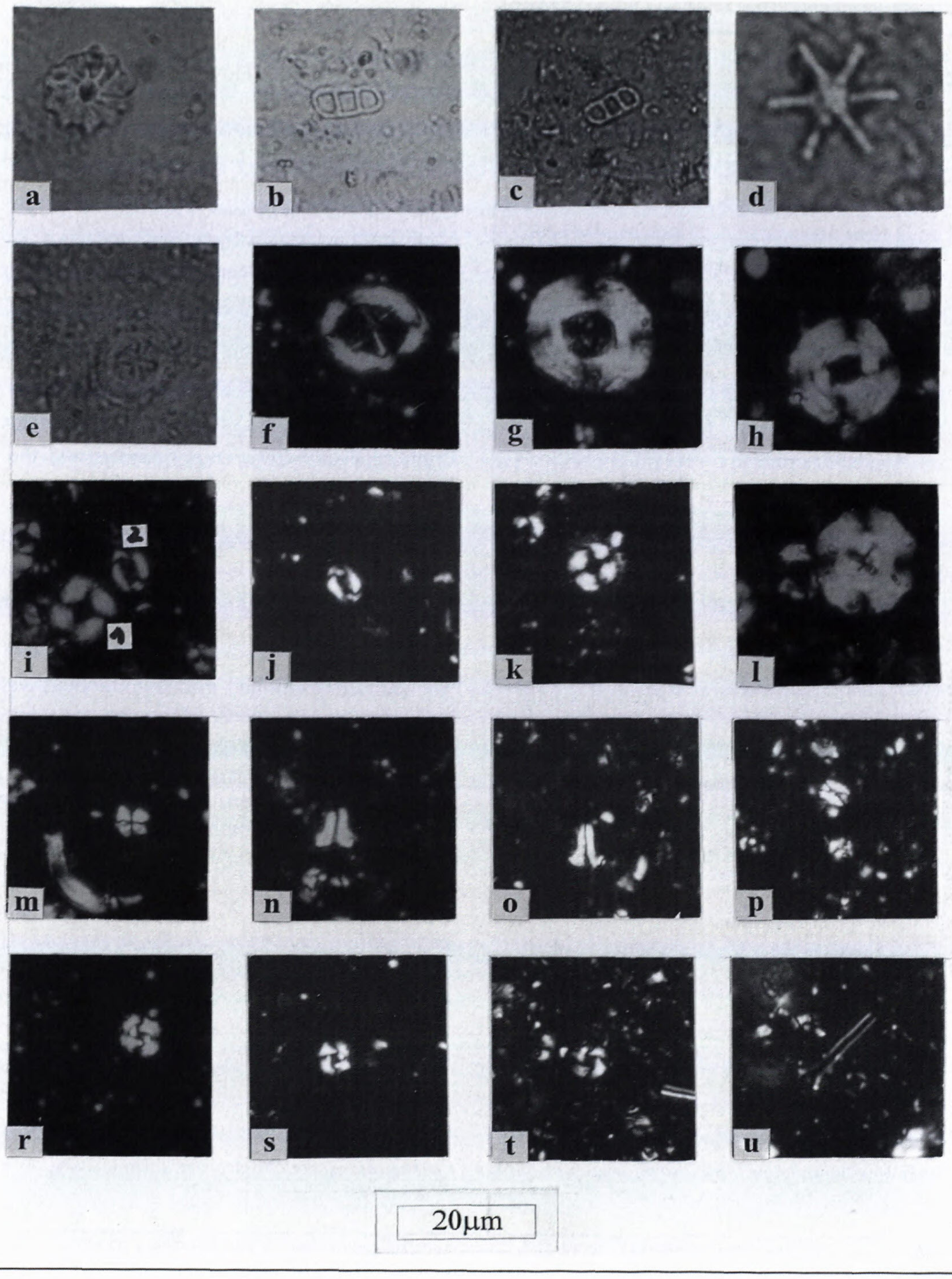


Fig. 4 SEM micrographs

a) *Thoracosphaera operculata*, Leluchów, section A, sample 55; b) Coccosphere of *Dictyococcites bisectus*, Leluchów, section A, sample 55; c) *Coccolithus pelagicus*, Leluchów, section A, sample 55; d) Coccosphere of *Dictyococcites bisectus*, Leluchów, section A, sample 55; ; e) *Dictyococcites callidus*, Leluchów, section A, sample 55; f) *Ericsonia fenestrata*, Leluchów, section A, sample 55

Fig. 5 LM microphotogaphs

a) *Discoaster barbadiensis*, Leluchów, section A, sample 51; b) *Isthmolithus recurvus*, Leluchów, section A, sample 53; c) *Isthmolithus recurvus*, Raslavice section , sample 16; d) *Discoaster nodifer*, Leluchów, section B, sample 36; e) *Chiasmolithus oamaruensis*, Leluchów, section A, sample 55; f) *Chiasmolithus oamaruensis*, Leluchów, section A, sample 55; g) *Reticulofenestra umbilica*, Leluchów, section B, sample 36; h) *Reticulofenestra hillae*, Leluchów, section B, sample 36; i_1) *Ericsonia formosa*, Leluchów, section B, sample 36; i_2) *Dictyococcites callidus*, Leluchów, section B, sample 36; j) *Dictyococcites callidus*, Raslavice section , sample 19; k) *Ericsonia formosa*, Raslavice section , sample 19; l) *Dictyococcites bisectus*, Leluchów, section A, sample 53; m) *Sphenolithus moriformis*, Leluchów, section B, sample 43; m) *Dictyococcites bisectus*, Leluchów, section B, sample 36; n) *Zygrhablithus bijugatus*, Leluchów, section A, sample 53; o) *Zygrhablithus bijugatus*, Raslavice section, sample 16; p) *Lanternithus minutus* , Raslavice section, sample 16; r) *Cyclicargolithus* ex. gr. *marismontium-floridanus*, Leluchów, section A, sample 55; s) *Cyclicargolithus floridanus*, Leluchów, section A, sample 53; t) *Cyclicargolithus floridanus*, Raslavice section, sample 16; u) *Blackites spinosus*, Raslavice section, sample 16

Sample No	Taxon	$\delta^{18}O$ (PDB)	$\delta^{13}C$ (PDB)
ZNAMIROWICE			
Zn - 5	Globigerina ex. gr. eocena s.l.	-3,75	-3,70
Zn - 6	Globigerina ex. gr. eocena	-3,56	-3,50
Zn - 9	Globigerina div. sp	-3,94	-2,90
Zn - 13	mixed planktonic foraminifers	-4,33	-3,30
Zn - 14	Globigerina div. sp	-4,62	-3,50
Zn - 15	mixed planktonic foraminifers	-4,24	-2,20
Zn - 17	Chilogumbelina sp. (cf. cubensis)	-4,72	-2,70
Zn - 22	mixed planktonic foraminifers	-4,24	-2,80
Zn - 26	mixed planktonic foraminifers	-4,53	-3,70
Zn - 28	mixed planktonic foraminifers	-4,82	-3,90
LELUCHÓW			
L - 36	mixed (Globigerina sp. + Turborotalia sp.)	-7,24	-0,90
L - 37	mixed (Globigerina sp. + Turborotalia sp.)	-6,95	-0,80
L - 38	mixed (Globigerina sp. + Turborotalia sp.)	-6,18	-0,90
L - 40	mixed (Globigerina sp. + Turborotalia sp.)	-5,88	-0,70
L - 41	mixed (Globigerina sp. + Turborotalia sp.)	-6,08	-0,60
L - 42	mixed (Globigerina sp. + Turborotalia sp.)	-5,88	-0,60
L - 44	mixed (Globigerina sp. + Turborotalia sp.)	-6,47	-0,30
L - 45	mixed (Globigerina sp. + Turborotalia sp.)	-5,69	-0,40
L - 46	mixed (Globigerina sp. + Turborotalia sp.)	-5,40	-0,20
L - 48	mixed (Globigerina sp. + Turborotalia sp.)	-5,59	-0,50
L - 50	mixed (Globigerina sp. + Turborotalia sp.)	-5,50	-0,30
L - 51	Eponides div. sp.	-6,00	-0,50
L - 54	mixed (Globigerina sp. + Turborotalia sp.)	-7,05	-0,80
L - 55	mixed (Globigerina sp. + Turborotalia sp.)	-7,47	-0,90

Table I Oxygen and carbon stable-isotope data for planktonic foraminifers from the Leluchów and Znamirowice sections

which coincides with the base of NP 21 (Martini & Ritzkowski, 1968). However, Cavelier (1979) showed that the extinction of *Discoaster saipanensis* and *Discoaster barbadiensis* was diachronous and occurred earlier in the higher latitudes than in the lower ones. It proved that the lower limit of zone NP 21 ranges in age from Late Eocene to Early Oligocene.

For the purpose of this work the standard zonation of Martini (1971) has been used. The detailed biozonal assignments are as follows:

Isthmolithus recurvus/Sphenolithus pseudoradians (NP 19-20) combined zone

Definition: The base of the zone is defined by the first occurrence of *Isthmolithus recurvus* and the top by the last occurrence of *Discoaster barbadiensis* and/or *Discoaster saipanensis*

Author: AUBRY (1983)

Age: Late Eocene

Remarks: This zone is identified in samples from Leluchów section A (48, 49) and B (46, 45, 44, 43) as well as from Raslavice section A (15-19) and B (22-24). The samples examined in this zone yield well preserved and diverse calcareous nannoplankton (Figs. 6, 7, 8) assemblages, characterised by the occurrence of *Isthmolithus recurvus*, *Discoaster barbadiensis*, *Discoaster saipanensis*. Such an association is believed to be indicative of the combined interval zone NP 19-20. *Dictyococcites bisectus* HAY, MOHLER & WADE, *Coccolithus pelagicus* (WALLICH), *Cyclicargolithus floridanus* ROTH & HAY, *Reticulofenestra umbilica* Hay, *Isthmolithus recurvus*, *Ericsonia formosa* (KAMPTNER) are the most commonly recorded species. Species which are also common to lesser extend include *Neococcolithes dubius* (DEFLANDRE), *Reticulofenestra callida* PERCH-NIELSEN, *Lanthernithus minuthus* Stradner, *Zygrablithus bijugathus* (DEFLANDRE).

Table II Calcareous nannoplankton biostratigraphy of the Late Eocene and Early Oligocene (Martini, 1971; Bukry, 1973; Okada & Bukry, 1980)

AGE		BUKRY (1973) ZONE		SUB-ZONE	MARTINI (1971) ZONE	
OLIGOCENE	E	CP 16	*Helicosphaera reticulata*	CP16c	NP 22	*Helicosphaera reticulata*
				CP 16b CP 16a	NP 21	*Ericsonia subdisticha*
EOCENE	L	CP 15	*Discoaster barbadiensis*	CP 15b	NP19-20	*Isthmolithus recurvus*
				CP 15a	NP 18	*Chiasmolithus oamaruensis*
	M	CP 14	*Reticulofenestra umbilica*	CP 14b	NP 17	*Discoaster saipanensis*
				CP 14a	NP 16 & NP 15	*Discoaster tani nodifer*
		CP 13	*Nannotetrina quadrata*	CP 13c CP 13b CP13a		*Nannotetrina fulgens*
		CP 12	*Discoaster sublodoensis*	CP 12b	NP 14	*Discoaster sublodoensis*
	E			CP 12a		

SECTION	SAMPLES	Braarudosphaera bigelowii	Chiasmolithus sp.	Chiasmolithus medius	Chiasmolithus oamaruensis	Coccolithus pelagicus	Coronocyclus nitescens	Coronocyclus cf. C. nitescens	Cribrocentrum coenurum	Cyclageiosphaera alta	Cyclicargolithus aff. C. abisectus	Cyclicargolithus floridanus	Dictyococcites sp.	Dictyococcites bisectus.	Dictyococcites callidus	Dictyococcites hesslandii	Discoaster sp.	Discoaster barbadiensis	Discoaster deflandrei	Discoaster saipanensis	Discoaster tani	Discoaster tani nodifer	Ericsonia sp.	Ericsonia cava	Ericsonia formosa	Ericsonia subdisticha	Fasciculithus tympaniformis	Helicosphaera compacta	Helicosphaera euphratis	Isthmolithus recurvus	Lanternithus minutus	Prinsus cf. P. bisulcus	Pontosphaera sp.	Reticulofenestra clatrata/ lockeri	Reticulofenestra dictyoda	Reticulofenestra hillae	Reticulofenestra reticulata	Reticulofenestra cf. R. reticulata	Reticulofenestra umbilica	Rhabdosphaeraceae indet.	Sphenolithus moriformis	Sphenolithus predistensus	Sphenolithus spiniger	Thoracosphaera operculata	Tranversopontis pulcheroides	Zygrhabilithus bijugatus
	55	X		X	X		X		X		X	X	X	X		X	X		X		X	X	X	X		X		X		X	X			X	X		X	X		X	X	X	X	X	X	X
	54						X				X	X		X		X			X											X	X				X	X	X	X	X	X	X	X				X
	53			X		X	X				X	X	X	X		X							X		X	X				X	X			X	X		X	X		X	X	X	X			X
	52		X			X					X	X	X	X		X	X		X		X		X		X	X	X			X		X		X	X	X		X	X	X	X	X	X	X		X
	51					X	X	X		X	X	X	X	X	X	X			X				X		X	X	X		X	X				X	X			X	X	X	X		X	X		X
	50					X		X			X	X	X	X		X	X						X	X	X	X				X				X	X	X	X	X	X	X	X		X	X		X
	49					X	X	X				X	X	X		X	X	X	X	X	X		X	X	X					X					X		X	X	X	X	X			X		X
	48					X	X	X				X	X	X		X	X	X	X	X			X	X	X				X	X			X		X	X	X	X	X	X				X		X

Fig. 6 Distribution of calcareous nannofosils in the Leluchów A section (for further explanation see Fig. 2)

Ericsonia subdisticha zone (NP 21)

Definition: The base of the zone is defined by the last occurrence of *Discoaster barbadiensis* and/or *Discoaster saipanensis* and the top by the last occurrence of *Ericsonia formosa*

Author: ROTH & HAY in HAY et al. (1967), emend. MARTINI (1970)

Age: Early Oligocene (Late Eocene/Early Oligocene cfr. Cavelier, 1979)

Remarks. This zone is identified in samples 20 and 21 in the Raslavice section as well as in samples from Leluchów sections A (50, 51, 52, 53) and B (42, 41, 40, 39, 38, 37). The zone assignment is based on a continuos range of *Ericsonia formosa*, following the disappearance of *Discoaster saipanensis* and *Discoaster barbadiensis*. The described assemblage (Figs. 6, 7, 8) is characterised by the predominance of placoliths over discoasters. Among the asteroliths *Discoaster deflandrei* and *Discoaster tani* are the only species, which were found. Assemblage is abundant in species like *Coccolithus pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, Reticulofenestra callida.* The level of reworking is low and represents not more than 7% of the discussed assemblage.

Helicosphaera reticulata zone (NP 22)

Definition: The base of the zone is defined by the last occurrence of *Ericsonia formosa* and the top by the last occurrence of *Reticulofenestra umbilica*

Author: BRAMLETTE & WILCOXON (1967), emend. MARTINI (1970)

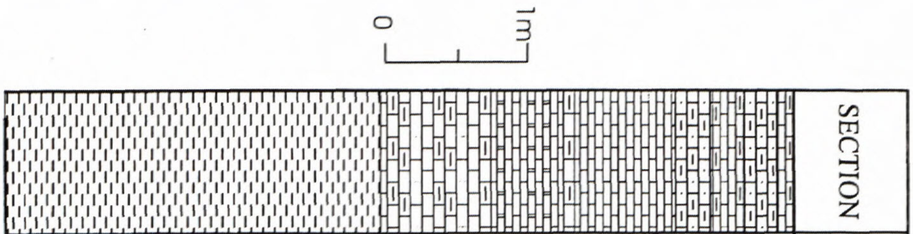
Age: Early Oligocene

Remarks: This zone is identified in samples from Leluchów sections A (54, 55) and B(36). The above mentioned samples contain the poorly preserved calcareous nannoplankton assemblage of low diversity (Figs. 6, 7). The assemblage is dominated by *Cyclicargolithus floridanus, Dictyococcites bisectus, Lanthernithus minuthus* and *Zygrablithus bijugathus* whereas *Reticulofenestra umbilica* and *Isthmolithus recurvus* become very rare.

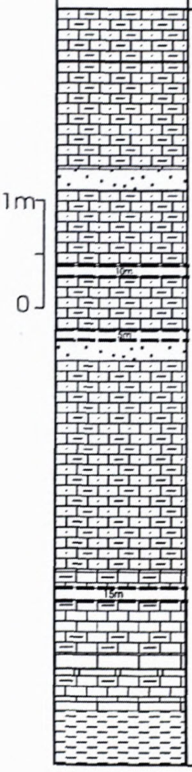
The formation of Eo- Parathethys

On the basis of stable isotope ($\delta^{13}C$, $\delta^{18}O$) studies, carried out for the Znamirowice and Leluchów sections (Fig. 9), it is possible to reconstruct and compare paleoenviromental condition in the Magura and Silesian basins. The values of stable isotopes ($\delta^{13}C$, $\delta^{18}O$) which were obtain from the Leluchów sections are distinctively

Fig. 7 Distribution of calcareous nannofosils in the Leluchów B section (for further explanation see Fig. 2)



CALCAREOUS NANNOPLANKTON / SAMPLES	46	45	44	43	42	40	41	39	38	37	36
Braarudosphaera bigelowii											X
Chiasmolithus sp.									X	X	X
Chiasmolithus medius											X
Chiasmolithus oamaruensis										X	X
Coccolithus pelagicus	X	X	X	X	X	X	X	X	X	X	X
Coronocyclus nitescens							X		X	X	X
Coronocyclus cf. C. nitescens											X
Cribrocentrum coenurum											X
Cyclicargolithus aff. C. abisectus						X	X	X	X	X	X
Cyclicargolithus floridanus	X	X	X	X	X	X	X	X	X	X	X
Dictyococcites sp.	X	X	X	X	X	X	X	X	X	X	X
Dictyococcites bisectus.	X	X	X	X	X	X	X	X	X	X	X
Dictyococcites callidus											X
Dictyococcites hesslandii	X	X	X	X	X	X	X	X	X	X	X
Discoaster sp.	X	X	X	X		X	X	X	X	X	X
Discoaster barbadiensis	X	X	X	X							
Discoaster deflandrei	X	X	X	X		X	X	X		X	X
Discoaster tani nodifer						X					X
Discoaster saipanensis	X	X	X	X							
Discoaster tani	X	X	X	X		X	X			X	
Ericsonia sp.	X	X	X	X	X	X	X	X	X	X	X
Ericsonia cava										X	X
Ericsonia formosa	X	X	X	X	X	X	X	X	X	X	
Ericsonia subdisticha						X	X	X	X	X	X
Fasciculithus tympaniformis							X		X		
Helicosphaera compacta											X
Helicosphaera dinsenii/ heezenii							X				
Helicosphaera euphratis	X						X				
Isthmolithus recurvus	X	X	X	X	X	X	X	X	X	X	X
Lanternithus minutus					X			X	X		
Reticulofenestra clatrata/ lockeri		X	X	X		X	X	X	X	X	X
Reticulofenestra dictyoda	X	X	X	X	X	X	X	X	X	X	X
Reticulofenestra hillae	X	X	X	X	X	X				X	X
Reticulofenestra reticulata	X	X	X	X	X	X	X			X	X
Reticulofenestra cf. R. reticulata	X		X	X		X	X	X	X	X	X
Reticulofenestra umbilica	X	X	X	X		X	X		X	X	X
Rhabdosphaeraceae indet.	X	X	X	X	X	X	X	X	X	X	X
Sphenolithus moriformis	X	X	X	X	X	X	X	X	X	X	X
Sphenolithus predistensus								X	X	X	X
Sphenolithus spiniger		X	X	X	X	X	X	X	X	X	X
Thoracosphaera operculata	X	X	X		X	X	X	X	X	X	X
Tranversopontis pulcheroides											X
Zygrhablithus bijugatus	X	X	X	X	X	X	X	X	X	X	X



SAMPLES	Chiasmolithus sp.	Chiasmolithus grandis	Chiasmolithus oamaruensis	Coccolithus pelagicus	Coranulus germanicus	Coronocyclus nitescens	Cyclicargolithus luminis	Cyclicargolithus floridanus	Dictyococcites bisectus.	Dictyococcites callidus	Dictyococcites hesslandii	Discoaster sp.	Discoaster barbadiensis	Discoaster deflandrei	Discoaster tani nodifer	Discoaster saipanensis	Discoaster tani	Ericsonia formosa	Ericsonia subdisticha	Isthmolithus recurvus	Lanternithus minutus	Reticulofenestra dictyoda	Reticulofenestra hillae	Reticulofenestra minuta	Reticulofenestra prebisecta	Reticulofenestra reticulata	Reticulofenestra umbilica	Rabdosphaera spinosus	Sphenolithus moriformis	Sphenolithus pseudoradians	Toweius gammation	Tranversopontis pulcher	Tranversopontis pulcheroides	Zygrhablithus bijugatus
← 20			X	X				X	X									X	X	X									X					X
← 21			X	X	X		X	X	X	X							X	X	X	X	X		X				X	X	X			X		X
← 22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
← 23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
← 24			X	X				X	X	X	X		X			X		X	X	X	X	X		X					X	X			X	X
← 19	X			X				X	X	X	X	X	X	X	X	X	X	X		X			X	X	X		X		X					
← 18				X			X	X	X									X	X			X		X										
← 17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
← 16	X	X		X			X	X	X	X	X	X	X		X	X	X	X		X			X				X		X		X			
← 15	X		X	X				X	X			X	X	X		X	X			X			X		X		X		X					X

Fig. 8 Distribution of calcareous nannofosils in the Raslavice section (for further explanation see Fig. 2)

different from those gained from Znamirowice. Therefore it may be concluded that during the Late Eocene - Early Oligocene time span, the relatively shallow Magura Basin was partly isolated from the World Ocean what caused limited circulation of water masses. At the same time, the deposition in the Silesian, Sub- Silesian and Skole Basins was still dominated by the open marine conditions.

One of the consequences of the Pyrenean orogeny, was partial isolation of the Northern Thethys from Thethys ss., and formation of the remnant basin so-called Eo- Prathethys (Nagymarosy, 1980). The process of isolation was initiated in the Magura Basin in the Latest Eocene to reach its maximum in the Early Oligocene (during the deposition of the Menilite Shales). In the next stage (Late Oligocene- Early Miocene) the procces of isolation took place in the northern part the Outer Carpathians Flysch Basin (Silesian-Subsilesian, Skole and Boryslaw - Pokuty sub- basins) and came to the end during the Middle Burdigalian (folding and uplifting of the Moldavides, see Oszczypko, 1997).

Discussion

The Globigerina Marls from the Leluchów sections revealed an assemblage belonging to NP 19-20, NP 21 and NP 22 whereas in the previous paper (Oszczypko M., 1996) nannoplankton assemblage of the Globigerina Marls was assigned to the NP 19-20. In the light of new investigations as well as a change in sample preparation, the author decides to determine the following calcareous nannoplankton zones: the combine interval zone NP 19-20 (Late Eocene), NP 21 (Late Eocene/Early Oligocene) and in the uppermost part of the section - NP 22 (Early Oligocene).

The Late Eocene nannoplankton assemblage of the Globigerina Marls is moderately diversified. Haq (1971,

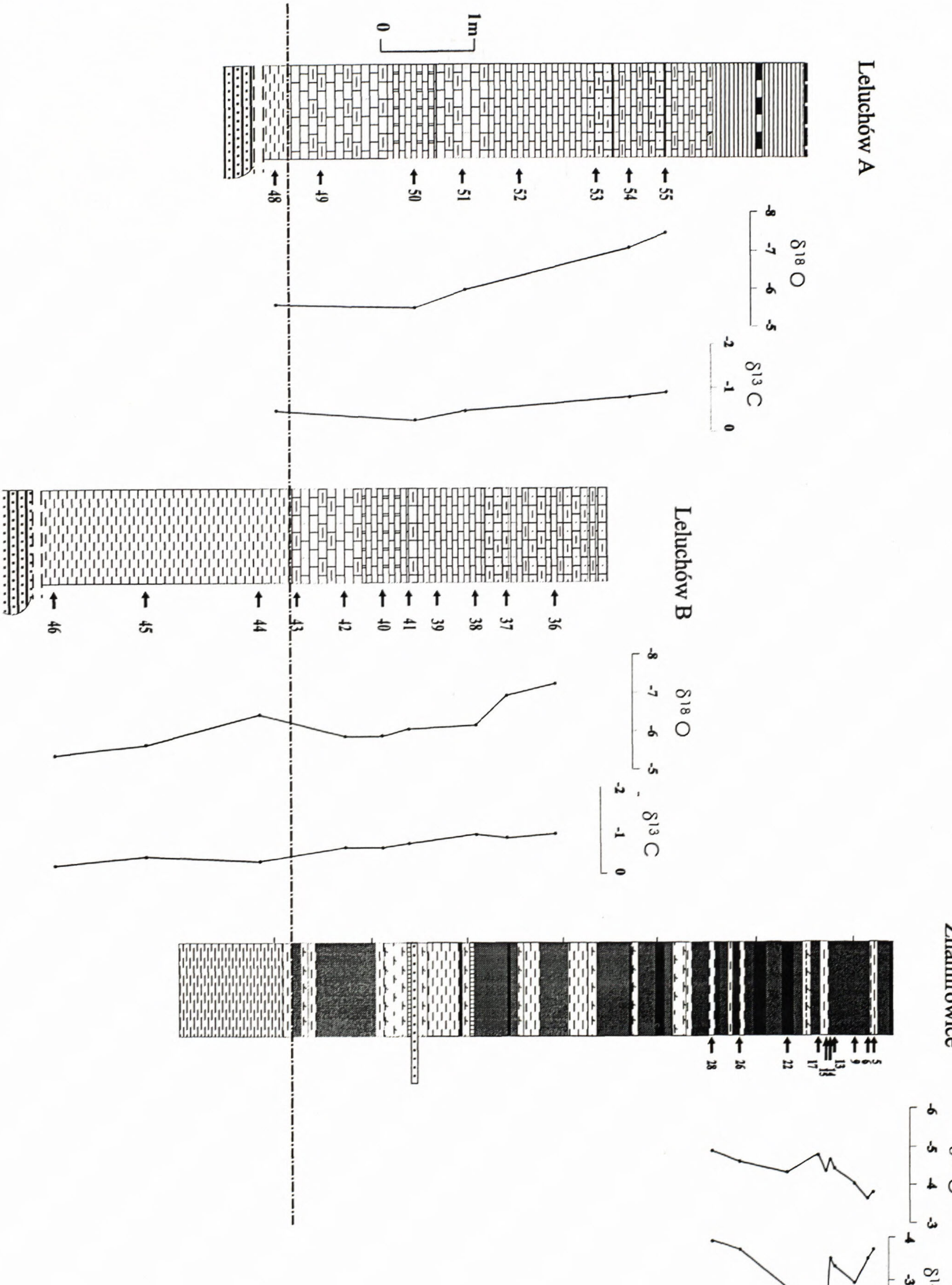


Fig. 9 Late Eocene-Oligocene stable isotope correlation

1973) and Bukry (1978) provided evidence of a strong relationship between calcareous nannoflora diversity and the temperature of the ocean water throughout the Paleogene (see also Andreyeva- Grigorovich & Savickaya, in press). According to those authors the low diversity is associated with a colder temperature and vice versa. Typical cold-water taxa *Isthmolithus recurvus*, *Zygrhablithus bijugatus*, *Lanternithus minutus*, *Chiasmolithus oamaruensis*, *Coccolithus pelagicus*, *Corannulus germanicus*, *Cyclicargolithus floridanus*, *Reticulofenestra reticulata* are dominant forms in the most samples of the upper part of described sections. At the same time the amount of warm-water taxa such as *Reticulofenestra umbilica*, *Discoaster saipanensis* and *Discoaster barbadiensis* is distinctly decreasing towards the top of the Leluchów and Raslavice sectiones. The domination of cold-water, subtropical and moderate latitude taxa coincide with the zone NP 21. These observation corresponds with that reported from the platform domain of South Ukraine, Krime and the Ukrainian Carpathians (Andreyeva-Grigorovich & Savickaya, in press).

Conclusions

1. Despite a few differences in lithology, there is possible to make biostratigraphic correlation of the Leluchów and Raslavice sections (Magura Nappe) with Znamirowice section (Silesian Nappe).

2. The nannoplankton research carried out for the Raslavice and Leluchów sections proved that the Eocene/ Oligocene boundary lies within the Globigerina Marls.

3. The Leluchów Marls Member and the Globigerina Marls in Raslavice differ from the typical Globigerina Marls (Znamirowice section). Beside the grey marls, the Leluchów Marls contain red and green ones which are typically pelagic sediments, enriched in nannofosils. Calcareous nannoplankton assemblages are dominated by taxons from the *Prinsiaceae* family.

4. The samples from the Leluchów and Raslavice sections contain a fairly abundant calcareous nannoplankton, which is assigned to a combined interval zone NP 19-20 and NP 21 of the standard Martini zonation. However, in the uppermost part of the Leluchów section the assemblage of calcareous nannoplankton belonging to the NP 22 has been also determined.

5. The nannoplankton assemblages form the upper portion of the Leluchów and Raslavice sections are dominated by cool-water taxons, which confirm the climatic changes in Late Eocene- Early Oligocene time.

6. The results of stable isotope analysis for the Leluchów section differ distinctively from those obtained in the Znamirowice section. During Late Eocene- Early Oligocene, the Magura basin was partly isolated from the World Ocean what might have caused a limited circulation of water masses.

7. The process of isolation of Silesian-Subsilesian, Skole and Bryslaw-Pokuty sub-basins from Thethys ss. was gradual and took place during the Oligocene and Early Miocene.

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