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Middle-Late Eocene phytoplankton from marl intraclasts (Podhale Paleogene, Inner Carpathians, Poland): biostratigraphic and paleoenvironmental implications

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Abstract: Organic-walled dinoflagellate cysts and calcareous nannoplankton are described from marly intraclasts found in submarine slump deposits within the Lower Oligocene Szaflary Beds exposed in the Leśnica Stream. Their Middle and Late Eocene age implies that the investigated deposits are coeval with the basal deposits of the Podhale Paleogene succession. These Middle and Upper Eocene marl intraclasts were eroded and transported into the flysch basin during the Early Oligocene. They represent the sediments deposited in the northern part of the Podhale Basin that is not exposed in recent times. Paleoenvironmental analysis of microfossils suggests sea-level oscillations during late Middle-Late Eocene (Bartonian–Priabonian) with its maximum during the earliest Late Eocene (earliest Priabonian). A drop of sea surface temperature during Late Eocene is also suggested on the basis of high-latitude microfossil occurrence.

Key words: Eocene, Carpathians, Poland, Central Carpathian Paleogene, Podhale Basin, paleogeography, biostratigraphy, calcareous nannoplankton, dinoflagellate cysts.

Introduction

The term “Podhale Paleogene” refers to a part of the Central Carpathian Paleogene deposits (Fig. 1; see also Soták et al. 2001) that occur in Poland between the Pieniny Klippen Belt in the north and the Tatra Mountains in the south (Fig. 2). The northern margin of the Podhale Paleogene along the contact with the Pieniny Klippen Belt is tectonic (e.g. Birkenmajer 1960, 1970, 1985) whereas its southern margin is erosional. As a consequence, the present-day northernmost peripheries of the Podhale Basin are now unknown because they are tectonically disturbed along the boundary with the Pieniny Klippen Belt structure (e.g. Birkenmajer 1970, 1985). The present-day northernmost deposits of the Podhale Paleogene that crop out along the contact with the Pieniny Klippen Belt are the Lower Oligocene Szaflary Beds — the Eocene rocks are exposed in contact with the Pieniny Klippen Belt deposits only in Slovakia (Orava and Haligovce area; see e.g. Gross &

Fig. 1. Tectonic sketch-map of the northern part of the Central Carpathian Paleogene Basin with location of the study area (arrowed).

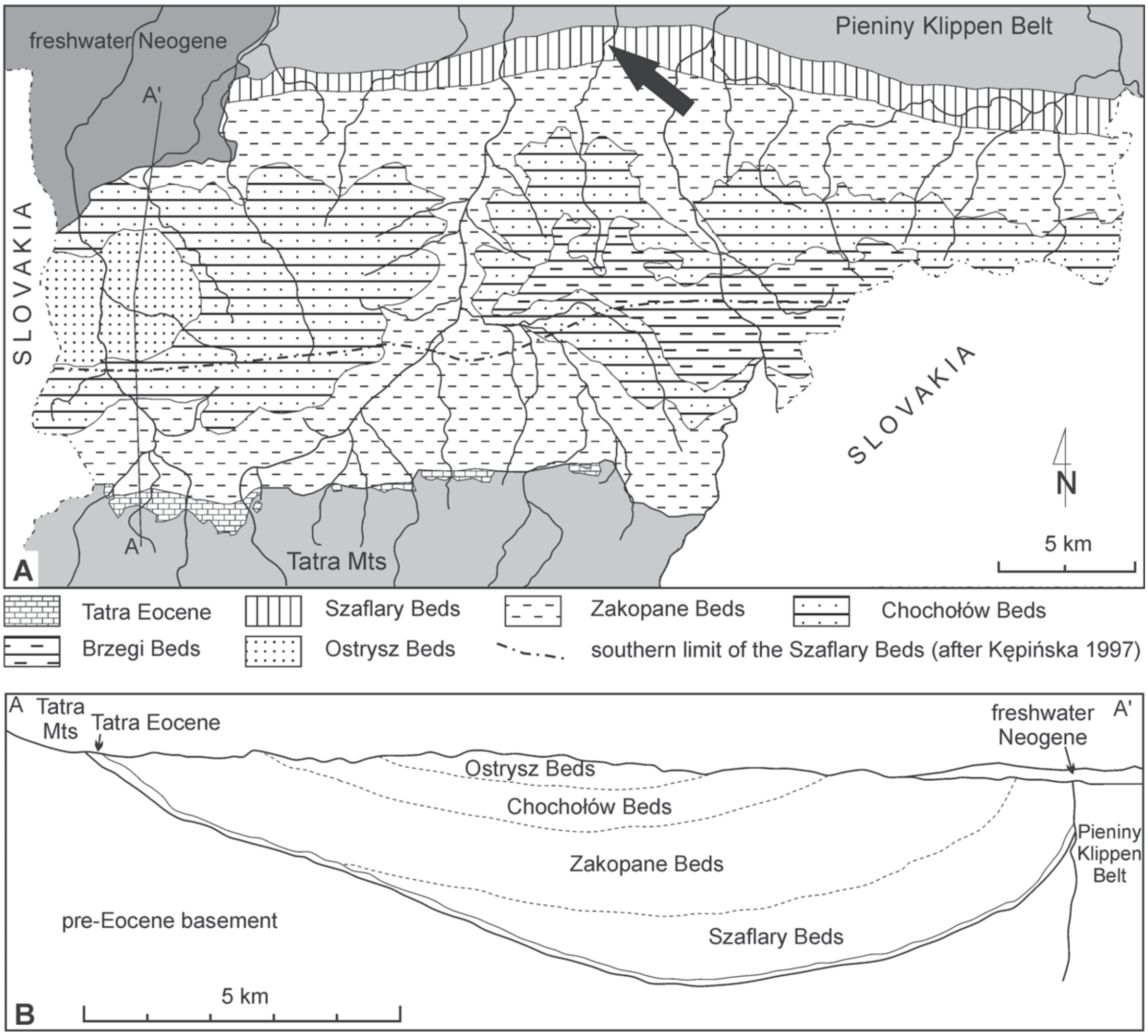


Fig. 2. Location of the study area (arrowed) against the background of a simplified sketch-map of the Podhale Paleogene (after Małecka 1982; with correction in Tatra Mts by Birkenmajer 2000).

Köhler 1987; Birkenmajer 1979 respectively). The basal strata of the Podhale Paleogene in this area, represented by the so-called Tatra Eocene (presumably Middle-Upper Eocene) are only known from boreholes (e.g. Kępińska 1997). However, incomplete coring and poor microfossil content of these basal intervals makes the recognition of this interval limited. Discovery of coeval marl intraclasts found in a submarine slump layer within the Szaflary Beds (Gedl 2004a) brings new information on the age, paleoenvironment and paleogeographical position of the basal deposits of the Podhale Paleogene. For this purpose dinoflagellate cysts and calcareous nannoplankton from marly intraclasts were studied.

Geological setting

The Podhale Paleogene sequence is traditionally divided into two informal units: the so-called Tatra Eocene (or Nummulitic Eocene) in the lower part (Borové Formation *sensu* Gross et al. 1984) and the so-called Podhale Flysch in the upper part. The basal part of the Tatra Eocene is usually developed as conglomerates of delta and cliff breccias origin (e.g. Passendorfer 1958) passing upwards into variously developed carbonates (e.g. Roniewicz 1969). Marly deposits that occur locally in the topmost part of the Tatra Eocene sequence (Alexandrowicz & Geroch 1963; Bartholdy et al. 1999) are more frequent in the northern part of the Podhale Basin (Sokołowski 1992; Jaromin et al. 1992; Kępińska 1997). The thickness of the Tatra Eocene rarely exceeds 100 meters (exceptional maximal thickness above 300 meters occurs in the Hruby Regiel Mountain area).

The Podhale Flysch deposits, resting upon the Tatra Eocene or locally directly on the Mesozoic substrate, reach up to 3000–3500 m thickness. This unit was informally divided by Gołąb (1959) and Watycha (1959) into the Szaflary Beds occurring in the northern part of the Podhale Basin, the Zakopane Beds (Huty Formation *sensu* Gross et al. 1984), the Chochołów Beds (Zuberec Formation *sensu* Gross et al. 1984) and the Ostrysz Beds known from the eastern part of the Podhale Basin (Biely Potok Formation *sensu* Gross et al.

1984). The Szaflary Beds, the oldest Podhale Flysch deposits in the peri-Klippen area, are developed as proximal flysch sediments. They are covered by the Zakopane Beds, the oldest flysch deposits in the peri-Tatric area.

The Middle-early Late Eocene (Bartonian–early Priabonian) age of the Tatra Eocene carbonates was determined on the basis of large and small foraminifers (e.g. Bieda 1963; Olszewska & Wieczorek 1998). The higher part of the Tatra Eocene exposed in Pod Capkami quarry was dated by means of calcareous nannoplankton as NP16–NP17 (Middle Eocene: upper part of Lutetian–Bartonian; Bartholdy et al. 1995). Some uncertainties occur concerning the dating of the uppermost part of the Tatra Eocene where frequent planktonic foraminifers were found (Alexandrowicz & Geroch 1963; Blaicher 1973; Olszewska & Wieczorek 1998; Bartholdy et al. 1999).

The age of the Szaflary Beds, often synonymized with the Šambron Beds *sensu* Chmelík (1957), based on dinocysts is Early Oligocene (but not the earliest Oligocene; Fig. 3). A younger, but also Early Oligocene age was determined for the Zakopane Beds (Gedl 1999, 2000a). As a consequence, a hiatus embracing the uppermost Eocene to lower part of Lower Oligocene was suggested between the Tatra Eocene and Podhale Flysch deposits. The hiatus is wider in the southern part of the Podhale Basin, where it also includes time equivalents of the Szaflary Beds (Gedl 2000a). A similar "mid-Oligocene" age of the Zakopane Beds was concluded by Garecka (2005) who correlated this lithostratigraphic unit with the NP24 Zone. The younger Chochołów Beds are correlated with the upper part of the Lower Oligocene (Rupelian; dinoflagellate cysts; Gedl 2000a) and Upper Oligocene (Chattian; foraminifers and calcareous nannoplankton; Olszewska & Wieczorek 1998; Garecka 2005 respectively).

Material

The slump layer with investigated marly intraclasts is exposed on the left bank of the Leśnica Stream (Fig. 4; see also Gedl 2004a). It occurs within thin-bedded flysch deposits with a distinctive bentonite layer a few meters above it. Few other slump layers are exposed in its vicinity (see Gedl 2000a, p. 81). The investigated slump layer is composed of a 1.2-m thick exotic-bearing, conglomeratic layer passing sharply upwards into 1.5-m thick sandstone layer (Fig. 5). The conglomeratic layer consists of well-rounded clasts (up

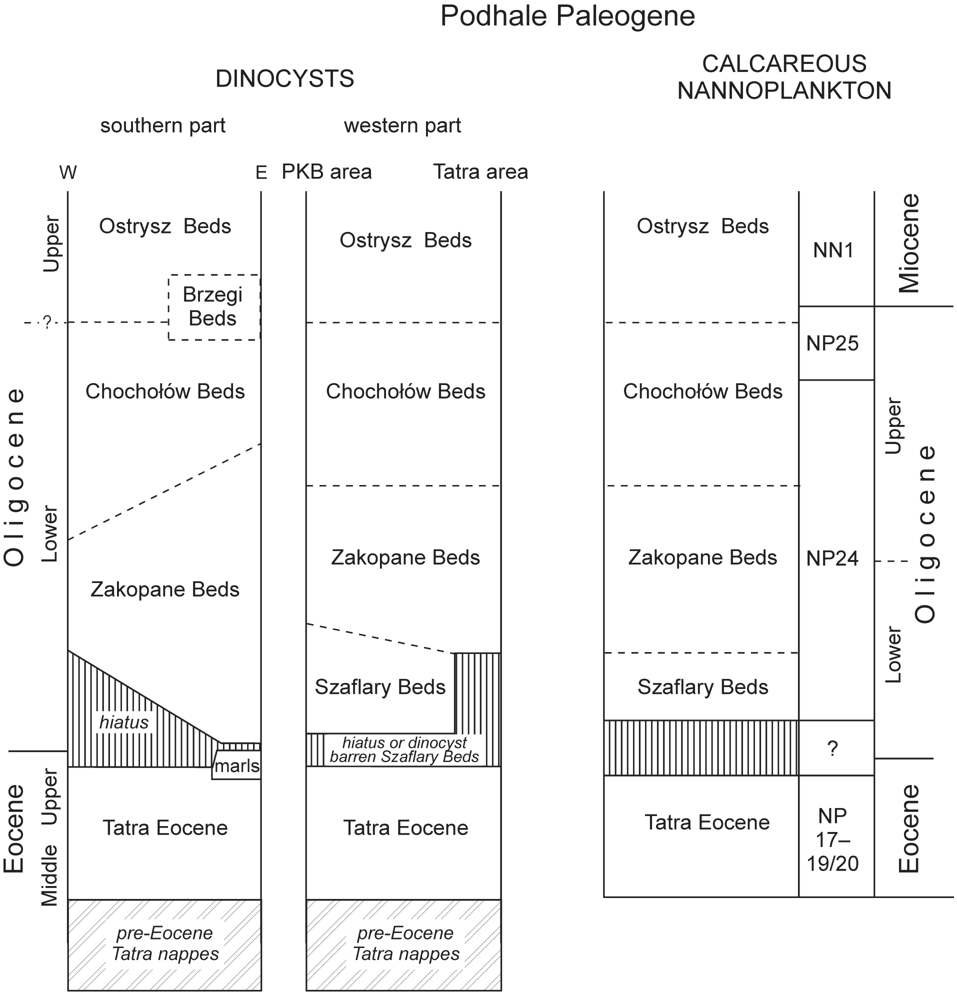


Fig. 3. Age of Podhale Paleogene (dinoflagellate cysts after Gedl 2000a; calcareous nannoplankton after Garecka 2005).

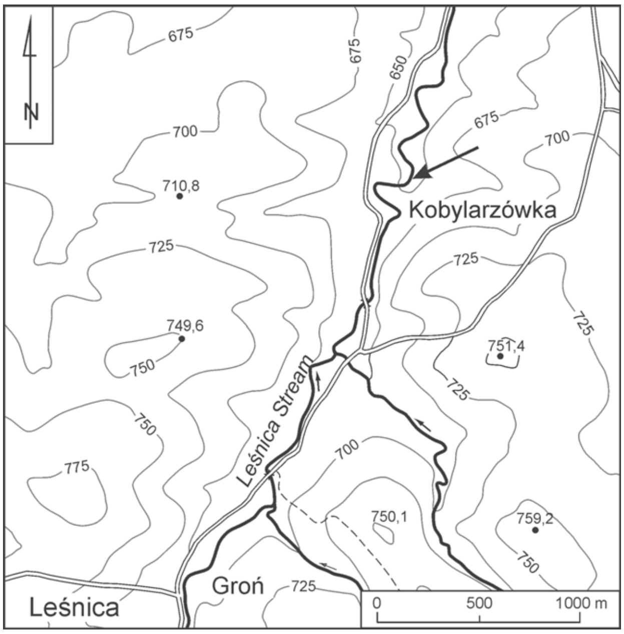


Fig. 4. Location of exposure of the investigated submarine slump layer (after Gedl 2004a).

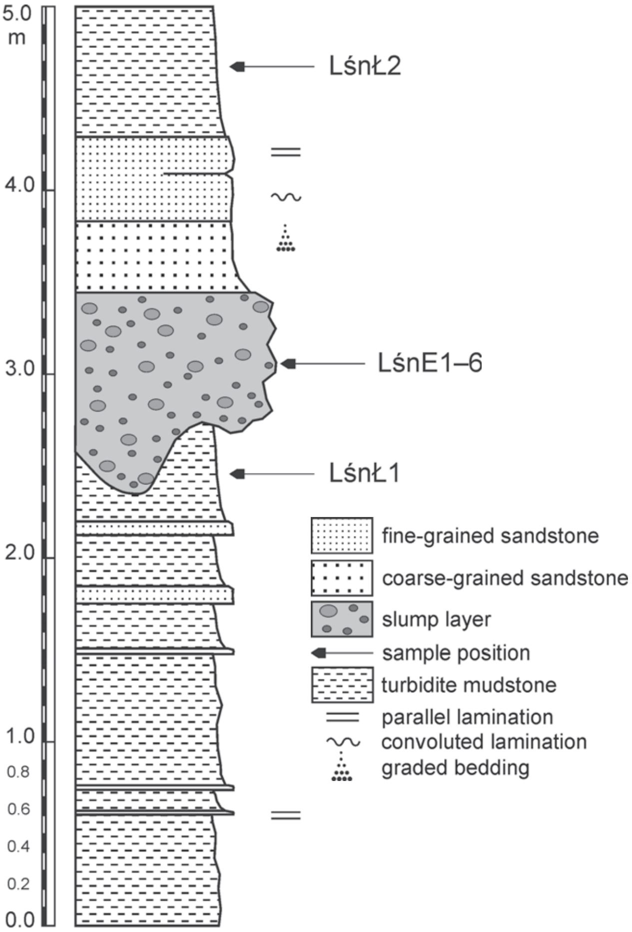


Fig. 5. Lithology of the investigated Szaflary Beds section with submarine slump layer (after Gedl 2004a), including position of investigated samples.

to several centimeters in diameter) representing mainly the Tatra-derived Triassic dolomites. Among those hard pebbles, infrequent soft cream yellow and pale brown, up to 10 cm in diameter, marly clasts of irregular shape occur. Six samples were taken from these marly clasts (LśnE1–LśnE6). Additionally, two samples were taken from the surrounding Szaflary Beds shales: sample LśnŁ1 from just below and sample LśnŁ2 from just above the slump layer (Fig. 5).

Methods

Dinoflagellate cysts. The samples for palynological investigation were processed following the standard palynological procedure including 38% hydrochloric acid (HCl) treatment, 40% hydrofluoric acid (HF) treatment, heavy liquid ($ZnCl_2$+HCl; density 2.0 g/cm^3) separation, ultrasound for 10–15 s and sieving at 15 μm nylon-mesh. Two slides were made from each sample using glycerine jelly as a mounting medium. All dinoflagellate cysts from both slides were determined and counted. Photographs were taken with the using a Sony DSC-S75 camera.

Samples, palynological residues and slides are stored in the collection of the Institute of Geological Sciences, Polish Academy of Sciences, Kraków.

Calcareous nannoplankton. Samples were prepared as smear slides. Calcareous nannoplankton was investigated with the light microscope at a magnification of 1500×, and photographed using a H-III Nikon camera.

Results

Dinoflagellate cysts (Figs. 6A, 7). Palynofacies of the flysch shales from just below and above the slump layer (Szaflary Beds; samples LśnŁ1 and LśnŁ2) is composed of land plant tissue remains and sporomorphs (mainly bisaccate pollen grains; a similar palynofacies dominated by terrestrial elements is characteristic for this part of the Szaflary Beds: see Gedl 2000a). Single specimens of *Deflandrea phosphoritica* and *Wetzeliella* sp. represent the extremely rare dinoflagellate cysts.

Marly intraclasts from the slump layer are characterized by different palynofacies. Terrestrial phytoclasts are represented by small-sized opaque phytoclasts and structured tissue remains. A different palynofacies than in other marly clasts was found in sample LśnE4 taken from a soft brownish marl. It is composed predominately of hyalinous resin particles. Sporomorphs and plant tissue remains are subordinate.

Dinoflagellate cysts are frequent, except in sample LśnE4, and are, often the dominating palynomorph. They also differ qualitatively being dominated by chorate taxa (Fig. 7). The taxonomic characteristics of the dinocyst assemblage can be found in Gedl (2004a).

Calcareous nannoplankton (Figs. 6B, 8). No calcareous nannoplankton (sample LśnŁ1) or single, very poorly preserved specimens of *Dictyococcites bisectus* were found (sample LśnŁ2) in the Szaflary Beds. This contrasts with much richer, although also poorly preserved, calcareous nan-

A Lithology	marl						flysch shale	
Taxon (in alphabetical order) / Sample	LśnE1	LśnE2	LśnE3	LśnE4	LśnE5	LśnE6	LśnŁ1	LśnŁ2
Achilleodinium biformoides	x				x	x		
Achomosphaera alcicornu	x		x		x	x		
Achomosphaera ramulifera	x							
Aiora sp. A	x					x		
Amphorosphaeridium? multispinosum			x					
Areosphaeridium diktyoplokum	x		x			x		
Areosphaeridium michoudii			x					
Batiacasphaera micropapilata	x							
Caligodinium sp.	x	x						
Charlesdowniea sp.	x		x			x		
Cordosphaeridium gracile	x		x			x		
Cordosphaeridium inodes		x						
Cordosphaeridium minimum			x					
Cordosphaeridium? solidospinosum			x		x			
Corrudinium incompositum			x					
Corrudinium? sp. A	x							
Dapsilidinium pseudocolligerum	x		x			x		
Deflandrea phosphoritica			x		x	x		
Deflandrea spp.	x	x	x			x	x	x
Diphyes colligerum	x							
Distatodinium ellipticum			x					
Dracodinium laszczynskii			x			x		
Dracodinium sp. A				x				
Enneadocysta multicornuta		x						
Enneadocysta pectiniformis	x	x	x	x				
Enneadocysta aff. *pectiniformis*	x							
Fibrocysta bipolaris	x		x					
Gongylodinium? sp. A	x							
Heteraulacacysta leptalea	x							
Heterosphaeridium sp. A	x		x		x			
Homotryblium plectilum	x							
Homotryblium tenuispinosum	x	x	x			x		
Hystrichokolpoma cinctum			x		x	x		
Hystrichokolpoma rigaudiae			x		x			
Impagidinium brevisulcatum	x		x					
Impagidinium dispertitum	x							
Impagidinium sp. A	x							
Impagidinium sp.			x			x		
Lingulodinium machaerophorum	x		x					
Lingulodinium pycnospinosum	x							
Melitasphaeridium pseudorecurvatum			x					
Nematosphaeropsis lemniscata	x							
Operculodinium centrocarpum	x		x		x	x		
Operculodinium aff. *centrocarpum*	x	x	x					
Operculodinium? hirsutum			x					
Operculodinium microtriainum	x	x	x		x	x		
Operculodinium tiara	x		x			x		
Pentadinium laticinctum granulatum			x					
Rhombodinium aff. *perforatum*	x							
Rhombodinium sp.	x							
Samlandia chlamydophora	x	x	x		x			
Spiniferites pseudofurcatus	x		x		x	x		
Spiniferites ramosus	x	x	x		x	x		
Systematophora placacantha	x	x	x			x		
Thalassiphora patula	x					x		
Thalassiphora pelagica	x		x			x		
Tityrosphaeridium cantharellus		x						
Wetzeliella articulata		x			x			
Wetzeliella sp.			x		x	x	x	x
Wetzeliella symmetrica				x				

B Lithology	marl						flysch shale	
Taxon (in alphabetical order) / Sample	LśnE1	LśnE2	LśnE3	LśnE4	LśnE5	LśnE6	LśnŁ1	LśnŁ2
Braarudosphaera bigelowii	x		x		x	x		
Braarudosphaera cf. *bigelowii*					x			
Chiasmolithus expansus						x		
Chiasmolithus aff. *grandis*						x		
Chiasmolithus cf. *grandis*	x							
Chiasmolithus aff. *oamaruensis*						x		
Chiasmolithus cf. *oamaruensis*	x							
Clathrolithus aff. *ellipticus*	x							
Clathrolithus aff. *spinosus*	x							
Coccolithus eopelagicus			x			x		
Coccolithus formosus	x	x	x		x	x		
Coccolithus cf. *formosus*	x							
Coccolithus pelagicus	x	x	x		x	x		
Coccolithus cf. *pelagicus*			x		x			
Corannulus germanicus	x							
Corannulus cf. *germanicus*						x		
Coronocyclus nitescens	x							
Cribrocentrum reticulatum	x		x		x	x		
Cyclicargolithus floridanus	x		x		x	x		
Dictyococcites bisectus	x		x		x	x		x
Dictyococcites cf. *bisectus*			x		x			
Dictyococcites callidus						x		
Dictyococcites srippsae					x			
Discoaster barbadiensis	x		x		x	x		
Discoaster cf. *barbadiensis*			x			x		
Discoaster binodosus	x					x		
Discoaster diastypus						x		
Discoaster cf. *deflandrei*	x							
Discoaster cf. *lodoensis*	x							
Discoaster multiradiatus	x					x		
Discoaster saipanensis	x				x	x		
Discoaster cf. *saipanensis*	x		x					
Discoaster strictus					x			
Discoaster tanii	x				x	x		
Discoaster cf. *tanii*			x		x	x		
Discoaster cf. *tanii nodifer*					x			
Helicosphaera compacta	x							
Helicosphaera cf. *compacta*	x				x			
Isthmolithus recurvus						x		
Lanternithus minutus	x				x			
Neococcolithes minutus	x					x		
Orthozygus aureus	x							
Pontosphaera scissura			x					
Reticulofenestra dictyoda		x				x		
Reticulofenestra hillae						x		
Reticulofenestra umbilica	x		x		x	x		
Reticulofenestra cf. *umbilica*	x	x	x		x	x		
Sphenolithus editus	x		x			x		
Sphenolithus aff. *editus*					x			
Sphenolithus aff. *furcatolithoides*		x						
Sphenolithus moriformis	x		x		x	x		
Sphenolithus pacificus	x				x	x		
Sphenolithus predistentus	x							
Sphenolithus cf. *pseudoradians*					x			
Sphenolithus radians	x							
Sphenolithus spiniger		x				x		
Thoracosphaera operculata					x			
Thoracosphaera saxea					x			
Transversopontis exilis	x							
Zygrhablithus bijugatus	x	x	x		x	x		

Fig. 6. Distribution of dinoflagellate cysts (**A**) and calcareous nannoplankton (**B**) in marl intraclasts and surrounding flysch shales.

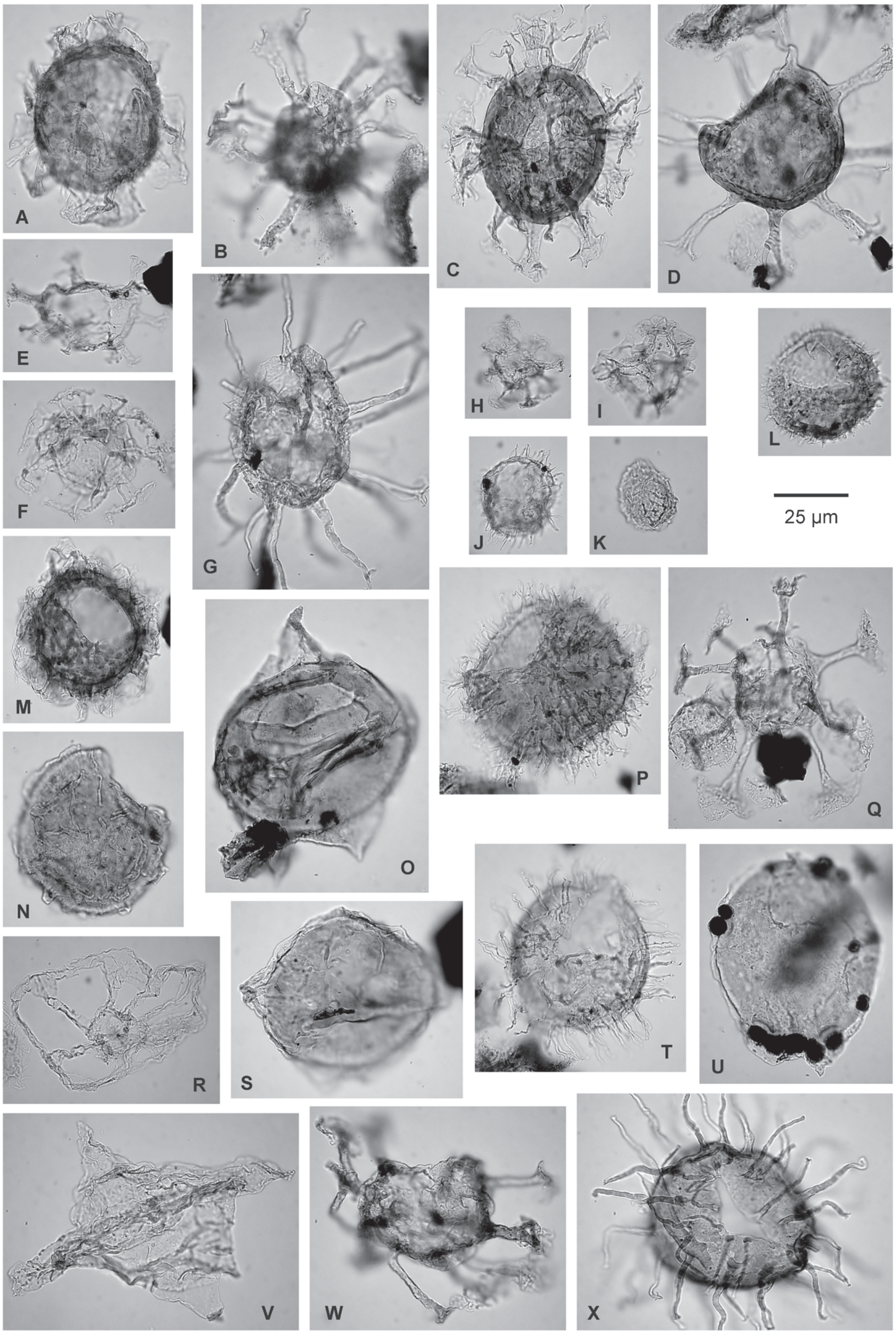


Fig. 7. Selected dinoflagellate cysts from marl intraclasts. Slide code and England Finder references are given. **A** — *Achilleodinium biformoides* (Eisenack, 1954) Eaton, 1976, LśnE1d[A51]; **B** — *Achomosphaera alcicornu* (Eisenack, 1954) Davey & Williams, 1966, LśnE5a[S33.2]; **C** — *Spiniferites pseudofurcatus* (Klumpp, 1953) Sarjeant, 1970, LśnE1d[A33.4]; **D** — *Cordosphaeridium gracile* (Eisenack, 1954) Davey & Williams, 1966, LśnE1b[H36.2]; **E** — *Homotryblium plectilum* Drugg & Loeblich Jr., 1967, LśnE1e[P40.3–4]; **F** — *Enneadocysta* aff. *pectiniformis sensu* Gedl (2004a), LśnE1d[D55.1–2]; **G** — *Cordosphaeridium*? *solidospinosum* Gedl, 1995, LśnE3b[L53.2]; **H** — *Cordosphaeridium minimum* (Morgenroth, 1966) Benedek, 1972, LśnE3b[T53.3–4]; **I** — *Impagidinium* sp. A *sensu* Gedl (2004a), LśnE1d[U47]; **J** — *Operculodinium* aff. *centrocarpum sensu* Gedl (2004a), LśnE2a[M32.3–4]; **K** — *Corrudinium incompositum* (Drugg, 1970) Stover & Evitt, 1978, LśnE3a[L31.3–4]; **L** — *Gongylodinium*? sp. A *sensu* Gedl (2004a), LśnE1d[K50.1]; **M** — *Samlandia chlamydophora* Eisenack, 1954, LśnE1d[S49.3]; **N** — *Corrudinium* sp. A *sensu* Gedl (2004a), LśnE1d[B34]; **O** — *Deflandrea* sp., LśnE3b[Y44.1]; **P** — *Operculodinium*? *hirsutum* (Ehrenberg, 1838) Lentin & Williams, 1973, LśnE3a[Y32.2]; **Q** — *Areosphaeridium diktyoplokum* (Klumpp, 1953) Eaton, 1971, LśnE1d[H44.3]; **R** — *Aiora* sp. A *sensu* Gedl (2004a), LśnE1d[Y53.3]; **S** — *Dracodinium laszczynskii* Gedl, 1995, LśnE6a[W31.3–4]; **T** — *Operculodinium centrocarpum* (Deflandre & Cookson, 1955) Wall, 1967, LśnE1b[V40]; **U** — *Dracodinium* sp. A *sensu* Gedl (2004a), LśnE4[G47.1–3]; **V** — *Rhombodinium* aff. *perforatum sensu* Gedl (2004a), LśnE1e[T31.3]; **W** — *Areosphaeridium michoudii* Bujak, 1994, LśnE3b[S31.2]; **X** — *Operculodinium microtriainum* (Klumpp, 1953) Islam, 1983, LśnE1d[O47].

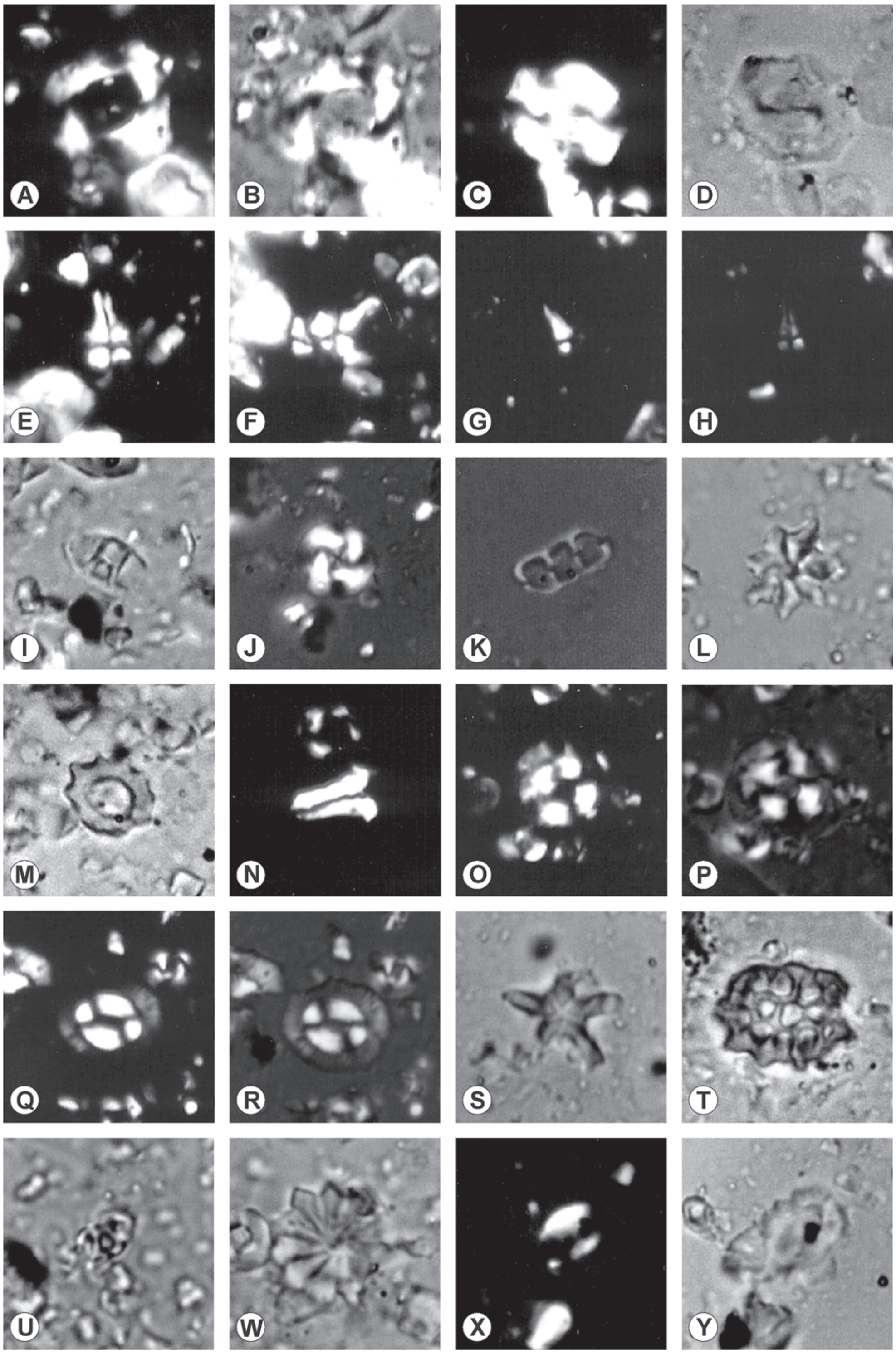


Fig. 8. Selected calcareous nannoplankton from marl intraclasts (CN — crossed nicols; NL — normal light). **A**, **B** — *Reticulofenestra umbilica* (Levin) Martini & Ritzkowski: A–CN, B–NL; **C**, **D** — *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival: C–CN, D–NL; **E**, **F** — *Sphenolithus pseudoradians* Bramlette & Wilcoxon, the same specimen photographed at various angles (both CN): E — 0°, F — 45°; **G**, **H** — *Sphenolithus predistentus* Bramlette & Wilcoxon, the same specimen photographed at various angles (both CN): G — 45°, H — 0°; **I** — *Neococcolithes minutus* Perch-Nielsen (NL); **J** — *Cribrocentrum reticulatum* (Gartner & Smith) Perch-Nielsen (CN); **K** — *Isthmolithus recurvus* Deflandre (CN); **L** — *Discoaster saipanensis* Bramlette & Riedel (NL); **M** — *Corannulus germanicus* Stradner (NL); **N** — *Zygrhablithus bijugatus* (Deflandre) Deflandre (CN); **O**, **P** — *Coccolithus formosus* (Kamptner) Haq: O — CN, P — NL; **Q**, **R** — *Coccolithus pelagicus* (Wallich) Schiller: Q — CN, R — NL; **S** — *Discoaster* cf. *tanii* Bramlette & Riedel (NL); **T** — *Clathrolithus spinosus* Martini (NL); **U** — *Orthozygus aureus* (Stradner) Bramlette & Wilcoxon (NL); **W** — *Discoaster barbadiensis* Tan (NL); **X**, **Y** — *Helicosphaera compacta* Bramlette & Wilcoxon: X — CN, Y — NL.

noplankton assemblages from the marly clasts (samples LśnE1 to LśnE6, except LśnE4).

A very rich calcareous nannoplankton assemblage dominated by *Dictyococcites bisectus*, *Discoaster barbadiensis*, *Discoaster saipanensis*, *Reticulofenestra umbilica* and *Zygrhablithus bijugatus* is found in sample LśnE1. In the same sample *Coccolithus pelagicus*, *Corannulus germanicus* and *Coccolithus formosus* occur frequently. The state of preservation is very poor. Damaged, broken specimens are the most common; their precise determination is often impossible. This especially refers to the representatives of the cold-water genus *Chiasmolithus*. Broken remains of large species of this genus, *Chiasmolithus* cf. *grandis* and *Chiasmolithus* cf. *oamaurensis*, are found in sample LśnE1 and are the only determinable remains of this genus. Representatives of Prinsiaceae, *Dictyococcites bisectus* and *Reticulofenestra umbilica*, are also found as broken remains only. Numerous representatives of Prinsiaceae are known to be resistant to dissolution. They often occur together with *Coccolithus pelagicus* as the only taxa in the impoverished Tertiary calcareous nannoplankton assemblages. *Corranulus germanicus* also shows the traces of dissolution. Representative of Helicosphaeraceae, *Helicosphaera compacta* is also very poorly preserved but in this case, there was no difficulty with determination of this species, although they are mainly preserved as the central parts only. Warm-water Discoasteraceae show damage to arms, one of their diagnostic features. There are some very small representatives of Sphenolithaceae observed in this sample. Unfortunately, their small size and poor state of preservation made suprageneric determination impossible.

Sample LśnE2 yielded an impoverished calcareous nannoplankton assemblage. Infrequent specimens of *Coccolithus formosus*, *Coccolithus pelagicus* and *Zygrhablithus bijugatus* are found. *Reticulofenestra dictyoda*, *Reticulofenestra* cf. *umbilica*, *Sphenolithus* aff. *furcatolithoides* and *Sphenolithus spiniger* occur as single specimens only.

More frequent nanofossils are found in sample LśnE3. Calcareous nannoplankton from this sample shows very poor preservation, mostly mechanic breaking. This refers mainly to the Prisniaceae (i.e. *Reticulofenestra* and *Dictyococcites*) as well to the Coccolithaceae and Discoasteraceae. The latter are infrequent and often have damaged or missing arms. Remains of large representatives of *Reticulofenestra*, most likely *Reticulofenestra umbilica*, are found in this sample.

Sample LśnE4, was the only one from the marly clast samples, to yield no calcareous nannoplankton. Two further samples, LśnE5 and LśnE6, contain rich, although poorly preserved calcareous nannoplankton assemblage. Assemblage of sample LśnE5 contains *Discoaster tanii*, *Discoaster* cf. *tanii nodifer* and *Helicosphaera* cf. *compacta*. The one from sample LśnE6 is dominated by *Dictyococcites bisectus*, *Reticulofenestra umbilica*, *Discoaster barbadiensis*, *Discoaster saipanensis*, *Discoaster tanii*, *Zygrhablithus bijugatus* and *Chiasmolithus* sp. All specimens are poorly or very poorly preserved. The latter especially refers to the very large forms of *Reticulofenestra umbilica*. The genus *Chiasmolithus* is also represented by very large forms preserved as incomplete specimens, often difficult to determine — *Chiasmolithus* aff. *grandis* and *Chiasmolithus* aff. *oamaruensis*. Numerous isolated arms of discoasters and fragments of multiarm forms of *Discoaster barbadiensis* and *Discoaster saipanensis* are found in this sample.

Sample No.	Calcareous nannoplankton age	Dinocyst age
LśnE1	earliest Late Eocene (NP18 Zone)	Bartonian–earliest Priabonian (*Areosphaeridium michoudii*)
LśnE2	latest Middle Eocene? (NP16 Zone?)	? (lack of age — diagnostic species)
LśnE3	latest Middle Eocene? (NP17 Zone?)	Bartonian–earliest Priabonian (*Areosphaeridium michoudii*)
LśnE4	? (lack of calcareous nannoplankton)	? (lack of age — diagnostic species except of long-ranging *Wetzeliella symmetrica*)
LśnE5	latest Middle Eocene (NP17 Zone)	? (lack of age — diagnostic species)
LśnE6	latest Late Eocene (NP19–20 Zone)	Late Priabonian (*Areosphaeridium diktyoplokum*)

Fig. 9. Comparison of dinocyst- and calcareous nannoplankton-age interpretation of the studied marly clasts.

Interpretation

Age of microfloral assemblages

The age of the dinocyst assemblages (Fig. 9) is based on comparison with dinocyst stratigraphic distribution in noth-western Europe (e.g. Bujak & Mudge 1994) and the Mediterranean (e.g. Brinkhuis & Biffi 1993) as well comparison with Paleogene dinocyst distribution in Middle-Upper Eocene and Oligocene strata of the Polish Carpathians (Bujak in Van Couvering 1981; Gedl 1996, 2000a,b, 2004a,b,c, 2005).

The first attempts to introduce of calcareous nannoplankton zonations of Tertiary deposits were undertaken in the early sixties (Brönnimann & Stradner 1960; Bramlette & Sullivan 1961). Several other zonal schemes were proposed a few years later, for example by Radomski (1967, 1968), Martini (1971) and Bukry (1973, 1975; the latter modified later by Okada & Bukry 1980). Two of them, those of Martini (1971) and Okada & Bukry (1980), became widely accepted and are now in common use. Their usefulness is related to the widespread occurrences of the zonal marker taxa making possible a correlation among widely separated areas. The zonation scheme proposed by Okada & Bukry (1980) is more useful in low latitude areas since most of the index taxa are tropical forms. Martini's zonation is, in turn, more helpful in higher latitudes. The latter scheme is therefore used in the present study (Fig. 9).

The inferred age of the calcareous nannoplankton assemblage from sample LśnE1 is the earliest Late Eocene. The assemblage is characteristic for the NP18 Zone (*Chiasmolithus oamaruensis* Zone) of Martini (1971). This is based on the presence of *Chiasmolithus* cf. *oamaruensis*, the lowest occurrence of which defines the base of the NP18 Zone, and *Corannulus germanicus* and *Orthozygus aureus* that have their lowest occurrence within the NP18 Zone. *Isthmolithus recurvus*, a diagnostic taxon for the NP19–20 Zones (*sensu* Martini 1976), has not been found in this sample. Several taxa found in sample LśnE1 have their lowest occurrences in the NP17 Zone (uppermost Middle Eocene): *Discoaster tanii* (lowest occurrence in the middle part of this zone), *Helicosphaera compacta* and *Sphenolithus predistentus*. The presence of *Clathrolithus* aff. *ellipticus* and *Clathrolithus* aff. *spinosus* was noted. These species are believed to be characteristic for the latest Middle Eocene (Aubry 1988), whereas Perch-Nielsen (1985) reports *Clathrolithus spinosus* as a Late Eocene species. A slightly younger age can be concluded for sample LśnE1 on the basis of its dinocyst assemblage. Lack of *Areosphaeridium michoudii* in this sample, and the presence of *Areosphaeridium diktyoplokum* imply Late Eocene (middle or late Priabonian) age. However, in the light of calcareous nannoplankton interpretation, the absence of *Areosphaeridium michoudii* could be accidental.

The age of sample LśnE2 cannot be precisely estimated. It contains very infrequent calcareous nannoplankton and poorly preserved dinoflagellate cysts among which no diagnostic species were identified. *Reticulofenestra* cf. *umbilica*, the youngest species identified in this sample, has its lowest occurrence within the NP16 Zone. This suggests a latest Middle Eocene age for this assemblage.

The presence of *Areosphaeridium michoudii* in sample LśnE3 indicates that this sample is no younger than NP19–20. In the same sample *Dracodinium laszczynskii* occurs. This species was described from the Middle Eocene and the lower part of Upper Eocene strata in the Flysch Carpathians (Gedl 1996, 2005). A similar age can be concluded for this sample on the basis of the presence of *Melitasphaeridium pseudorecurvatum* that occur in this sample only. This species has the highest occurrence in the early Late Eocene (top of the NP18 Zone; Stover et al. 1996). Presence of *Discoaster* cf. *tanii* in sample LśnE3 suggests the latest Middle Eocene age of this sample. The lowest occurrence of this species is found in the middle part of the NP17 Zone. The lower boundary of this zone is defined by the highest occurrence of *Chiasmolithus solitus*, its upper limit is based on the lowest occurrence of *Chiasmolithus oamaruensis*. The NP17 Zone is correlated with *Discoaster saipanensis* Subzone of Okada & Bukry (1980). Its lower boundary is defined by the highest occurrences of *Chiasmolithus solitus* and *Discoaster bifax*, its upper boundary is defined by the highest occurrence of *Chiasmolithus grandis* and the lowest occurrence of *Chiasmolithus oamaruensis*. None of these index taxa were found in the sample LśnE3. Only the presence of *Discoaster* cf. *tanii* allows attribution to the middle part of the NP17 Zone. The dinoflagellate cysts of sample Lśn3 resemble dinocyst assemblages found in deposits overlying the Pucov Conglomerate at Pucov (Slovakia) and correlated with NP18–20 Zones (Soták et al. 2007).

The age of sample LśnE4 remains uncertain. This sample contains no calcareous nannoplankton, and very rare dinoflagellate cysts. This is presumably due to restricted environmental conditions. The dinocyst species present in this sample (*Wetzeliella symmetrica* and *Enneadocysta pectiniformis*) are long ranging. Thus, an upper Middle Eocene (Bartonian)–Oligocene age-assessment of this sample can be concluded.

A latest Middle Eocene age (NP17 Zone), similar as that of the sample LśnE3, is accepted for the sample LśnE5. This is based on the presence of *Discoaster tanii*, *Discoaster* cf. *tanii nodifer* and *Helicosphaera* cf. *compacta*, species that have their lowest occurrences in the NP17 Zone. As in the sample LśnE3, no index species of older and younger zones (i.e. *Chiasmolithus solitus* and *Chiasmolithus oamaruensis*) were found. In sample LśnE5 a presence of *Sphenolithus* cf. *pseudoradians* was noted. The lowest occurrence of this species, according to Martini's zonation, defines the upper boundary of the NP19 Zone (i.e. the lower boundary of the following NP20 Zone; the uppermost Upper Eocene). However, stratigraphic value of this species as an index taxon is limited. This species was also noted from older, Middle Eocene, deposits (NP15 Zone), and it is often difficult to distinguish from older *Sphenolithus radians*, especially in the case of poorly preserved material. The dinoflagellate cysts found in this sample cannot a precise age. Only the presence of *Aiora* sp. A, which was also found in sample LśnE1 might indicate the same age as the latter sample. This would imply a slightly younger age (NP18).

The presence of *Areosphaeridium diktyoplokum* and the lack of *Areosphaeridium michoudii* in sample LśnE6 suggest the latest Eocene age of this assemblage. The highest occurrence of *Areosphaeridium diktyoplokum* is a widely accepted marker of the Eocene-Oligocene boundary (e.g. Williams et al. 1993; Stover et al. 1996). This implies that the age of the sample cannot be younger than Eocene. The highest occurrence of *Areosphaeridium michoudii* in the North Sea defines the top of the E8a Subzone of Bujak & Mudge (1994) correlated with the top of the NP18 Zone. However, the highest occurrence of *Areosphaeridium michoudii* in the Polish Carpathians is found in the NP19–20 Zone (Gedl 2005). This, in turn, delimits the lower age boundary of the sample LśnE5 that cannot be older than the NP19–20 Zone. Age interpretation of calcareous nannoplankton from this sample implies the latest Eocene age (NP19–20 Zone). This interpretation is based on the co-occurrence of *Isthmolithus recurvus*, *Discoaster barbadiensis* and *Discoaster saipanensis*. The lowest occurrence of *Isthmolithus recurvus* defines the lower boundary of the NP19–20 Zone (Aubry 1983). The same event defines the lower boundary of the NP19 Zone in the scheme of Martini (1971). After fusion of the NP19 and NP20 Zones, Martini (1976) used the highest occurrence of *Chiasmolithus grandis* as the event that defines the lower boundary of the fused NP19–20 Zone. The upper boundary of this zone is defined as the highest occurrence of *Discoaster saipanensis* (Martini 1971; Aubry 1983), a taxon present in the sample LśnE6. The presence of *Cribrocentrum reticulatum* was noted in this sample. The highest occurrence of this species is known in lower latitudes from the top of the NP18 Zone, whereas it is reported from Oligocene strata in the higher latitudes. Thus, the end of the latest Eocene (late Priabonian) age is correlated with the higher part of the NP19–20 Zone.

The above-presented marl clast age-assessment indicates that they are recycled. Although the age of the surrounding flysch shales (samples LśnŁ1 and LśnŁ2) could not be precisely determined during this study due to lack of diagnostic species, Gedl (2000b) accepted a Early Oligocene age of the Szaflary Beds on the basis of the occurrence of species such as *Chiropteridium galea*, *Chiropteridium lobospinosum* and *Wetzeliella gochtii* in neighbouring outcrops.

Paleoenvironment

Dinocyst and calcareous nannoplankton assemblages found in the marl intraclasts have been studied for reconstruction of sedimentary conditions during the Middle-Late Eocene in this part of the Central Carpathian Paleogene Basin. Interpretation of the environmental preferences of Tertiary and recent dinoflagellate cysts is based on works by several authors, including Brinkhuis (1994), Dale (1996) and Rochon et al. (1999). That of calcareous nannoplankton is based mainly on studies of Báldi-Beke (1984), Wei & Wise (1990), Aubry (1992) and Nagymarosy & Voronina (1992). Three aspects of paleoenvironment are discussed here: distance from the shoreline, salinity and climatic fluctuations.

The oldest sample LśnE2 contains a dinocyst assemblage that seems to have inhabited shelf waters. There are no oceanic dinoflagellate cysts. The presence of near shore *Homotryblium tenuispinosum* is rather a result of hydrodynamic transport, which is also implied from palynofacies that contains frequent terrestrial elements. The composition of calcareous nannoplankton generally confirms the offshore depositional setting. *Coccolithus pelagicus*, *Reticulofenestra dictyoda* and *Sphenolithus* sp., all found in this sample, are believed to be offshore taxa. Their climatic interpretation is somewhat confusing. *Coccolithus pelagicus* is interpreted as a cold-water species, *Reticulofenestra dictyoda* as temperate-water, and *Sphenolithus* sp. is a warm-water genus. However, this assemblage may be interpreted rather as cold- to temperate-water because there are no representatives of *Discoaster*, a warm-water genus that occurs frequently in younger samples.

Different phytoplankton assemblages characterize two samples representing the NP17 Zone: LśnE3 and LśnE5. The samples: LśnE5 contains a dinocyst assemblage qualitatively similar to that from sample LśnE2. The most frequent are chorate taxa representing genera *Spiniferites* and *Operculodinium*, whereas no *Impagidinium* was found. Additionally, *Hystrichokolpoma* spp. and *Achomosphaera alcicornu* occur in this sample. The calcareous nannoplankton assemblage differs significantly by frequent occurrence of the warm-water genus *Discoaster*, which is characteristic of open waters. *Helicosphaera* cf. *compacta*, another warm-water taxon found in this sample, is rather a near shore species, possibly transported into a more remote basin part. Further expansion of the basin is recorded in phytoplankton assemblages from sample LśnE3. Oceanic dinoflagellate cysts (*Impagidinium* spp., *Corrudinium incompositum*) occur for the first time in the investigated material. Most of the calcareous nannofossils represent offshore taxa (e.g. *Coccolithus pelagicus*, *Discoaster* sp., *Sphenolithus* sp.). Moreover, the palynofacies of this sample is dominated by dinoflagellate cysts implying pelagic sedimentation. The presence of *Pontosphaera scissura* and *Braarudosphaera bigelowii*, and Wetzelielloideae among the dinoflagellate cysts, all believed to be near-shore taxa associated with reduced salinity, suggests a low-salinity environment in the peripheral part of the basin. Warm-water conditions are suggested by the presence of *Discoaster* sp.

Similar paleogeography must have characterized this part of the Podhale Basin also during the earliest Late Eocene (early Priabonian; NP 18 Zone; sample LśnE1). An offshore environment is indicated by the presence of the oceanic dinoflagellate cysts *Impagidinium* spp. and *Nematosphaeropsis lemniscata*, and offshore nannofossils *Discoaster* sp. and *Coccolithus pelagicus*. Near-shore taxa (e.g. *Helicosphaera compacta*, *Homotryblium* spp.), some of them characteristic of reduced salinity environments (e.g. Wetzelielloideae, *Braarudosphaera bigelowii*, *Neococcolithes minutus*), were transported into the distal part of the basin. The occurrence of cold-water *Chiasmolithus* may indicate a drop in temperature of surface waters during the early Priabonian, although warm-water nannofossils like *Discoaster* have also been found in this assemblage.

The dinocyst assemblage from the youngest sample LśnE6 contains frequent chorate gonyaulacoids but it differs from the dinocyst assemblages in the older samples by relatively common occurrence of peridinioids (*Deflandrea* spp. and the Wetzelielloideae). Oceanic dinoflagellate cysts are very rare (single *Impagidinium* specimen). Frequent occurrence of peridinioids during the latest Late Eocene (late Priabonian) might be related to changes in nutrient availability in the surface waters of the Podhale Basin. This may be related to the reduced salinity in the near shore waters shown, for example, by *Braarudosphaera bigelowii* and *Neococcolithes minutus*. The extension of the basin could be the same as during the earliest Late Eocene (early Priabonian) — calcareous nannoplankton assemblage is dominated by offshore taxa (*Discoaster* sp., *Sphenolithus* sp., *Reticulofenestra* sp.). Occurrence of *Isthmolithus recurvus*, another cold-water species, may indicate a further drop of temperature of surface waters in the Podhale Basin during the latest Late Eocene (late Priabonian).

A different environment is indicated for the marly deposits represented by sample LśnE4. Its palynofacies dominated by terrestrial elements, mainly the hyalinous resins suggests a very near shore depositional setting. Because the age of this sample has not been precisely determined its relation to the other samples is not certain.

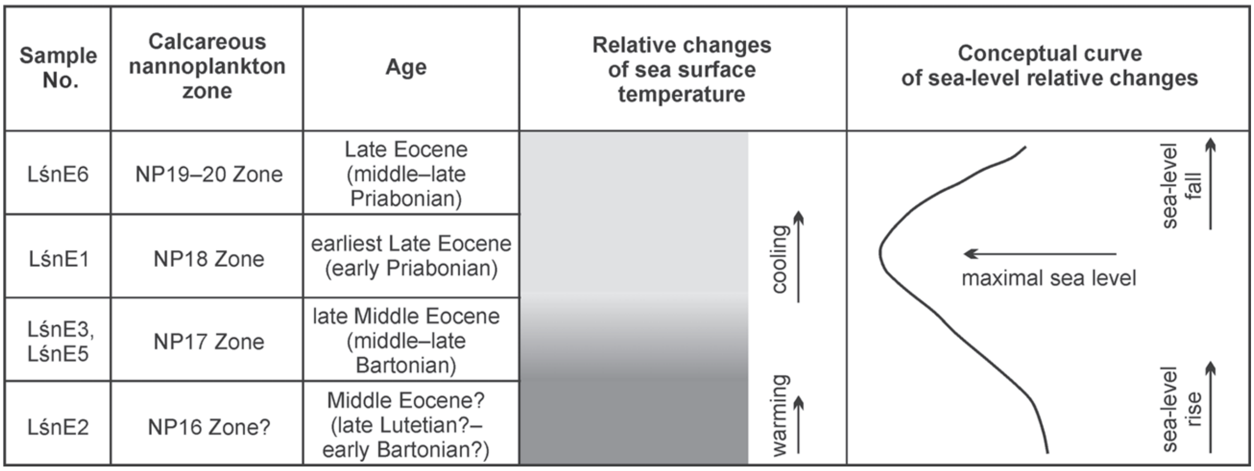
Discussion

Marly intraclasts investigated in this paper represent the remains of upper Middle–Upper Eocene (Bartonian–Priabonian) deposits from northern, no longer existing part of the Podhale Basin that became tectonically damaged during formation of the Pieniny Klippen Belt structure (see Birkenmajer 1985). The paleogeographical location of the original sediments in the northern part of the basin is based on analysis of paleocurrent directions in the Leśnica Stream (Krysiak 1976). Occurrence of Eocene intraclasts, together with remains of Mesozoic substrate in submarine slump deposit, indicates extensive erosion of the northern border of the Podhale Flysch Basin during the Early Oligocene. This presumably took place on the tectonically controlled submarine ramp that was concluded as the depositional model for the Szaflary Beds by Wieczorek (1989).

In Poland, the basal deposits of the present-day northern part of the Podhale Basin were drilled by the Biały Dunajec PAN-1 and Bańska IG-1 boreholes (Jaromin et al. 1992; Sokołowski 1992; Kępińska 1997). Large and small foraminifers found in the Tatra Eocene from Bańska IG-1 were interpreted as Middle Eocene (Kulka 1983; Olszewska & Wieczorek 1998). No microfossils were found in the Biały Dunajec PAN-1 succession except for damaged shells of nummulites (Jaromin et al. 1992). The Tatra Eocene deposits are developed here as conglomerates (Biały Dunajec PAN-1; Jaromin et al. 1992) or conglomerates passing upwards into pelitic limestones (Bańska IG-1; M. Cieszkowski in J. Sokołowski 1992). However, due to poor core recovery, especially in the Bańska IG-1 borehole, the complete lithological development is not certainly known. Marly deposits that occur locally in the topmost part of the Tatra Eocene succession are hard and rather dark coloured (Alexandrowicz & Geroch 1963; Sokołowski 1973; Olszewska & Wieczorek 1998) so they significantly differ in lithology from the soft, pale beige marly intraclasts from the Leśnica Stream. Thus the investigated marls represent a unique lithofacies within the Podhale Paleogene succession in Poland. The only lithologically comparable deposits are the cream yellow marls found by S. Sokołowski (in Blaicher 1973, p. 120) at the base of the peri-Tatric Zakopane Beds exposed in the Przyporniak Stream (see also Gedl 2000a, p. 98, fig. 23). Blaicher (1973) compared foraminifers from these sediments with the ones from the Upper Eocene Globigerina Marl of the Outer Carpathians. Olszewska & Wieczorek (1998) dated the marly deposits as foraminiferal Zones P15–P16 (i.e. uppermost Middle–Upper Eocene) that generally agree with the results of the present paper.

Changes of dinocyst and calcareous nannoplankton assemblages and palynofacies most likely reflect the sea surface changes in the Central Carpathian Paleogene Basin during the Middle and Late Eocene (Fig. 10). The most offshore paleoenvironment recorded in NP18 Zone (possibly “the highstand” phase) is preceded and followed by more inshore settings recorded in NP16?–NP17 and NP19–20 Zones respectively (possibly fall of the sea surface). This agrees well with the correlation of the eustatic curve with the lithostratigraphic division of the Central Carpathian Paleogene Basin deposits shown by Soták et al. (2001, fig. 10). The paleoclimatic interpretations of these authors also fit well the scenario presented in this paper. Late Middle Eocene (Bartonian) phytoplankton assemblages were replaced by cold-water ones during the Late Eocene (Priabonian).

Comparison of described in this paper phytoplankton assemblages with the ones from other localities may lead to some regional paleogeographical conclusions. The similarity in taxonomical diversity of dinocyst assemblages described from Outer Carpathians coeval deposits (Gedl 2004c, 2005) suggests the existence of sea-way connections between the Inner and Outer Carpathian basins during the Middle and Late Eocene. Analysis of younger, Oligocene phytoplankton assemblages from the Podhale Flysch deposits (Gedl 2000a,b; Garecka 2005) shows significant differences with the ones from the Oligocene of the Outer Carpathians. Both dinocyst and calcareous nannoplankton assemblages from the Oligocene Menilite-Krosno Beds are extremely taxonomically impoverished or even absent (e.g. Gedl 1999, 2004c; Garecka 2005; Gedl & Leszczyński 2005). This suggests various paleoenvironmental conditions in those basins during the Oligocene and possibly the Early Miocene. A possible reason might have been a closure of the connections between the Outer and Inner Carpathian basins during the earliest Oligocene.



Sample No.	Calcareous nannoplankton zone	Age
LśnE6	NP19–20 Zone	Late Eocene (middle–late Priabonian)
LśnE1	NP18 Zone	earliest Late Eocene (early Priabonian)
LśnE3, LśnE5	NP17 Zone	late Middle Eocene (middle–late Bartonian)
LśnE2	NP16 Zone?	Middle Eocene? (late Lutetian?– early Bartonian?)

Fig. 10. Age of the investigated marl intraclasts and conceptual sea surface level and temperature changes.

Conclusions

1. Soft, pale beige marly intraclasts found within a submarine slump layer within the Oligocene Szaflary Beds represent Middle-Upper Eocene deposits. Their presence here indicates erosion of the northern part of the Podhale Basin substrate during the Early Oligocene. These marls are the only known remain of the basal parts of the Podhale Paleogene succession in this part of the Central Carpathian Paleogene Basin.

2. The marly intraclasts contain generally rich dinocyst and calcareous nannoplankton assemblages. Interpretation of their ages (latest Middle-Late Eocene) agrees with dating of the basal intervals of the Podhale Paleogene succession from more southern parts of the basin.

3. Paleoenvironmental interpretation suggests that the most offshore sedimentary setting recorded during the earliest Late Eocene (early Priabonian; NP18 Zone) was preceded and followed by more inshore paleoenvironments. A relative drop of the sea surface temperature during the Late Eocene (Priabonian; NP18-20 Zones) is suggested in relation to warmer surface waters during the late Middle Eocene (Bartonian; NP17 Zone).

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Appendix

An alphabetical listing of dinoflagellate cyst (their taxonomic citations are given in Williams et al. 1998) and calcareous nannoplankton taxa found in the studied material.

Dinoflagellate cysts

Achilleodinium biformoides (Eisenack, 1954) Eaton, 1976
Achomosphaera alcicornu (Eisenack, 1954) Davey & Williams, 1966
Achomosphaera ramulifera (Deflandre, 1937) Evitt, 1963
Aiora sp. A *sensu* Gedl (2004a)
Amphorosphaeridium? *multispinosum* (Davey & Williams, 1966) Sarjeant, 1981
Areosphaeridium diktyoplokum (Klumpp, 1953) Eaton, 1971
Areosphaeridium michoudii Bujak, 1994
Batiacasphaera micropapillata Stover, 1977
Caligodinium sp.
Charlesdowniea sp.
Cordosphaeridium gracile (Eisenack, 1954) Davey & Williams, 1966
Cordosphaeridium inodes (Klumpp, 1953) Eisenack, 1963
Cordosphaeridium minimum (Morgenroth, 1966) Benedek, 1972
Cordosphaeridium? *solidospinosum* Gedl, 1995
Corrudinium incompositum (Drugg, 1970) Stover & Evitt, 1978
Corrudinium? sp. A *sensu* Gedl (2004a)
Dapsilidinium pseudocolligerum (Stover, 1977) Bujak, Downie, Eaton & Williams, 1980
Deflandrea phosphoritica Eisenack, 1938
Deflandrea sp.
Diphyes colligerum (Deflandre & Cookson, 1955) Cookson, 1965
Distatodinium ellipticum (Cookson, 1965) Eaton, 1976
Dracodinium laszczynskii Gedl, 1995
Dracodinium sp. A *sensu* Gedl (2004a)
Enneadocysta multicornuta (Eaton, 1971) Stover & Williams, 1995
Enneadocysta pectiniformis (Gerlach, 1961) Stover & Williams, 1995
Enneadocysta aff. *pectiniformis sensu* Gedl (2004a)
Fibrocysta bipolaris (Cookson & Eisenack, 1965) Stover & Evitt, 1978
Gongylodinium? sp. A *sensu* Gedl (2004)
Heteraulacacysta? *leptalea* Eaton, 1976
Heterosphaeridium sp. A *sensu* Gedl (2004a)
Homotryblium plectilum Drugg & Loeblich Jr., 1967
Homotryblium tenuispinosum Davey & Williams, 1966
Hystrichokolpoma cinctum Klumpp, 1953
Hystrichokolpoma rigaudiae Deflandre & Cookson, 1955
Impagidinium brevisulcatum Michoux, 1985
Impagidinium dispertitum (Cookson & Eisenack, 1965) Stover & Evitt, 1978
Impagidinium sp. A *sensu* Gedl (2004a)
Impagidinium sp.
Lingulodinium machaerophorum (Deflandre & Cookson, 1955) Wall, 1967
Lingulodinium pycnospinosum (Benedek, 1972) Stover & Evitt, 1978
Melitasphaeridium pseudorecurvatum (Morgenroth, 1966) Bujak, Downie, Eaton & Williams, 1980
Nematosphaeropsis lemniscata Bujak, 1984
Operculodinium centrocarpum (Deflandre & Cookson, 1955) Wall, 1967
Operculodinium aff. *centrocarpum sensu* Gedl (2004a)
Operculodinium? *hirsutum* (Ehrenberg, 1838) Lentin & Williams, 1973
Operculodinium microtriainum (Klumpp, 1953) Islam, 1983
Operculodinium tiara (Klumpp, 1953) Stover & Evitt, 1978
Pentadinium laticinctum subsp. *granulatum* Gocht, 1969
Rhombodinium aff. *perforatum sensu* Gedl (2004a)
Rhombodinium sp.
Samlandia chlamydophora Eisenack, 1954
Spiniferites pseudofurcatus (Klumpp, 1953) Sarjeant, 1970
Spiniferites ramosus (Ehrenberg, 1838) Mantell, 1854
Systematophora placacantha (Deflandre & Cookson, 1955) Davey, Downie, Sarjeant & Williams, 1969
Thalassiphora patula (Williams & Downie, 1966) Stover & Evitt, 1978
Thalassiphora pelagica (Eisenack, 1954) Eisenack & Gocht, 1960
Tityrosphaeridium cantharellus (Brosius, 1963) Sarjeant, 1981
Wetzeliella articulata Eisenack, 1938
Wetzeliella symmetrica Weiler, 1956
Wetzeliella sp.

Calcareous nannoplankton

Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947
Chiasmolithus expansus (Bramlette & Sullivan, 1961) Gartner, 1970
Coccolithus eopelagicus (Bramlette & Riedel, 1954) Bramlette & Sullivan, 1961
Coccolithus formosus (Kamptner, 1963) Wise, 1973
Coccolithus pelagicus (Wallich, 1877) Schiller, 1930
Corannulus germanicus Stradner, 1962
Coronocyclus nitescens (Kamptner, 1963) Bramlette & Wilcoxon, 1967
Cribrocentrum reticulatum (Gartner & Smith, 1967) Perch-Nielsen, 1971
Cyclicargolithus floridanus (Roth & Hay, 1967) Bukry, 1971
Dictyococcites bisectus (Hay, Mohler & Wade, 1966) Bukry & Percival, 1971
Dictyococcites callidus Perch-Nielsen, 1971
Dictyococcites scrippsae Bukry & Percival, 1971
Discoaster barbadiensis Tan, 1927
Discoaster binodosus Martini, 1958
Discoaster diastypus Bramlette & Sullivan, 1961
Discoaster multiradiatus Bramlette & Riedel, 1954
Discoaster saipanensis Bramlette & Riedel, 1954
Discoaster strictus Stradner, 1961
Discoaster tanii Bramlette & Riedel, 1954
Helicosphaera compacta Bramlette & Wilcoxon, 1967
Isthmolithus recurvus Deflandre, 1954
Lanternithus minutus Stradner, 1962
Neococcolithes minutus (Perch-Nielsen, 1967) Perch-Nielsen, 1971
Orthozygus aureus (Stradner, 1962) Bramlette & Wilcoxon, 1967
Pontosphaera scissura (Perch-Nielsen, 1971) Romein, 1979
Reticulofenestra dictyoda (Deflandre, 1954) Stradner, 1968
Reticulofenestra hillae Bukry & Percival, 1971
Reticulofenestra umbilica (Levin, 1965) Martini & Ritzkowski, 1968
Sphenolithus editus Perch-Nielsen, 1978
Sphenolithus moriformis (Brönnimann & Stradner, 1960) Bramlette & Wilcoxon, 1967
Sphenolithus pacificus Martini, 1965
Sphenolithus predistentus Bramlette & Wilcoxon, 1967
Sphenolithus radians Deflandre, 1952
Sphenolithus spiniger Bukry, 1971
Thoracosphaera operculata Bramlette & Martini, 1964
Thoracosphaera saxea Stradner, 1961
Transversopontis exilis (Bramlette & Sullivan, 1961) Perch-Nielsen, 1971
Zygrhablithus bijugatus (Deflandre, 1954) Deflandre, 1959