Slovak Geol. Mag., 6, 2-3(2000), 150–154

Palaeogeography of the Podhale Flysch (Oligocene; Central Carpathians, Poland) - its relation to the neighbourhood areas as based on palynological studies

PRZEMYSŁAW GEDL

Institute of Geological Sciences, Polish Academy of Sciences, Senacka 1,
31-002 Kraków, Poland; ndgedl@cyf-kr.edu.pl

Abstract: Organic matter (palynofacies) and dinocyst distribution in the Podhale Flysch deposits differ in quality and quantity depending on age and geographic positions of its lithostratigraphic units. Land plant tissue dominated palynofacies of the Lower Oligocene Szaflary beds, the lowermost part of the flysch sequence, seems to represent a relatively nearshore, eutrophic environment highly influenced by fresh water. It resembles palynofacies of coeval Menilite beds of the Outer Flysch Carpathians. The main difference is the presence of relatively numerous dinocysts in the Podhale Flysch, contrary to strongly impoverished or even barren in dinocysts the Menilite beds. A palynofacies similar to that of the Szaflary beds occurs in the peri-Klippen Zakopane beds. The south-eastern outcrops of the Zakopane beds are devoid of dinocysts; black opaque phytoclasts appear as the only palynofacies constituent. Palynofacies of the Chochołów beds shows a pronounced lateral variation: a land plant tissue dominated palynofacies occurs in the western part of the study area, gradually passing eastwards into black opaque phytoclast palynofacies barren of dinocysts. This resembles palynofacies of the Outer Carpathian Krosno beds. Palynofacies of the Ostrysz beds, the youngest unit of the Podhale Flysch, is characterized by relatively numerous dinocysts representing mainly chorate taxa which often are associated with environments of increased salinity.

Key words: Oligocene, Podhale Flysch, palaeogeography, palynofacies, dinocysts

Geological setting

The Podhale Flysch more than 3000 m thick forms a part of the Central Carpathian Palaeogene Basin deposits (Fig. 1). The flysch deposits overlie transgressive conglomerates and carbonate platform deposits (the so-called Tatra Eocene) of Middle-Upper Eocene age. In the Polish part (Fig. 2), the Podhale Flysch begins with the Szaflary beds in the north and the Zakopane beds in the south. Age of the Szaflary beds has been determined on the basis of dinocysts as Early Oligocene (Fig. 3), the Zakopane beds probably represent a higher part of Rupelian (Gedl, 1999b, in press). Dinocyst occurrence in peri-Tatra Zakopane beds suggest an older age, probably coeval with that of the Szaflary beds. A hiatus between the Tatra Eocene carbonates and the succeeding flysch deposits is suggested, decreasing or even disappearing in an eastern part of the basin (Blaicher, 1973; Gedl, in press).

The Chochołów and Ostrysz beds (the latter known only from the western part of the Podhale Basin), represent sandy flysch deposits representing latest Early Oligocene(?) to Late Oligocene ages (Gedl, 1995a, 1999b, in press). The so-called Brzegi beds differing from the Chochołów beds by more shaly development represent the youngest flysch deposits in the eastern part of the Podhale Basin (Fig. 2). They are presumably coeval with the Ostrysz beds (Fig. 3; Gedl, in press).

Palaeogeography and palaeoenvironment

The Tatra Eocene deposits are barren of dinocysts. Their palynofacies is composed predominately of black opaque phytoclasts. No sporomorphs were found. A similar palynofacies is characteristic of marly deposits locally developed at the top of the Tatra Eocene, and of the lowermost part of the Szaflary beds as known from the boreholes. Such palynofacies is characteristic for: either (i) near-shore, high energy environments (*cf.* Blondel *et al.*, 1993) with limited land organic matter input and aerobic bottom conditions, or (ii) offshore, oligotrophic settings. The latter is suggested by mass occurrence of Nummulites species which favour oligotrophic conditions (*cf.* Brasier, 1995). The carbonate deposits of the Tatra Eocene presumably formed on isolated marine shoals surrounded by oligotrophic waters with no direct land input. The Tatra island, which existed during deposition of transgressive conglomerate, was flooded by the Late Eocene sea. Oligotrophic conditions persisted also at the begining of flysch sedimentation. A majority of the Szaflary beds are dominated by land plant tissue remains with relatively numerous dinocysts; this indicates a change in palaeoenvironmental conditions. A northern land supplied clastic and organic material (Fig. 4a; Krysiak, 1976; Gedl, 1998b, in press). Fresh water input resulted in change of trophic conditions into nutrient-rich

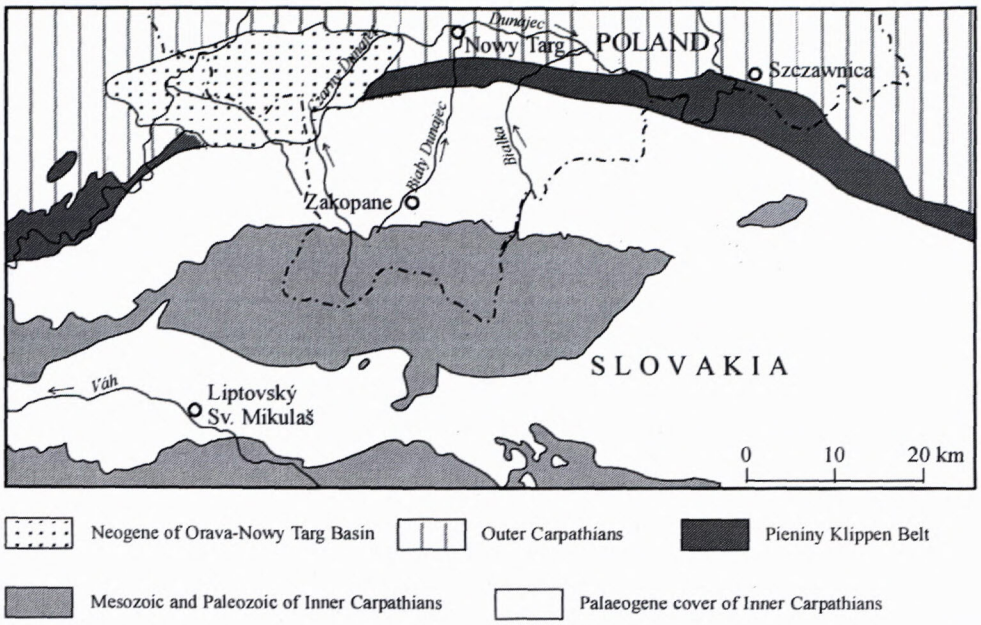


Fig. 1. Position of study area against schematic geological map of the Palaeogene cover of Inner Carpathians

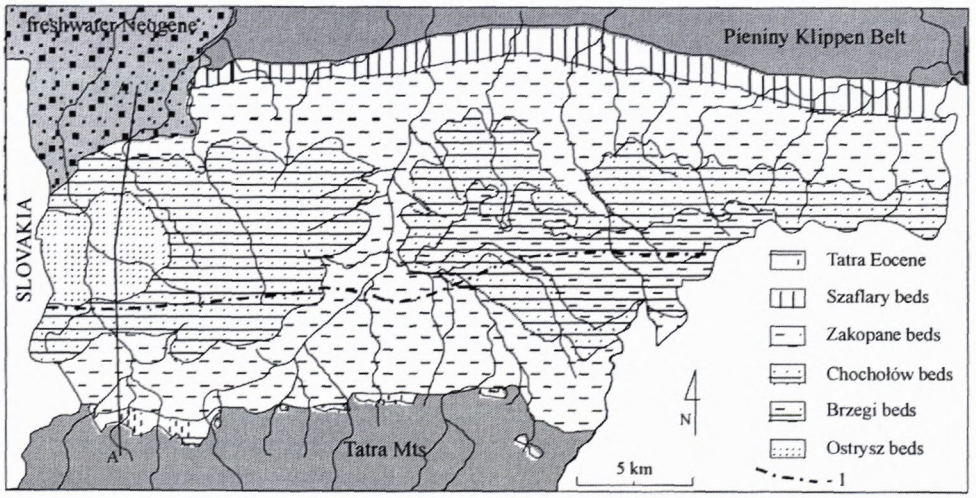


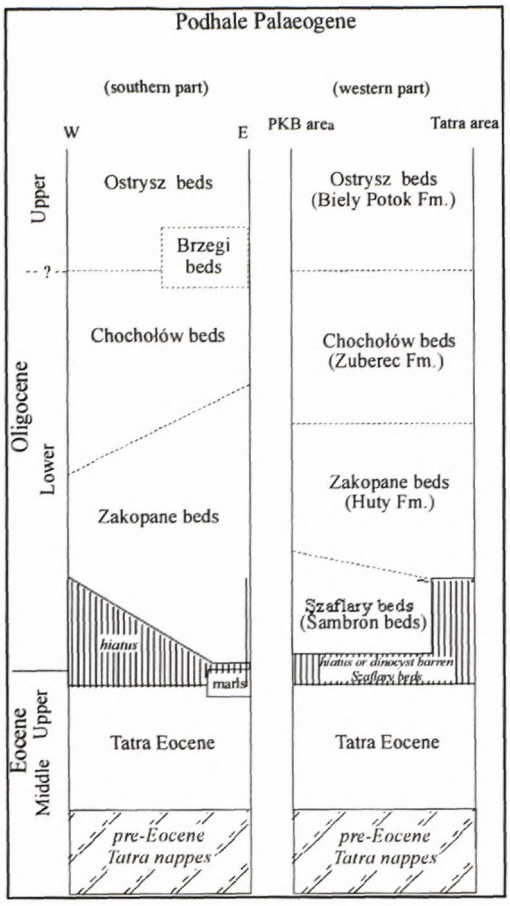
Fig. 2. A scheme of the Podhale Palaeogene lithostratigraphic units in Poland (after Małecka, 1982; simplified); 1- southern limit of the Szaflary beds (after Kępińska, 1997)

ones, favourable for Dinoflagellates, and in decrease of salinity in subsurfal photic zone (Gedl, 1998a). This is indicated by relatively frequent occurrence of dinocysts dominated by Peridinioids (*Deflandrea*, Wetzelielloideae) and by „blooms" of Gonyaulacoids (*Chiropteridium* and *Membranophoridium*; *cf.* Malone, 1991; Powell *et al.*, 1992). High terrestrial organic matter input into the basin caused depletion in oxygen in the bottom part of the basin.

Sedimentation of eastern part of the peri-Tatra Zakopane beds (probably coeval with the Szaflary beds) took place in different conditions. Their black opaque phytoclast palynofacies probably resulted from offshore depositional setting distant from land with oligotrophic conditions in the subsurfal water layer and aerobic conditions at the bottom (Gedl, 1998a). These beds were presumably deposited on an elevated part of the basin floor above depocentrum of the Szaflary beds (Fig. 5b).

Such palaeogeographic setting persisted until a higher part of Rupelian when a new clastic source area had appeared, west from the study area (Fig. 5c). Sedimentation of the Zakopane beds then covered the whole Podhale Basin. Dinocysts from the peri-Klippen and the western peri-Tatra Zakopane beds become similar to those from the Szaflary beds. A western source area became a dominating one, although the northern one was still active.

Palynofacies of the Chochołów beds is horizontally differentiated: a land-plant tissue dominated palynofacies of the westernmost Chochołów beds is being replaced eastwards by a *Deflandrea*-dominated palynofacies (this is a transitional palynofacies type between land-plant tissue dominated palynofacies and black opaque phytoclast dominated one, characterized by high amount of black opaque phytoclasts and very rare dinocysts among which *Deflandrea* is the most common taxon) and into dinocyst-



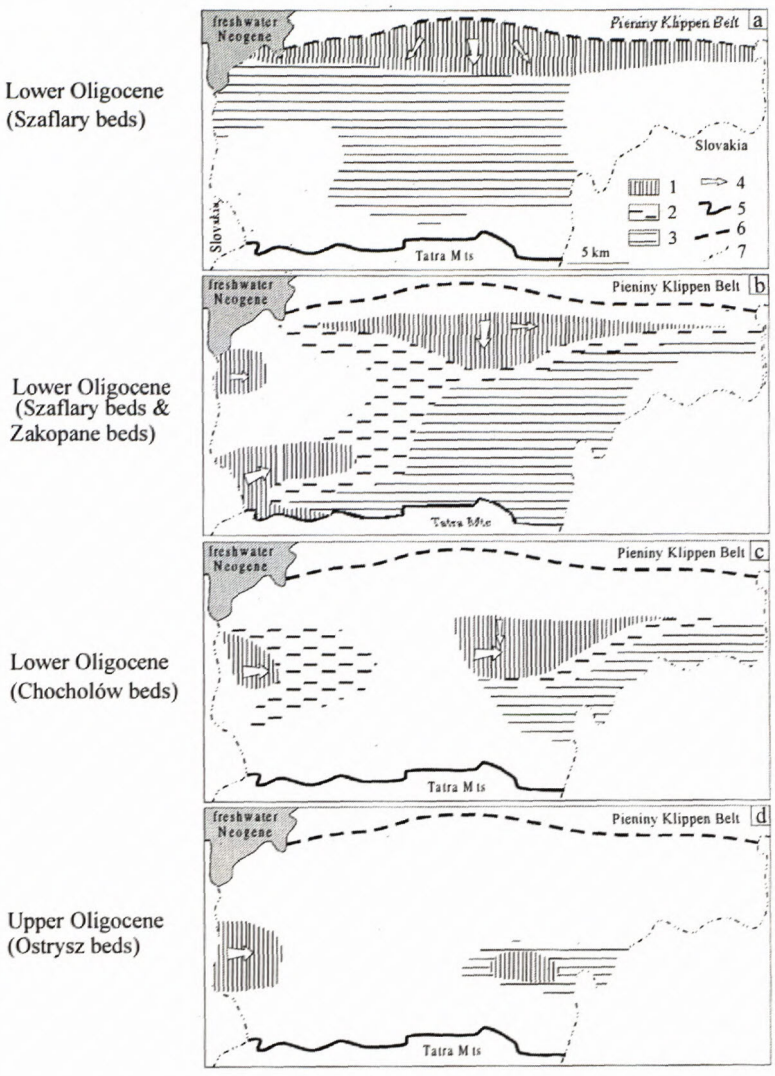


Fig. 3. Age of the Podhale Flysch as based on dinocysts (after Gedl, in press); age of the Tatra Eocene after Bieda (1963), age of marly deposits (marls) after Blaicher (1973)

Fig. 4. Palynofacies distribution and inferred transport directions in the Podhale Flysch deposits (after Gedl, 1998b); a - Szaflary beds (Lower Oligocene); b - uppermost part of Szaflary beds and Zakopane beds (Lower Oligocene); c - Chochołów beds (Lower Oligocene); d - Ostrysz beds and Brzegi beds (Upper Oligocene)

barren black opaque phytoclast palynofacies in the east ernmost area (Fig. 4c). This trend confirms results of previous sedimentological studies which indicated transport direction from west to east (e. g. Marschalko & Radomski, 1960). In the Chochołów beds, dinocysts are either absent or infrequent. In the latter case, *Deflandrea* and *Caligodinium* are often the most common and best preserved taxa as compared with much worse preserved Gonyaulacoids. The Chochołów beds in the central part of the study area (vicinity of Czarna Góra; see Gedl, in press) where a very rich dinocyst assemblage was found (mainly *Deflandrea*, *Chiropteridium*, *Caligodinium*, *Membranophoridium*) are an exception. Wetzelieloideae, absent or present as single specimens in most of the Chochołów beds occurrences, are relatively common in the Czarna Góra area. This dinocyst assemblage resembles more that of the Szaflary and Zakopane beds than those from other parts of Chochołów beds. It is suggested that the northern source area was active also during the Chochołów beds deposition (Fig. 4c).

Palynofacies of the Ostrysz beds is characterized by occurrence of well preserved land pland tissues and relatively numerous sporomorphs (especially spores). Dinocysts appear there more frequently, as compared with the Chochołów beds. The latter are mostly chorate Gonyaulacoids like *Homotryblium*, *Polysphaeridium* or *Spiniferites*. Taxa such as *Dapsilidinium* and *Distatodinium* occur more frequently than in older lithostratigraphic units. Peridinioids become much less numerous, Wetzelielloideae appear mostly as single specimens, and only *Deflandrea* occurres more frequently. Numerous occurrence of epicystal Gonyaulacoids such as *Homotryblium* and *Polysphaeridium* suggest increased salinity conditions prevailing in the marginal areas of the Podhale Basin during Late Oligocene.

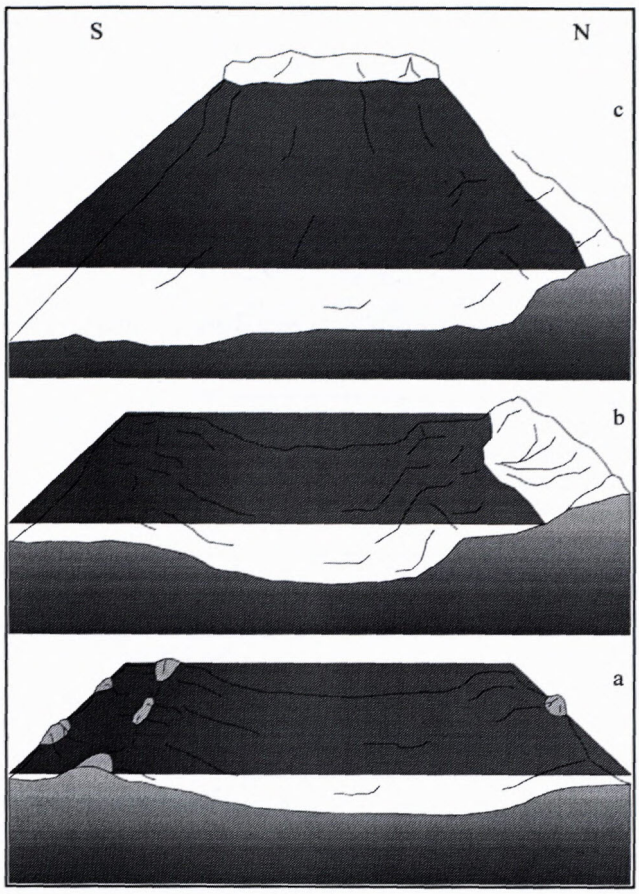


Fig. 5. Schematic reconstruction of Podhale Basin palaeogeography (Late Eocene-Oligocene; S, N directions refer to present-day situation: they could be different during Palaeogene - see Márton et al., 1999); a) development of carbonate platforms in southern and northern parts of the basin (Upper Eocene); b) sinking of carbonate platforms and begining of hemipelagic sedimentation (marly deposits - uppermost Eocene, and south-eastern Zakopane beds - Lower Oligocene); a land appears in northern part resulting in Szaflary beds deposition (Lower Oligocene); c) uniformity of sedimentation - the Zakopane beds occur in the whole basin - western land-area becomes a dominating source area (a similar palaeogeography existed also during deposition of the Chochołów beds, however, the western land become the most pronounced source area for the Podhale Basin).

It is difficult to reconstruct bathymetry of the Podhale Flysch basin based on dinocysts. Lack or very infrequent presence of oceanic taxa (i. e. *Nematosphaeropsis*, *Impagidinium*) suggest a relatively shallow and isolated basin. On the other hand, eutrophic conditions in photic zone exclude oceanic taxa inhabiting oligotrophic waters. It is likely that the oceanic dinocyst association was replaced by a dinocyst association (*Deflandrea*) that benefited from increased nutrient accessibility.

Presence of a high lattitude dinocyst *Impagidinium velorum*, most common in the Ostrysz beds, might suggest cooling of the subsurfal water layer. Presence of extremely large Wetzelielloideae which exceed 200 μm of cyst length, an indicator of gigantism, is also typical for cool climates.

Comparison with Outer Carpathian Oligocene deposits

Upper Eocene deposits of the Polish Flysch Carpathians are characterized by rich and diversified dinocyst assemblages which almost completely disappear at the beginning of deposition of the Lower Oligocene Menilite beds in the Dukla, Silesian and Skole nappes (Bujak *in* Van Couvering *et al.*, 1981; Gedl, 1999a). In the Menilite beds dinocysts are either absent or a strongly impoverished dinocyst assemblage composed of Wetzelielloideae and *Caligodinium* is present. Palynofacies of the Menilite beds, independently of its facies, is composed of terrestrial plant remains and sporomorphs. This feature makes it similar to the palynofacies of the Szaflary beds. The latter, however, is never as rich in terrestrial plant remains. It contains more numerous and diversified dinocysts, except of one locality of the Szaflary beds (at Szaflary; see Gedl, in press) where palynofacies is identical with that of the Outer Carpathian Menilite beds. This suggests palaeoenvironmental conditions favourable for Dinoflagellates in the Podhale Basin during Oligocene.

Similar palynofacies of the Magura Nappe deposits was found (P. Gedl, unpubl.) in Oligocene deposits of the Malcov Formation at Leluchów (see Birkenmajer & Oszczypko, 1989). A different palynofacies (and presumably also age) of the Malcov Formation was found in the Nowy Targ area (*cf.* Gedl, 1995b).

Dinocysts from the Chochołów beds are most similar to those from the Krosno beds of the Flysch Carpathians: among rare dinocysts, *Deflandrea* appears as the most common taxon. No dinocyst assemblage comparable to that of the Ostrysz beds was found so far in the Outer Carpathians.

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