Acta Palaeobot. Suppl. 2: 293–301, 1999 — Proceedings 5th EPPC

TERRESTRIAL PLANT FOSSILS IN THE TRANSGRESSIVE PALAEOGENE LITTORAL/FLYSCH SEQUENCE OF THE TATRA MOUNTAINS (CENTRAL CARPATHIANS)

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ABSTRACT. A review of first reported over a century ago, fossil plant remains, from the Palaeogene transgressive littoral/flysch sequence on the northern slope of the Tatra Mountains is given. Collections and samples housed in Polish museums and scientific institutions have been checked. The plant remains had been transported by sea currents and/or rivers from the south where at that time, the land mass of the Inner Carpathians had been subject to gradual inundantion. Some fossil plant impressions from the Chłabówka locality are presented. The most probable age of the plant fossils is late Middle and/or early Late Eocene, with the exceptions of the oldest one (Raciborski 1892), which could be older Middle Eocene and the younger coalified wood pieces, which belong to the Oligocene.

KEY WORDS: stratigraphy, plant macrofossils, Eocene, Palaeogene, Tatra Mts, Carpathians

INTRODUCTION

The Tatra Mts represent the highest (2655 m a. s. l.) and most northerly alpine massif in the whole of the Carpathian belt. They are latitudinally elongated and asymmetric with steep S and SE slopes and relatively gentle N and W slopes. This massif is surrounded by depressions developed on the Palaeogene flysch: Podhale to the north, Spisz to the east and Liptov to the south. The morphological asymmetry is caused by the geological structure. The main ridge and the S as well the SE slopes are composed of Palaeozoic crystalline rocks cut by faults and directly bordered by Palaeogene deposits, while folded Mesozoic formations are preserved on the N and W slopes. The whole of this structure dips gently to the north beneath transgressive carbonate Formation of the Palaeogene. These coarse-grained deposits contain marl intercalations with plant impressions. Higher, in the overlying shaly flysch formation, coaly plant remains were found (Fig. 1 and 2).

Occurrences of plant detritus and streaks of coal have been noted in the Palaeogene on the northern slope of the Tatra Mountains for over a century. However, only a little information relating to the better preserved plant fossils has been published (Raciborski 1892, Kuźniar 1910, Szafer 1958, Starczewska-Koziołowa 1961, Bąkowski 1967, Frankiewicz 1975, Zastawniak, in: Passendorfer 1983). Samples of these plant remains are stored in: (1) the Geological Museum of the Institute of Geological Sciences of the Polish Academy of Sciences in Cracow (GM ING, collection of Kuźniar), (2) the Władysław Szafer Institute of Botany of the Polish Academy of Sciences in Cracow (KRAM-P, collections of Szafer and Starczewska-Koziołowa, and Łomnicki), (3) the Museum of the Earth of the Polish Academy of Sciences in Warsaw (samples collected by Grzybek-Kinle, Stecki, Balcerzak, Baranowska-Zarzycka, Bąkowski and Juchniewicz), (4) the Museum of the Geological Faculty of Warsaw University (samples collected in Chłabówka by Głazek), (5) the Tatra Museum in Zakopane (samples collected in Chłabówka by Passendorfer and samples picked up by occasional collectors from different localities), (6) private collection of Frankiewicz in Cracow. For a comprehensive study of these floral findings international cooperation is necessary, as the first locality found by Raciborski (1892) lies in Slovakia. This paper presents all the available information on fossil plant remains and their collections, except marine calcareous algae which are beyond its scope.

HISTORY OF INVESTIGATIONS

The first information on plant macrofossils was published by Raciborski (1892), who reported from the grey and reddish shales of the "Palaeocene" which lay beneath the transgressive Eocene conglomerates numerous Equisetineae, included one he named *Equisetum uhligi*

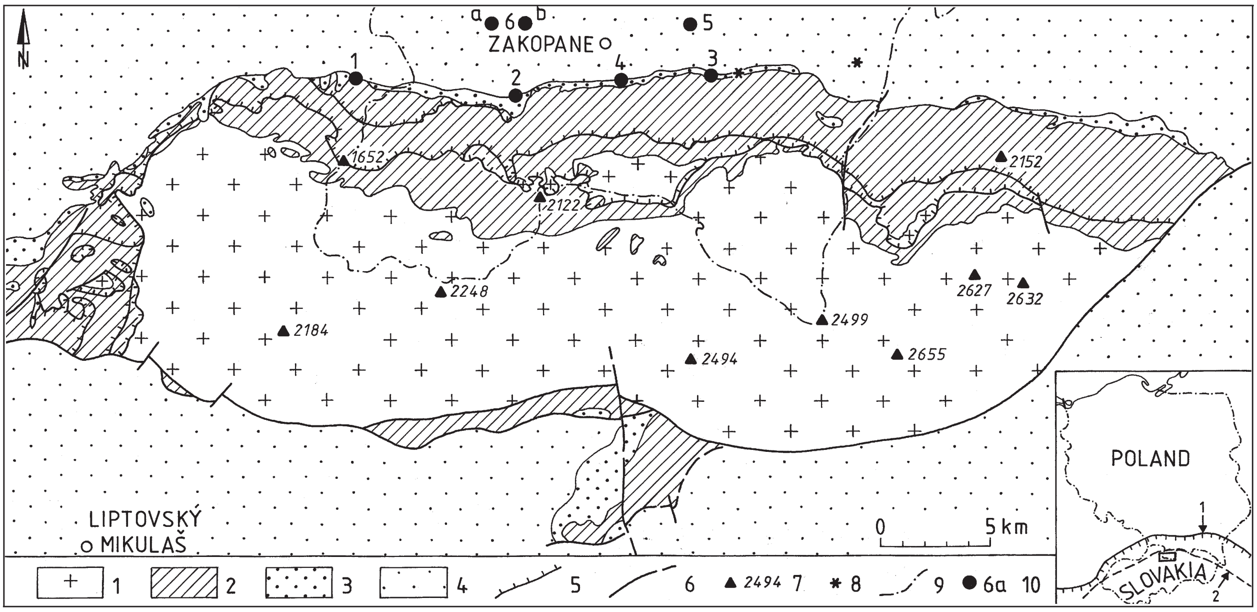

Fig. 1. Sketch map of the Tatra Mountains showing localities with terrestrial plant fossils within the Palaeogene sequence of Podhale. 1 – Palaeozoic crystalline rocks, 2 – Mesozoic sedimentary rocks, 3 – basal carbonate clastics of the Eocene sequence, 4 – Podhale flysch, 5 – main overthrusts, 6 – faults, 7 – important peaks with altitudes in m a. s. l., 8 – dated tuffite localities, 9 – state boundary, 10 – localities of discussed plant macroremains („Turek valley" – 1; Hruby Regiel – 2; Chłabówka – 3; Skijump Krokiew in Zakopane – 4; Olczyski Stream – 5; Głęboki and Butorowski Streams – 6a,b). The inset shows the wider context: 1 – frontal overthrust of the Carpathians, 2 – Pieniny Klippen Belt – the boundary of the Inner Carpathians

Raciborski (*nomen nudum* and *obsoletum*), an oak leaf similar to that of *Ilex aquifolium* L., two coniferous species and poorly preserved leaves of probably Myricaceae and Salicaceae from the "Turek valley" in Slovakia (Fig. 1: 1).

Later, Kuźniar (1910) briefly described abundant plant remains from a road cutting in the northern slope of Hruby Regiel in top part of Upper Eocene detrital carbonates (Fig. 1: 2). He described leaf remains of *Poacites* sp., *Podocarpus eocenica* Ung., *Quercus urophylla* Ung., *Quercus* sp., *Carpinus grandis* Ung., *Ficus morloti* Ung., *Populus mutabilis repando-crenata* Heer, *Laurus lalages* Ung., *Daphnogene paradisiaca* Ung., *D. melastomacea*? Ung., *Dryandroides angustifolia*? Ung., *Apocynophyllum lanceolatum* Ung., *Sapotacites sideroxyloides* Ettingsh., *Eucalyptus oceanica* Ung., *Pyrus troglodytarum* Ung., *Amygdalus pereger* Ung. and two fruits of *Nipadites burtini* Brongt.

More recently Szafer (1958) briefly reported a new discovery of plant remains in a marl intercalation between Eocene conglomerates at Chłabówka quarry (Fig. 1: 3). He wrote about the finding of leaves of Lauraceae *(Cinnamomum* spp.*),* Palmae*,* Myrtaceae and Cornaceae*,* and suggested also that *Ficus,* Myricaceae and Sterculiaceae might be present. This collection was briefly revised by Zastawniak (in: Passendorfer 1983). She illustrated leaves of *Sabalites* and *Daphnogene,* and suggested the presence of ?Apocynaceae and Salicaceae. Earlier from this locality several fragments with leaves were collected by Głazek and Passendorfer. Another locality with similar stratigraphic features was discovered during the reconstruction of Skijump Krokiew in Zakopane (Fig. 1: 4) by Starczewska-Koziołowa (1961), but her collection has not been described at all.

A considerably younger sample with plant remains was found by Grzybek-Kinle in the Zakopane Shales Formation in the Olczyski Stream (Fig. 1: 5). It consists of imprints on a sandstone slab, together with remnants of coaly plant matter which include a spadix and leaf fragments. Bąkowski (1967) described, illustrated and broadly discussed these specimens, naming them as *Phoenix szaferi* sp. nov. Similar remains identified as palm remnants were noted by Frankiewicz (1975) from outcrops in the Głęboki and Butorowski streams NW of Zakopane (Fig. 1: 6a and 6b). However, according to Dr Volker Wilde (Forschungsinstitut Senckenberg) these remains represent not imprints of palm fructifications but bivalve wood-borings (personal communication of August 31, 1999). This opinion was later confirmed by Prof. Andrzej Radwański (November 5, 1999, Warsaw University). Such an interpretation is more consonat with environment of deep sea turbidite sedimentation, in which drowned pieces of drift wood are common.

All fossil remains had probably been transported by sea currents and/or rivers from the south where a gradual inundantion of the land mass of the Inner Carpathians – Spisz-Vepor Land ("Spišsko-veporská pevnina" of Andrusov 1965) – had occurred at that time.

GEOLOGICAL SETTING

REGIONAL SITUATION

The Tatra Mountains belong to the Inner Carpathians, which had been folded, elevated and eroded during the period between the Late Cretaceous (post-Early Turonian) and the Late Eocene (before Priabonian). The Inner Carpathians had been separated from the European Continent by the deep flysch basin of the Outer Carpathians from the Early Cretaceous untill the Early Miocene. The present boundary between the Inner and Outer Carpathians lies along the Pieniny Klippen Belt, which is a remnant of the ancient subduction zone where a considerable portion of the drowned European substrate of Outer Carpathian flysch nappes was consumed during the Miocene folding. The Pieniny Klippen Belt and the Tatra Mountains are separated by a 15–18 km wide asymmetric syncline filled with deposits up to 3 km thick of the Eocene – Oligocene littoral/flysch sequence. These formations were deposited by the sea, which invaded the Inner Carpathians from the basin of the Outer Carpathians, and are separated from the Outer Carpathian Flysch nappes by a belt of Mesozoic klippen pierced upward from beneath the Palaeogene flysch during the Miocene folding.

The Palaeogene sedimentation in the Outer Carpathians, to the north of the Pieniny Klippen Belt, was almost a continuation of that of the Maastrichtian. Further to the south coarse-grained transgressive deposits of the Middle and Late Eocene had covered discordantly not only the folded and denuded Mesozoic deposits, but even the Palaeozoic crystalline rocks (e. g. at the western end of the Tatra Mts). This period of subaerial erosion was longer and is excellently evidenced further to the south in Slovakia by continental deposits (bauxite, coal bearing strata, and palaeokarst deposits) with Palaeogene fossil plants determined probably by C.v.Ettingshausen in the middle of the last century as *Laurus Lalages* Ung. and *Andromeda protogaea* Ung. (in: Hauer 1852, p. 169; cf. Andrusov 1965). The Palaeogene littoral/flysch sequence overlaped the Tatra area to a depth of at least 1.5 km. The Tatra Mountains were elevated about 15 million years ago, it means since Middle Miocene, and the Palaeogene blanket which had covered them was almost completely eroded (Andrusov 1965, Burchart 1972, Činčura 1993, Kováč *et al*. 1993). Probably the original Palaeogene sedimentation took place just a few hundred kilometres to the south, because a geological restoration of the tectonic structures gave a minimum figure of c. 300 km (Świdziński 1971) and as palaeomagnetic studies of Eocene rocks (Grabowski 1997) have revealed no measurable shift of remnant magnetization vectors, the distance must have been less than 700 km. Thus, the sedimentation area would have occurred some 3 – 6^{o} south of its present position. However, the climate then was much warmer than it is at the present day. A general cooling of the Earth has occurred since the Terminal Eocene Event. It should be noted that the Alpine-Carpathian climatic barrier was created after the Miocene uplift.

STRATIGRAPHY OF THE PODHALE LITTORAL/FLYSCH SEQUENCE

The Podhale littoral/flysch sequence on the northern slope of the Tatra Mts evidently nonconformably overlaps folded Mesozoic sedimentary formations and even Palaeozoic crystalline rocks. This sequence was divided lithostratigraphically by Gołąb (1959) into four formations (Fig. 2):

(1) Basal conglomerates or ”nummulitic Eocene” (conglomerates, dolomitic arenites and marls) named the Sulov Formation in 1860 by D. Štur (cf. Andrusov 1965) and currently defined in Slovakia as the Borov Formation (Kováč *et al.* 1993, Nemčok *et al.* 1995). This Formation is very diverse, both in composition as well as thickness, the latter varying between 0 and 363.2 m (Roniewicz 1969, Kępińska 1997). Here and there red breccia and conglomerate with as occasional silty-clayey intercalation form the Lower Member of this Formation, reaching a maximum thickness of c. 50 m. Probably it was in the top part of this Member that the plant remains were found by Raciborski (1892). Higher members of this Formation consist of grey conglomerates interstratified with dolomitic arenites, limestones and marls with marine fossils. These rocks also vary greatly in thickness from 0 to over 300 m (mostly 10 to 100 m) and lie directly on the older substrate (Starczewska-Koziołowa 1961, Roniewicz 1969, Kępińska 1997). It is in this higher part of the Formation that most of the discussed plant remains have been found (Kuźniar 1910, Szafer 1958, Starczewska-Koziołowa 1961, Passendorfer 1983), as well as the 0.7 m thick tuffite layer (Głazek *et al.* 1998). This tuffite layer can be correlated with the thick tuffites found in other Carpathian localities, which occur near the base of the Priabonian and have been dated c. 40 ± 2 ma (Van Couvering *et al.* 1981, Głazek *et al.* 1998). It is evident that this Formation covered a diversified relief during the transgression and represents locally freshwater deposits filling valleys (red beds), passing upwards into littoral and shallow marine deposits (grey conglomerates and carbonates) which cover nearly the whole area.

(2) An over 1000 m thick shaly flysch sequence of the Zakopane Formation (in Slovakia called the Huty Formation) with rare turbidite and tuffite intercalations. It was in this Formation, c. 900 m from the bottom, that remains were found which have been identified as a palm fructification. They were described by Bąkowski (1967) and were similar to those noted by Frankiewicz

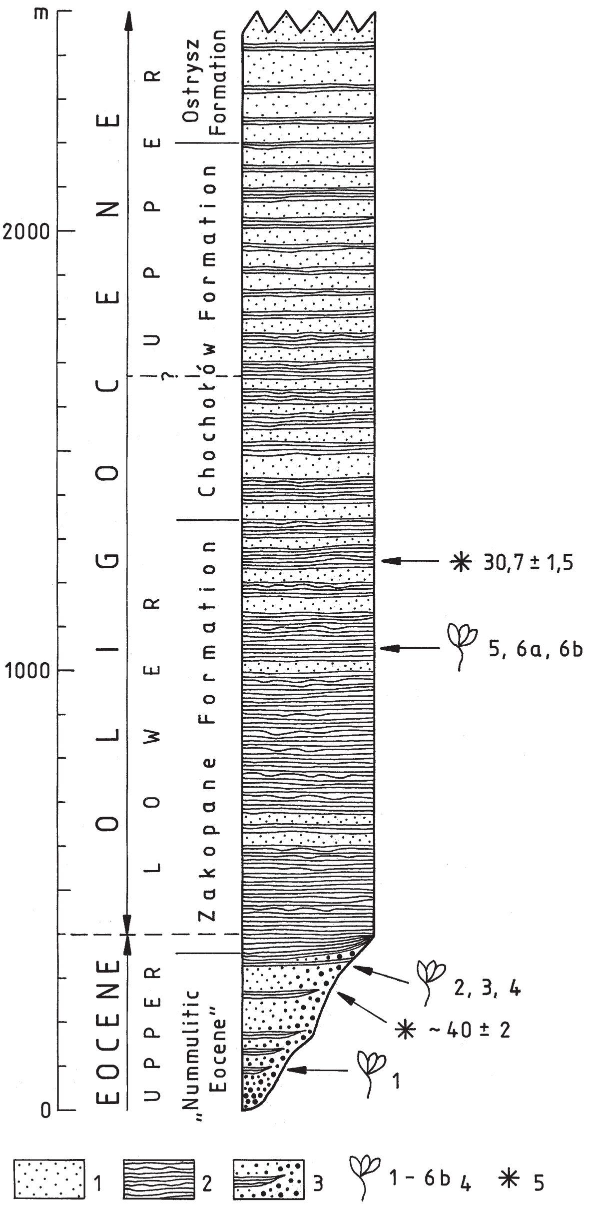

Fig. 2. Schematic stratigraphic column of the Palaeogene sequence on the northern slope of the Tatra Mountains compiled after Roniewicz (1969), Roniewicz & Pieńkowski (1977), Kępińska (1997), Gedl (1998) and the observations of J. Głazek. The positions of the discussed plant fossils and dated tuffites are marked. 1 – sandstones (turbidites), 2 – shales, 3 – basal carbonates: conglomerates, calcarenites and marls, 4 – the supposed stratigraphic position of the localities discussed (1 – 6b), 5 – dated (in millions of years) tuffite layers

(1975). However, these remnants represent wood drift strongly borred by terredinids (cf. p.00). Zircons of one tuffite layer found in the top part of this Formation were dated by C. W. Naeser (in: Van Couvering *et al.* 1981, see also Głazek *et al*. 1998) with fission-track method at 30.7 ± 1.5 ma.

(3) Chochołów or Zuberec (in Slovakia) Formation of sandstone – shaly flysch deposits.

(4) Sandstone flysch Ostrysz Formation (in Poland) or Biely Potok Formation (in Slovakia)

The Middle and Late Eocene age of marine conglomerates, dolomitic arenites and marls around the Tatra Mts and the Late Eocene – Oligocene age of the Podhale Flysch (Fig. 2) have been accepted since Uhlig's (1897) synthesis of the geology of these mountains. Later on Kuźniar (1908, 1910) and Bieda (1959, 1963) had tried to estimate the age of this stratigraphy more precisely on the basis of study of large foraminifers. Bieda (1959, 1963) had differentiated four nummulitic assemblages within the „nummulitic Eocene" and the Zakopane shales and clasified them as Middle and Upper Eocene. However, their results were subsequently questioned by Olempska (1973) and Kulka (1985), because differences in nummulitic assemblages can be explained by ecological factors rather than by age differences. Alexandrowicz & Geroch (1963) and Blaicher (1973) reported assemblages of small foraminifers with *Globigerapsis (=Globigerinatheka) index* (Finlay*)* in the bottom part of the Zakopane Formation and in a marl intercalation in the upper part of the conglomerates. This assemblage is of Late Priabonian age (cf. Beckmannn *et al.* 1981, Molina *et al.* 1993).

But Dudziak (1983, 1984, 1986) on poorly preserved and illustrated nannoplankton assemblages suggested Late Eocene age of the Zakopane Formation (NP zones 17–19) and Lower Oligocene age of the Chochołów and Ostrysz Formations. More recently Gedl (1995) has produced evidence that the top formation of the Podhale Flysch (Ostrysz Formation) belongs to the Late Oligocene and has confirmed the Early Oligocene age of the Zakopane Formation (Gedl 1998). Independently Bartholdy *et al.* (1995) evidenced late Middle Eocene age (Bartonian, NP 16–17) in the top of „nummulitic Eocene".Similar conclusions result from other current investigations (Bartholdy 1997, Olszewska & Wieczorek 1998).

Hence, most of the localities of terrestrial plant fossils in the Tatric Palaeogene mentioned so far belong to the late Middle and/or early Late Eocene or to the Early Oligocene. However, the first locality found at the base of the conglomerates (Raciborski 1892) could be slightly older, of Middle Eocene age (Fig. 2).

PLANT FOSSILS

The Eocene in Central Europe is characterized by the presence of a Palaeotropical flora. It was composed of evergreen laurel and rainforests rich in species, and poor mangrove forest with the palm *Nypa* (Mai 1995). Climatic and palaegeographic conditions in the area were favourable to the growth of diverse, rich vegetation in which palms, representatives of the families Fagaceae (*Dryophyllum*, *Eotrigonobalanus* and *Pasania*), Lauraceae (*Cryptocarya, Daphnogene, Laurophyllum, Lin-*

dera, Litsea and *Ocotea*), Menispermaceae, Icacinaceae, Annonaceae, Mastixiaceae, Moraceae (*Ficus*) and others, togerther with the coniferous Taxodiaceae (particularly *Arthrotaxis* and *Doliostrobus*), Cupressaceae, Pinaceae and Cephalotaxaceae predominated. These plants were accompanied by less numerous deciduous trees and shrubs belonging to the genera of the younger Arcto-Tertiary element (e.g. *Platanus, Populus, Pterostyrax, Rubus, Sambucus, Sassafras, Sequoia* and *Taxodium*). According to Mai (1995), the evergreen *Eotrigonobalanus-Quercus*-Lauraceae Forest, Taxodiaceae-Lauraceae Forest and marshy-laurel Forest with Myriaceae and Ericaceae were the dominant plant communities in those times.

With regard to the physiognomic features of leaves, the Eocene floras were characterized by coriaceous leaves with entire margins. In the Late Eocene, the size of leaves in particular taxa became smaller, placing them in the notophyllous class (20.25 – 40.5 cm^2; Mai 1995).

The identification in the fossil flora of those taxa which are preserved only as leaf impressions, mostly with entire margins and camptodromous venation, is difficult and frequently impossible without cuticular analysis. Moreover, if the plant remains are only impressions of small leaf fragments, one can tell very little about the taxonomic composition of the fossil flora. That is why most collections from the Tatra Eocene have not as yet been described and the major part of the already published preliminary results of plant taxa determinations (Raciborski 1892, Kuźniar 1910, Szafer 1958, Zastawniak in: Passendorfer 1983) should be considered uncertain.

The plant remains collected in Chłabówka (Szafer 1958) are only impressions of small leaf fragments without plant tissue. They are mostly of entire-margined leaves, narrow-oblong with a distinct midvein and less distinct lateral veins, features generally indicative of coriaceous leaves.

Pteridophytes are represented in the Chłabówka flora by the genus *Acrostichum* L. from the family Pteridaceae (Pl.1, fig.1). Only one specimen is preserved (KRAM-P 238/636). Two pinnae of a frond can be seen, with numerous fine, more or less parallel lateral veins, close together and anastomosing. The fossil remains of *Acrostichum* and *Nypa* are indicators of brackish habitats in paratropical coastal swamps, which occurred in Europe until the Late Eocene. Nowadays *Acrostichum* is a paratropical plant growing in mangrove and coastal swamps.

In the whole material, only one specimen of a coniferous plant has been found (Coniferae indet., Fig.3, KRAM-P 238/638). Its systematic affiliation has not been identified. Two fragments of shoot are visible about 2 cm long, with spirally arranged and decurrent leaves. One leaf has been preserved whole; it is sharply pointed, 1 mm wide and about 5 mm long. Both shoot fragments are of the same type. Similar leaf shoots are characteristic of some genera from the families Taxodiaceae (*Athrotaxis* D.Don and *Doliostrobus* Marion). The precise identification of the specimen from Chłabówka is impossible due to its poor state of preservation.

Fig. 3. Coniferae indet. – impression of shoots from the Eocene of Chłabówka, Tatra Mountains (drawing by J. Wieser, KRAM-P 238/636)

All the other plant remains in the material from Chłabówka are of angiosperms. A small fragment of a relatively narrow leaf with a dentate margin has been determined as ?*Eotrigobalanus furcinervis* (Rossm.)Walther et Kvaček (Pl. 1, fig. 6). This fossil species with great leaf variability was one of the more important members of the Fagaceae in the Palaeogene forests of Eurasia (Kvaček & Walther 1989). Leaf impressions of the Form genus *Daphnogene* Unger (Pl. 1, figs 2–4) belong to the family Lauraceae. They are of entire-margined leaves with characteristic acrodromous venation.

The other form genus identified in the flora of Chłabówka is probably *Rhodomyrtophyllum* Rüffle et Jähnichen from the family Myrtaceae. Here belongs a relatively large leaf with entire margin and slightly cuneate base (Pl. 1, fig.10).

Monocotyledonous plants are represented mostly by impressions of leaf fragments of *Sabalites* sp. from the family Arecaceae. It should be noted that a fruit of the palm *Nypa* was found at the Late Eocene locality in Hruby Regiel (Kuźniar 1910).

A leaf fragment from the family Araceae (Pl. 1, fig. 5) has also been identified in the material from Chłabówka. Today this family is a large one, consisting mostly of herbaceous plants, some of which inhabit marshes. The family is pantropical, with just a few species occurring in temperate zones (Heywood *et al*. 1978).

It may be expected that further, more detailed investigations of plant remains from the Tatra Eocene sites will add to the list of fossil taxa and make a complete reconstruction of the Eocene vegetation of that area possible.

CONCLUSIONS

According to current investigations (Bartholdy 1997, Gedl 1998, Głazek *et al*. 1998, Olszewska & Wieczorek 1998) the most probable age of the discussed fossil plant localities is late Middle and/or early Late Eocene, with the exceptions of the first (Raciborski 1892), which could be older Middle Eocene and the younger coalified drift wood, which belong to the Early Oligocene.

The collections of fossil plant remains from all the localities of the Tatra Eocene are available in museums and scientific institutions in Poland, so a modern reappraisal of them is both possible and necessary. Moreover, some of the localities could be further exploited, collections enlarged, and conclusions supplemented.

ACKNOWLEDGEMENTS

We wish to express many thanks to authorities of museums holding the collections and Dr J. K. Frankiewicz for giving us access to collected by him specimens from the Zakopane Formation. The paper was greatly improved by constructive review of Anonymous Reviewer. We owe special thanks to Dr V. Wilde and Prof. A. Radwański for their suggestions on nature of the samples described as "*Phoenix szaferi*". We would like to extend our appreciation to Mr. A. Copping for linguistic verification of the English text. We owe our thanks to J. Wieser, M. Sc. for his drawing of plant remains, to W. Szałopieta, M. Sc. for his copying of the other drawings in Indian ink and to A. Pachoński for taking the photographs.

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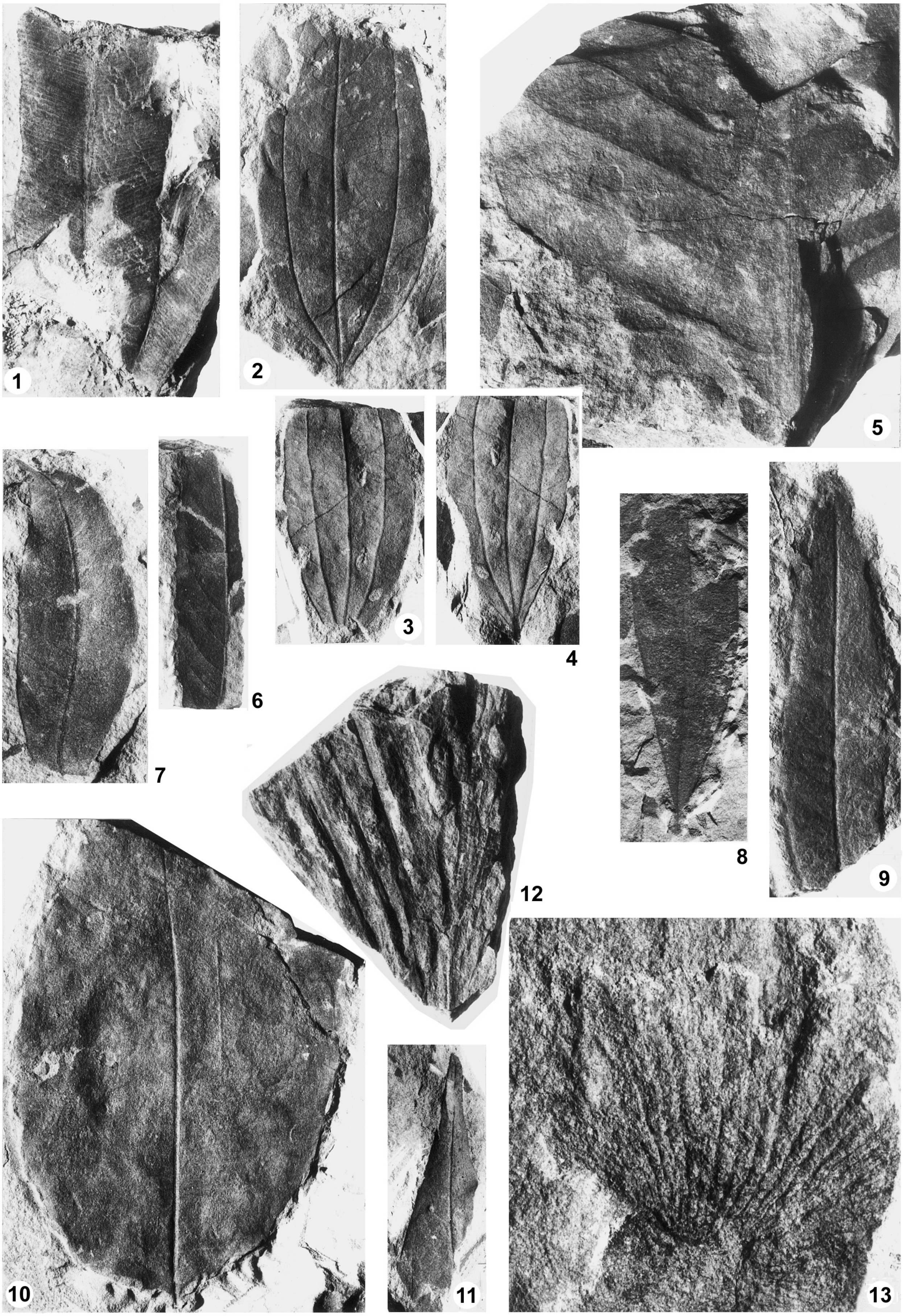
PLATE

Plate 1

Plant impressions from the Eocene of Chłabówka, Tatra Mts

1. *Acrostichum* sp., two pinnae of frond, × 2, KRAM-P 238/636
2. *Daphnogene* sp., × 1, KRAM-P 238/654
3. *Daphnogene* sp., × 1, KRAM-P 238/587
4. *Daphnogene* sp., × 1, KRAM-P 238/554
5. Araceae, × 1, KRAM-P 238/98
6. ? *Eotrigonobalanus furcinervis* (Rossm.) Walther et Kvaček, × 1, KRAM-P 238/121
7. Dicotyledonous leaf, × 1, KRAM-P 238/553
8. Lauraceous leaf, × 1, KRAM-P 238/580
9. Lauraceous leaf, × 1, KRAM-P 238/34
10. ? *Rhodomyrtophyllum* sp., × 1, KRAM-P 238/398
11. Apical part of dicotyledonous leaf with drip-tip, × 1, KRAM-P 238/575
12. *Sabalites* sp., × 1, KRAM-P 238/627
13. Palm (?) leaf, × 2, KRAM-P 238/552

Photograph by A.Pachoński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