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TROPHIC CONDITIONS DURING THE EARLY OLIGOCENE STAGE OF THE DEVELOPMENT OF THE PODHALE FLYSCH BASIN (INNER CARPATHIANS, POLAND): A DINOCYST RECORD

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ABSTRACT. The early stages of the Palaeogene flysch deposition in the northern part of the Podhale Basin were characterized by oligotrophic conditions contemporaneous with a build-up of carbonates in the southern part. In the latter area, oligotrophic conditions continued during the deposition of the Zakopane beds (Early Oligocene), whereas eutrophic conditions reigned in the north during the deposition of the Szaflary beds.

KEY WORDS: trophic conditions, dinocysts, palynofacies, Oligocene, Podhale Flysch, Inner Carpathians, Poland

INTRODUCTION

The Zakopane and Szaflary beds, lowermost deposits of the Podhale Flysch in Poland, originated in different palaeogeographical settings. Sedimentation of the Szaflary beds took place in the northern part of the present-day Podhale Basin (Fig. 1b). The Szaflary beds, representing a proximal flysch facies, are presumably isochronic (in the upper part) with the lower part of finer-grained, shaly Zakopane beds (cf. Gedl in press). The deposition of these two units followed upon the Eocene carbonates of the Tatra Mts. The different palaeogeographical and sedimentary settings of the two basal units of the Podhale Flysch are reflected in their different palynofacies. One important reason for these differences was the differing distances from the source area and, as a consequence, different trophic conditions.

GEOLOGICAL SETTING

The Podhale Flysch (Fig. 1a) represents part of the Central Carpathian Palaeogene deposits. In the Polish part, they begin with Middle-Late Eocene transgressive conglomerates and carbonate platform deposits (the so-called "Tatra Eocene"), followed by Oligocene flysch deposits (the Podhale Flysch). The "Tatra Eocene" sequence begins (Fig. 2) with Middle Eocene deltaic and cliff-facies transgressive marine conglomerates deposited upon degraded pre-Eocene Tatra nappes (Passendorfer 1950, 1958). The conglomerates pass upward into carbonate deposits often rich in the tests of large foraminifers (e.g. Roniewicz 1966, 1969). The "Tatra Eocene" deposits are well-developed only in the southern part of the Podhale Basin (up to 300 m thick), whereas in the central and northern parts, they are represented by much thinner conglomerates, talus and marly deposits (Blaicher 1973, Olszewska & Wieczorek 1998). The carbonate deposits are overlain by presumably diachronous flysch deposits, more than 3000 m thick (Fig. 2).

The Szaflary beds, being the oldest Early Oligocene flysch deposits (Gedl 1998, in press) are developed in the northern part of the Podhale Basin (Fig. 1b). They represent a proximal flysch facies. The common occurrence of brown bituminous shales makes this unit similar to the menilite shales of the Outer Carpathians (cf. Jucha & Kotlarczyk 1961). In contrast, the Zakopane beds, the oldest flysch deposits in the southern part, diachronous over the carbonates, and presumably of late Early Oligocene age (Gedl 1998, in press, Olszewska & Wieczorek 1998) are developed as darkish grey, predominantly shaly flysch deposits. The Chochołów and Ostrysz beds (the latter known only from the western part of the Podhale Basin), represent flysch deposits from the end of the Early Oligocene(?) to the Late Oligocene (Gedl 1998, in press) and terminate the flysch sequence of the Podhale Basin.

MATERIAL AND METHODS

Samples from natural outcrops and boreholes from the carbonate unit ("Tatra Eocene"), the Zakopane and Szaflary beds were

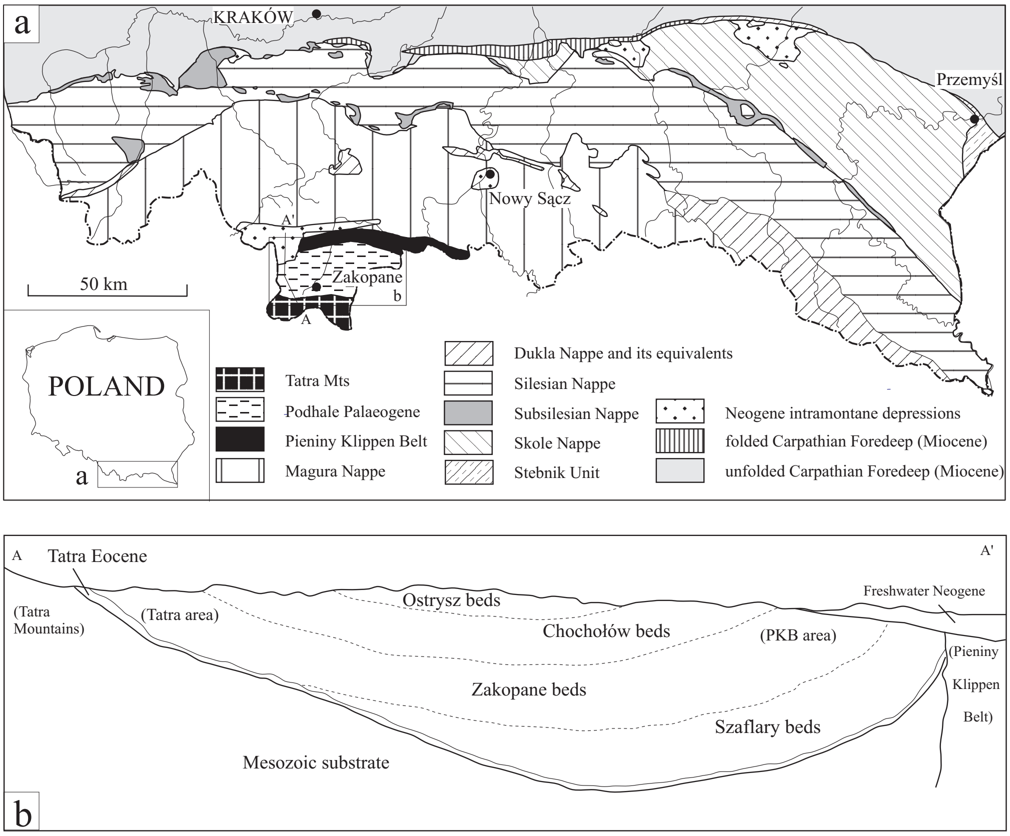

Fig. 1. Area of study: a) location of the Podhale Palaeogene on the tectonic map of the Polish Carpathians (after Książkiewicz 1977); b) cross-section of the Podhale Palaeogene (after Chowaniec *et al*. 1992)

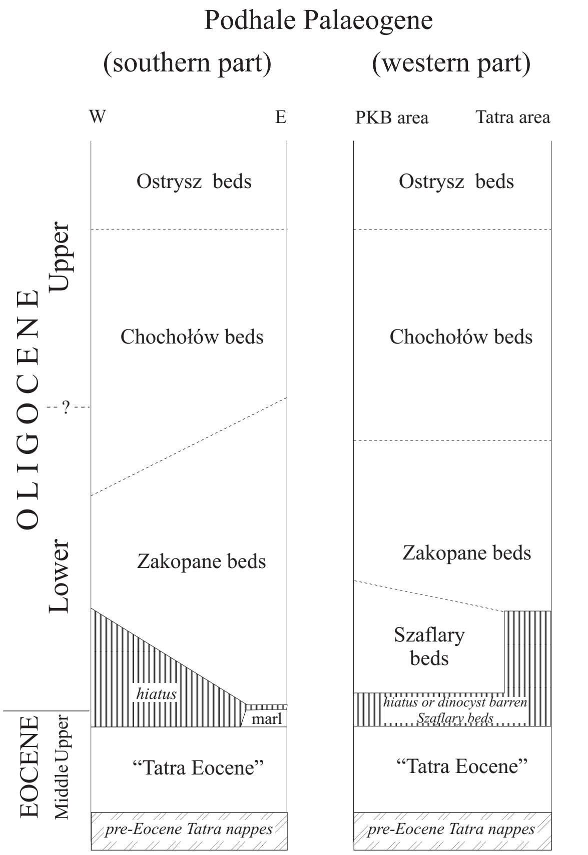

Fig. 2. Lithostratigraphy of the Podhale Palaeogene (after Gedl 1998)

studied (Fig. 3). In the case of the flysch deposits, samples were collected from the uppermost parts of shales between sandstones in order to get the most "pelagic" material.

The samples were processed according to the following palynological procedure: 20–30 g of cleaned and crushed rock was treated with 38% hydrochloric acid (HCl) to remove carbonates, sieved through a 15 µm sieve (with ultrasonic treatment), then treated with 40% hydrofluoric acid (HF) to remove silicates, neutralized and sieved again through a 15 µm sieve (with ultrasonic treatment). The organic matter was separated from undissolved or insoluble particles with heavy liquid ($ZnCl_2$+HCl; density 2.0 g/cm^3), sieved through a 15 µm nylon sieve and transferred into glycerine water for storing. Glycerine-gelatine jelly was used as a mounting medium; two slides were made from each sample. The rock samples, palynological residuum and slides are stored in the collection of the Cracow Research Centre of the Institute of Geological Sciences, Polish Academy of Sciences.

1000 palynomorphs and phytoclasts were counted from each slide, and all dinocysts were counted from two slides. The phytoclasts and palynomorphs were divided into the following groups: (i) black, opaque, mainly equidimensional phytoclasts (a high abundance of these particles is characteristic for high energy littoral environments, e.g. beaches and sand barriers – see Blondel *et al*. 1993, or for aerobic offshore settings with limited terrestrial input and low primary productivity); (ii) variously preserved land plant remains, mainly cuticular tissue (a high abundance of these phytoclasts is usually associated with shelf environments in the vicinity of river mouths, but may also occur in offshore settings influenced by turbiditic sedimentation); (iii) sporomorphs (their concentration is decreasing towards basin centres, e.g. Stover & Williams 1982, although turbidite deposition, as in the case of (ii),

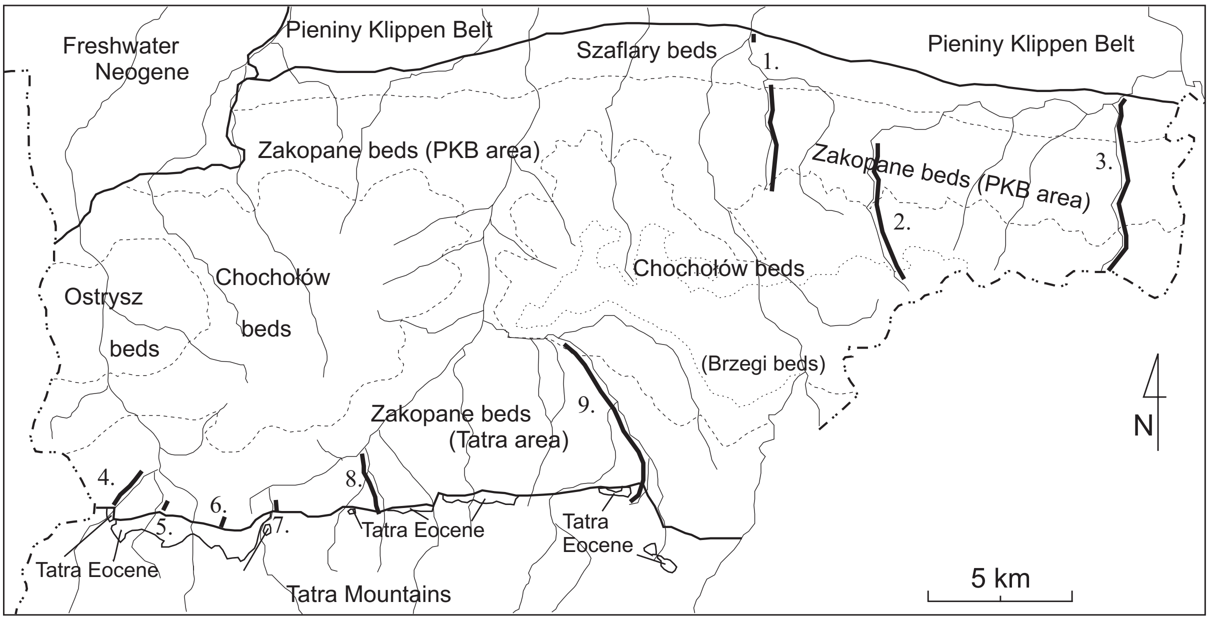

Fig. 3. Distribution of the sections mentioned in the text (geological sketch-map after Małecka 1982, simplified): 1. Trybski Stream; 2. Łapszanka Stream; 3. Kacwinianka Stream; 4. Siwa Woda; 5. Dolina Lejowa; 6. Staników Żleb; 7. Mała Łąka; 8. Biały Stream; 9. Cicha Woda

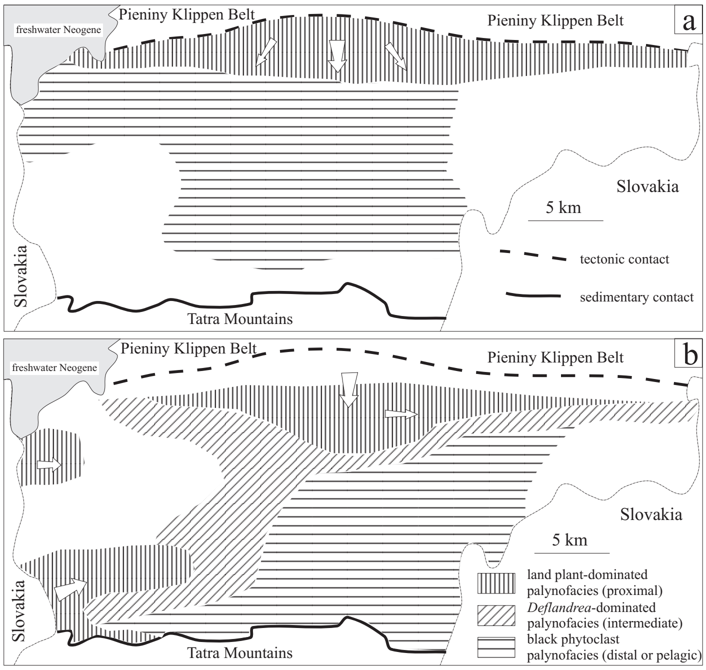

Fig. 4. Palynofacies distribution and possible transport directions during (a) deposition of the Szaflary beds and (b) the Szaflary and Zakopane beds (after Gedl 1998)

may transport them into oceanic settings; bisaccate pollen grains, because of their high buoyancy, may be transported over long distances by wind or float on the sea surface before sinking); (iv) marine palynomorphs subdivided into:

– the Wetzelielloideae and Deflandreoideae subfamilies (representatives of which are often considered to have inhabited littoral, eutrophic brackish environments (e.g. Islam 1984, Köthe 1990, Brinkhuis 1994), although it seems possible that their distribution in a marine system was controlled by nutrient availability, rather than by basin depth or salinity range (Gedl in prep.),

– other dinocysts, except for *Impagidinium* whose trophic preferences are uncertain (e.g. *Homotryblium*, *Glaphyrocysta*, *Spiniferites* etc);

– *Impagidinium* (this genus is known from recent oligotrophic oceanic settings, e.g. Harland 1983).

RESULTS

The palynofacies of the “Tatra Eocene” carbonates, notwithstanding their facies, consist almost 100% of the black woody particles (i). No palynomorphs or phytoclasts are present. The same palynofacies is typical for the overlying Zakopane beds in the southern part of the Podhale Basin (Pl. 1 figs 1, 2). This palynofacies of the Zakopane beds is thickest in the eastern part (in the Cicha Woda section it embraces the whole of the Zakopane beds, several hundred metres thick) thinning out westward to a few metres (in the Staników Żleb section) and wedging out in the Siwa Woda section (Gedl 1998). The black-phytoclastic palynofacies of the peri-Tatra Zakopane beds is replaced upwards by the land-plant (ii) and sporomorph (iii) dominated palynofacies which contain up to a small percentage of dinocysts. The transition between these two palynofacies is characterized by the appearance of poorly preserved dinocysts representing mainly the Deflandreoideae and Wetzelielloideae. Higher up, this dinocyst assemblage is replaced by better preserved specimens belonging to these two subfamilies and, still higher, by representatives of the genera *Homotryblium*, *Glaphyrocysta* and *Membranophoridium*. Dinocyst assemblages from the basal part of the Zakopane beds in the westernmost sections (i.e. Dolina Lejowa and Siwa Woda) are composed of well-preserved taxa dominated by the representatives of Wetzelielloideae and Deflandreoideae.

The palynofacies of the organic-rich Szaflary beds and the lower part of the overlying Zakopane beds in the northern part of the Podhale Basin (Fig. 4) are different. They are composed of mostly well-preserved land plant tissues (ii) and sporomorphs (iii). Relatively well-preserved dinocysts are either very rare or relatively frequent (up to a few per cent). Dinocyst assemblages are often characterized by well-preserved Wetzelielloideae (as in the Kacwinianka Stream or Łapszanka Stream sections), and by much more poorly preserved *Glaphyrocysta*-morphotype taxa and *Homotryblium*. In a few cases (e.g. the Trybski Stream section) the dinocysts become very frequent (“blooms”), being composed of

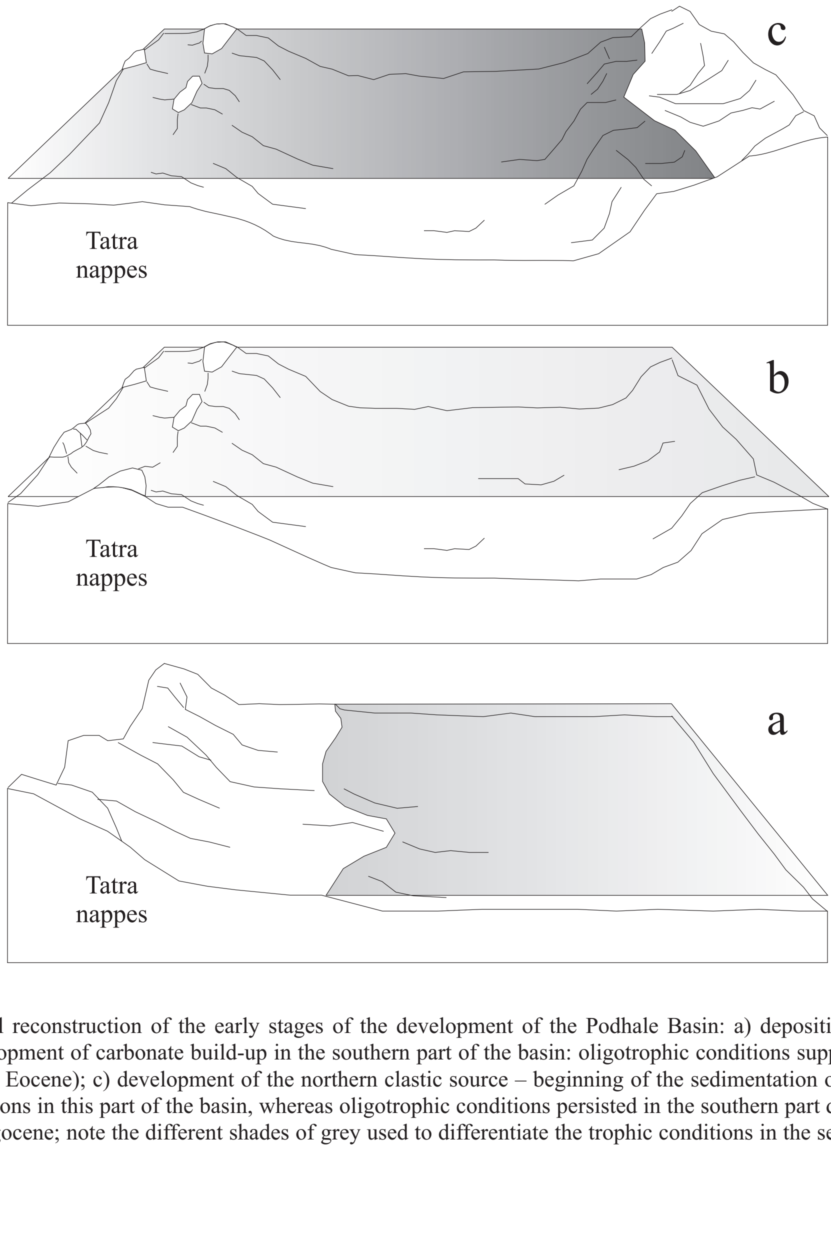

Fig. 5. Palaeogeographical reconstruction of the early stages of the development of the Podhale Basin: a) deposition of basal conglomerates (Middle Eocene); b) development of carbonate build-up in the southern part of the basin: oligotrophic conditions supported the mass occurrence of large foraminifers (Late Eocene); c) development of the northern clastic source – beginning of the sedimentation of the Szaflary beds associated with eutrophic conditions in this part of the basin, whereas oligotrophic conditions persisted in the southern part during the deposition of the Zakopane beds (Early Oligocene; note the different shades of grey used to differentiate the trophic conditions in the sea – oligotrophic [pale] and eutrophic [dark])

monospecific assemblages of *Membranophoridium* and *Glaphyrocysta*-morphotype taxa (Pl. 3, fig. 1). Another characteristic feature of the northern flysch deposits in the Podhale Basin is the common presence of the multicellular algae *Pterospermella* and *Tasmanites*, which often occur as the dominant or sole marine palynomorphs in a sample.

INTERPRETATION

The differences described above seem to have been related to the palaeogeography of the Podhale Flysch Basin: the Szaflary beds and the overlying Zakopane beds (northern part) were deposited closer to the source area at the northern margin of the basin, whereas the deposits of the upper part of the carbonate "Tatra Eocene", and the overlying Zakopane beds (southern part), probably represent pelagic or hemipelagic deposits of an intrabasin high (Fig. 5). An effect of such a palaeogeographical setting would have been the variable trophic conditions in the subsurface photic zone.

The deposition of the upper part of the carbonate "Tatra Eocene", the earliest beds of the Podhale Palaeogene, presumably took place in the shallow marine environment of an intrabasin high. The mass occurrence of large foraminifers (mainly represented by the genus *Nummulites*) indicate oligotrophic conditions (cf. Brasier 1995). The nutrient poor, "blue waters" of the southern part of the Podhale Basin became an unfavourable area for dinoflagellate development. Similar trophic conditions must have persisted in this area in the early stages of the clastic sedimentation of the Zakopane beds, which were presumably deposited on a shoal rising above the basin floor with respect to the Szaflary and Zakopane beds in the north. Eutrophic conditions appeared in the southern area only in the westernmost part of the Zakopane beds (Dolina Lejowa and Siwa Woda sections), possibly as a result of the opening up of a new, western source area for the Podhale Flysch turbidites. These trophic differences possibly reflect also the diachronism of the Zakopane beds in the peri-Tatra area (Gedl 1998).

In contrast with the southern margin of the present-day Podhale Basin, the northern one was characterized by eutrophic conditions. The latter area, during the deposition of the Szaflary beds and the lower part of the Zakopane beds, was characterized by a high nutrient supply brought down by the rivers. This is supported by the fact that the palynofacies of the Szaflary beds is often composed 100% of land plant remains (Pl. 2, figs 1, 2). The eutrophic "green water" conditions resulted in dinocyst assemblages which are characterized by the dominance of representatives of Wetzelielloideae (mainly *Wetzeliella* and *Rhombodinium*) or "blooms" of the gonyaulacea taxa (*Membranophoridium* and *Chiropteridium*) (Pl. 3, figs 1, 2). The common presence of the Wetzelielloideae, as well as that of the multicellular algae believed to have inhabited brackish environments, support the view that the subsurface water layer of the Podhale Basin in this area was influenced by fresh water.

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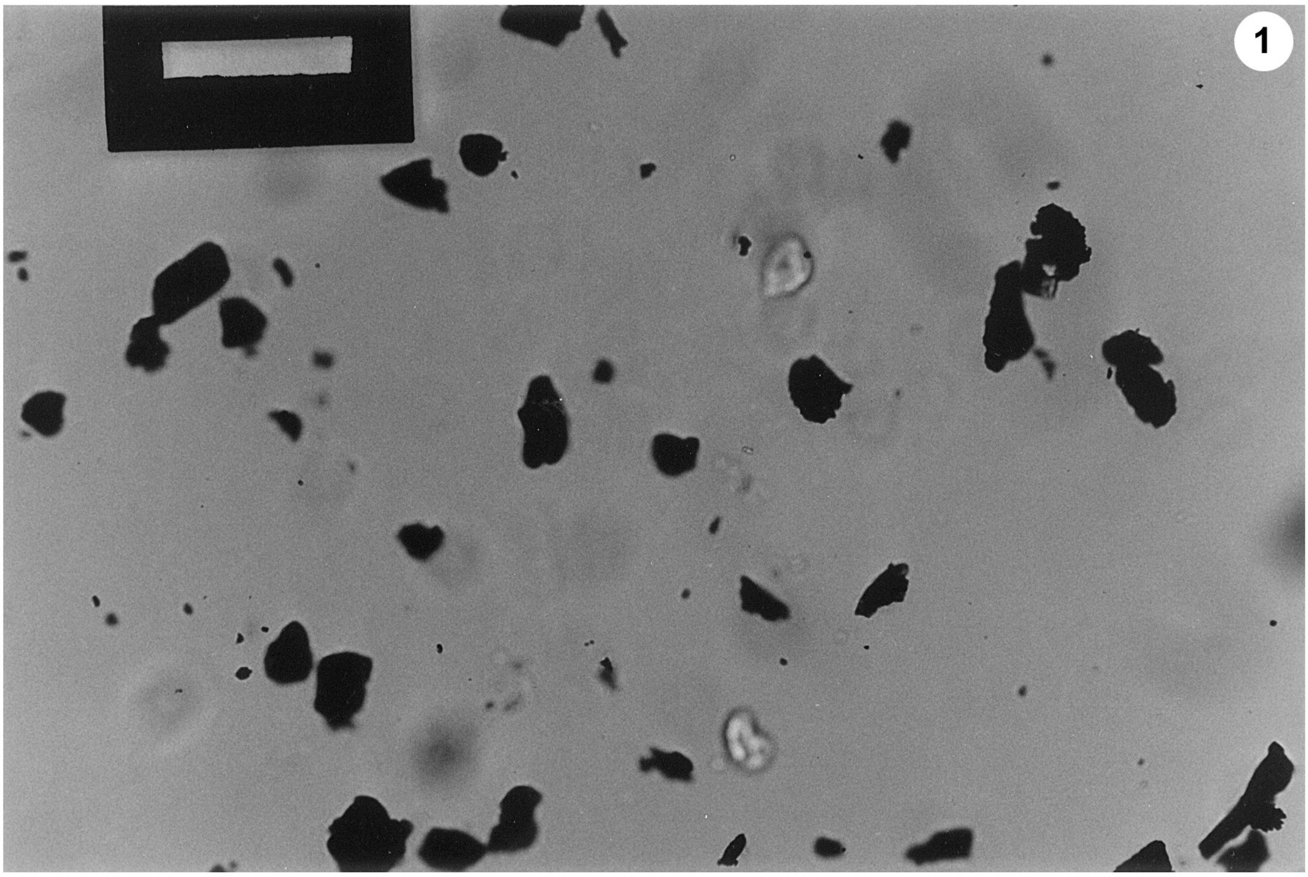
PLATES

Plate 1

Palynofacies of the peri-Tatra Zakopane beds dominated by black, opaque phytoclasts; no dinocysts are present (scale bar indicates 100 µm and referrs to all plates):

1. Biały Stream section
2. Cicha Woda Stream section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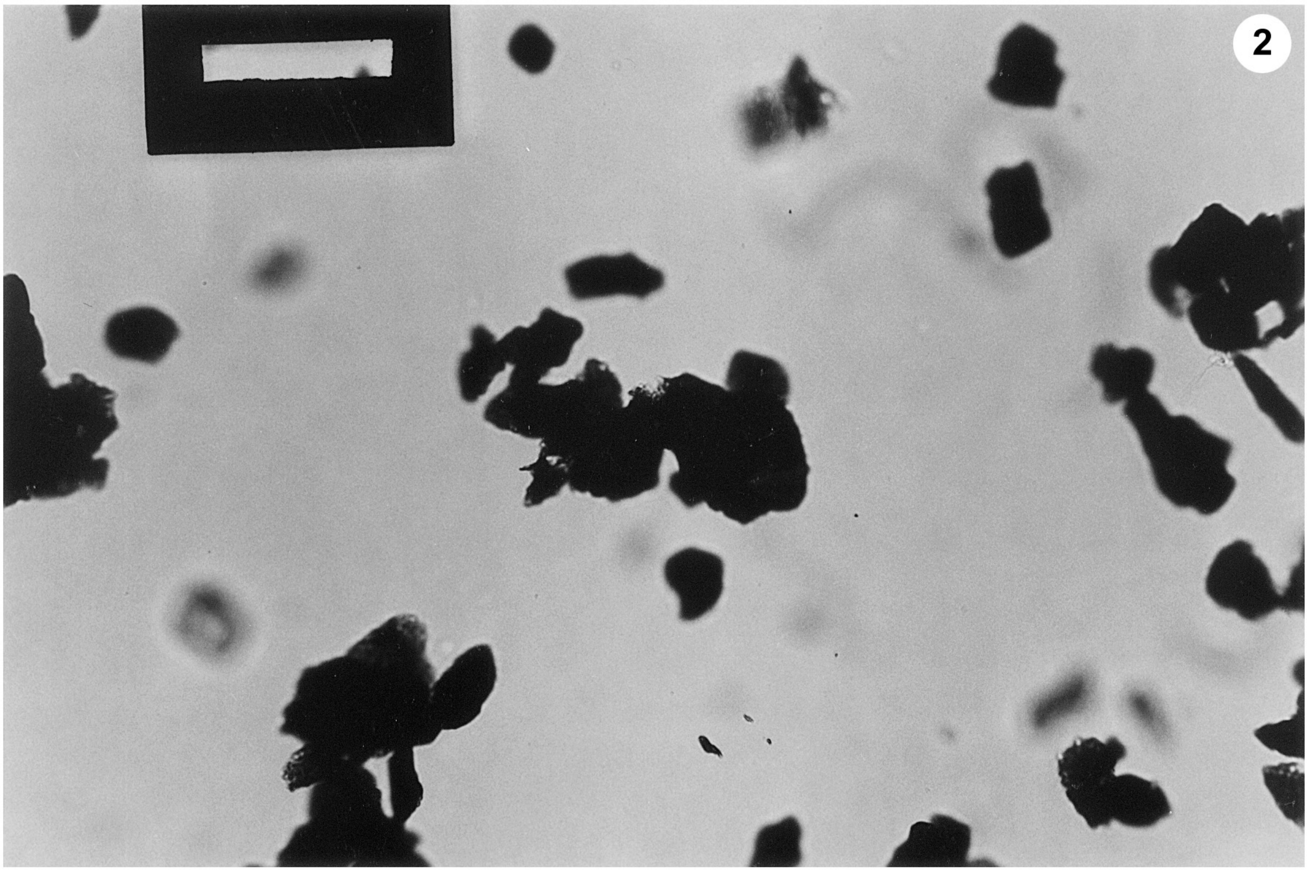
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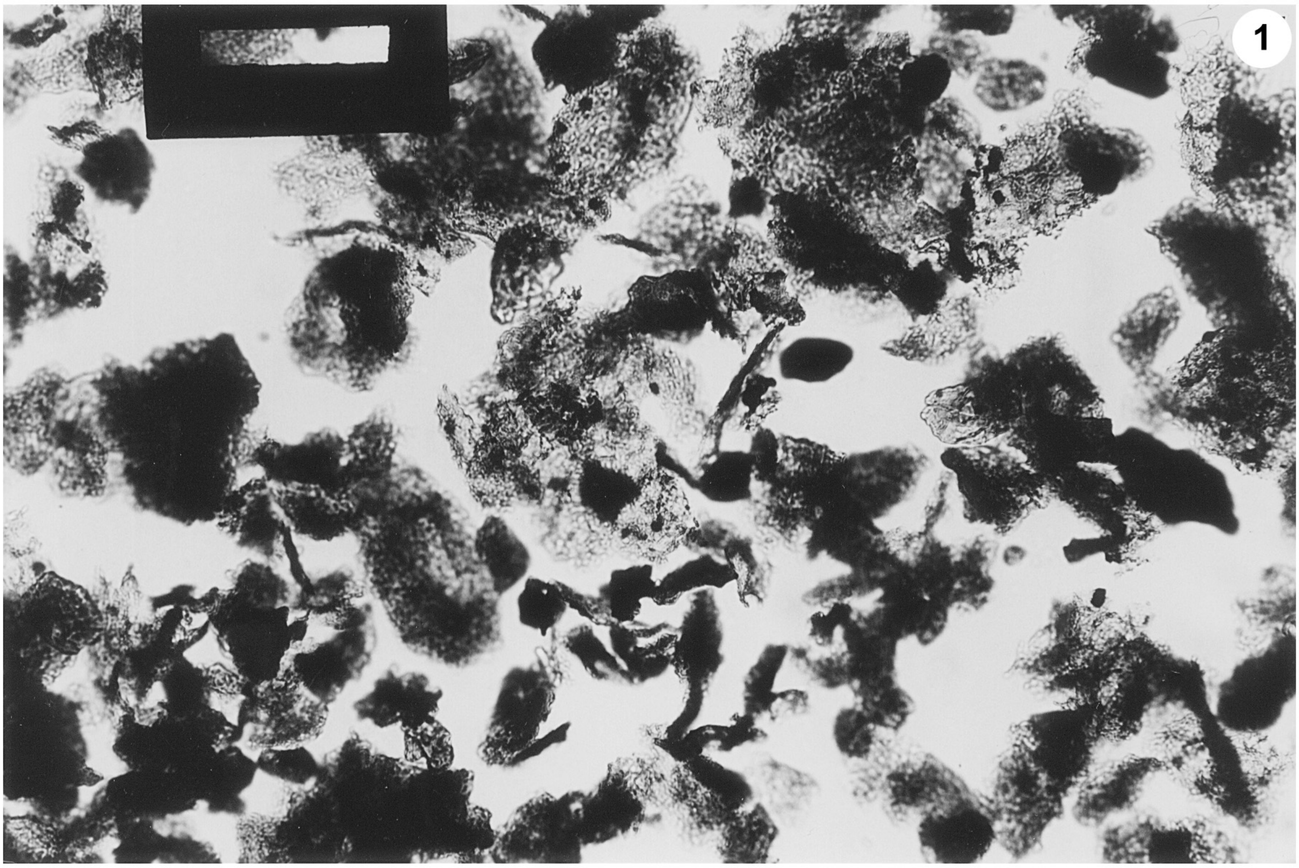
Plate 2

Palynofacies of the Szaflary beds dominated by land plant remains:

1. Szaflary section
2. Leśnica Stream section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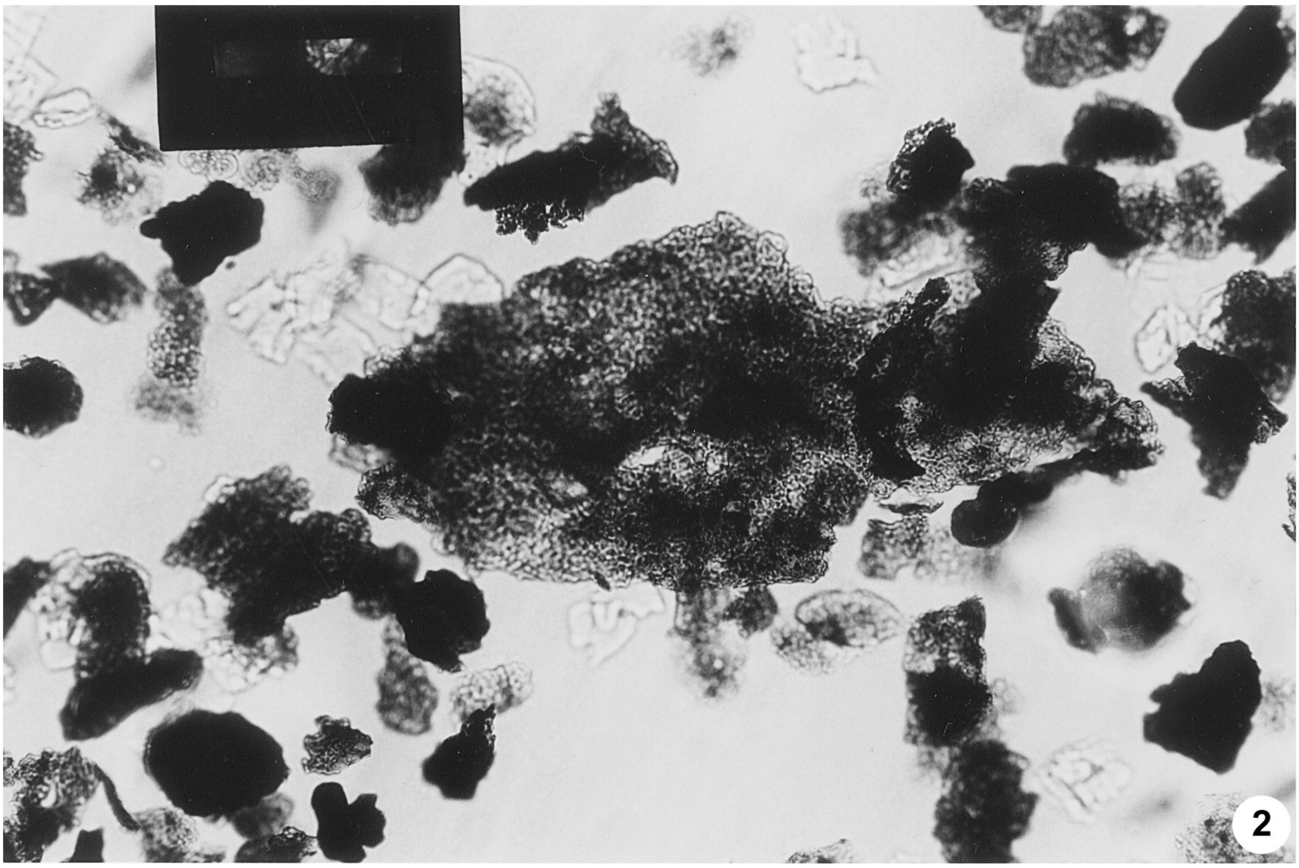
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Plate 3

Palynofacies of the Szaflary beds characterized by the mass occurrence of dinocysts representing the Areoligeraceae family and the Wetzelielloideae subfamily:

1. Trybski Stream section
2. Leśnica Stream section