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NEW FOSSIL FLORAS FROM NEOGENE DEPOSITS IN THE BEŁCHATÓW LIGNITE MINE

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New fossil floras from Neogene deposits in the Bełchatów Lignite Mine*

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ABSTRACT. The results of a study of macroscopic plant remains (mainly leaves) derived from two different floras (KRAM-P 211/214 and KRAM-P 217) in the Bełchatów Lignite Mine are presented. Both fossil floras are characterized by a relatively small floristic diversity. Plant remains (leaves, coniferous shoots, fruits and seeds) from fossil assemblage of KRAM-P 211/214 (28 taxa) belong to families Osmundaceae, Pinaceae, Taxodiaceae, Cupressaceae, Aceraceae, Betulaceae, Fagaceae, Juglandaceae, Lauraceae, Myricaceae, Nyssaceae, Ulmaceae, Hydrocharitaceae, and Smilacaceae and from fossil assemblage KRAM-P 217 (28 taxa) to Pinaceae, Taxodiaceae, Aceraceae, Betulaceae, Cyrillaceae, Ebenaceae, Ericaceae, Fagaceae, Hippocastanaceae, Juglandaceae, Loranthaceae, Myricaceae, Malvaceae sensu lato, Poaceae, and Smilacaceae. Among them eight new taxa to the Polish Tertiary were reported. Taxa characteristic of the arctotertiary geoflora dominate, palaeotropical element has a small share. Remains of azonal vegetation prevail in both assemblages; there are mainly swamp forest and riparian forest species. Some of the taxa found indicate the presence of Mixed Mesophytic Forest that represent zonal vegetation. Recent counterparts of the fossil plant taxa occur above all in south-eastern North America, East Asia, Transcaucasia, and southern Europe. The palaeoclimates corresponding to both fossil floras have been included into the Cfa type in Köppen's classification (moderately warm and humid climate). The flora KRAM-P 211/214 is of the Early Miocene (Ottnangian-Karpatian) age and KRAM-P 217 flora is considered to be the Late Miocene (Pannonian-Pontian) age.

KEY WORDS: plant megafossils, palaeoecology, palaeoclimate, Miocene, Bełchatów Lignite Mine, Poland

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INTRODUCTION

In central Poland there are many lignite deposits in Tertiary alluvial sediments of which the largest are mined for power industry purposes. The coal deposit that is exploited by the Bełchatów Lignite Mine is one of the largest deposits of this kind in Europe. It was discovered as a result of geological investigation at the beginning of the 1960s (Stuchlik et al. 1990). In addition, palaeobotanical review of the Bełchatów cores was carried out. The first palynological analyses were carried out by Raniecka-Bobrowska (1962a) and were later continued by others (Grabowska et al. 1963). In summation, of these palynological analyses, the main coal seam was provisionally dated as of Middle Miocene age (Ziembińska-Tworzydło 1966).

During the period from 1960–1977 palaeobotanical studies on the Bełchatów deposit were limited to palynological investigations. Beginning in 1977, as the lignite seam was made accessible for exploitation by gradual removal of the overburden, comprehensive micro- and macrofloral palaeobotanical studies on the Tertiary deposits were carried out in the exposure by researchers from the Władysław Szafer Institute of Botany PAS, Kraków. Geological and palaeozoological investigations (mostly of the malacofauna) and bone remains of vertebrates (Jerzmańska & Hałuszczak 1986, Stworzewicz & Szynkiewicz 1988) accompanied these studies.

Comprehensive palaeobtoanical study of the Tertiary outcrop at the Bełchatów Lignite Mine, undertaken between 1977–1990, was summarized by Stuchlik et al. (1990) in a preliminary review. The data collected permitted the age of deposits filling the Bełchatów Graben to be established as Neogene, those of the main coal seam as Early Miocene, and those of the sedimentary series of the overburden as Late Miocene-Pliocene (Stuchlik et al. op. cit.). After 1990, palaeobotanical studies in the outcrop at Bełchatów Lignite Mine were continued by Worobiec (1995), Worobiec and Florjan (1997), Stuchlik and Szynkiewicz (1998), Worobiec and Lesiak (1998), and Wójcicki and Zastawniak (1998).

The present floristic analysis of the two fossil floras collected in the outcrop at Bełchatów Lignite Mine between 1993–1995, aims to reconstruct the local plant assemblages, determine their age and characterize the palaeoclimate. These analyses were based on the macro-remains of leaves, and to a lesser extent on accompanying fossil fruits and seeds. The fossil leaves from the Bełchatów outcrop appeared ideal for study, mostly comprising compressions with elements of well-preserved anatomical structure.

GEOLOGY

The Bełchatów Lignite Mine is situated in the southern part of the central European Lowlands, in central Poland, in the region between two rivers: Warta and Pilica, approx. 15 km south of Bełchatów (Fig. 1). In this area lignite occurs within a series of tectonic depressions, referred to in the literature as the Kleszczów Graben (Stuchlik et al. 1990). This system of tectonic depressions extends over a distance of more than 40 km, from the village of Rząśnia in the west to Kamieńsk and Ręczna in the east. Gotowała and Hałuszczak (1999) determined the full extent of the Kleszczów Graben, from east to west, at 78

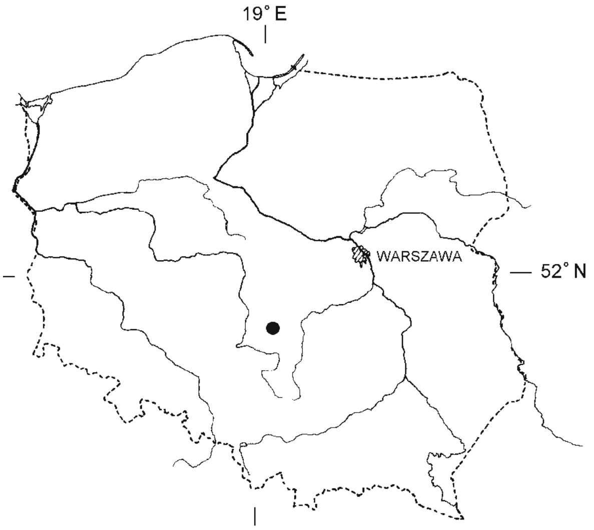

Fig. 1. Location of the Bełchatów Lignite Mine

km. The graben predominantly opened in Mesozoic (Jurassic and Cretaceous) basement deposits and is filled with between 200–250 m, locally over 600 m, of Cainozoic deposits (Gotowała & Hałuszczak op. cit.). In places, these deposits are cut by faults or are folded. A small occurrence of Permian rocks in the form of a salt diapire (“Dębina”) divides the lignite deposits into the conventional (used for industrial purposes) Bełchatów Field and Szczerców Field. To the east of the Bełchatów Field lies the Kamieńsk Field (Matl 2000) with no economic value. So far only the Bełchatów Field has been exploited.

The Tertiary deposits of the Kleszczów Graben formed when its base subsided. According to Krzyszkowski (1993) the rate of subsidence varied and influenced the lithology of the deposits. The origin of the Kleszczów Graben followed a few stages of structural development (Hałuszczak 1995, Gotowała & Hałuszczak 1999). The results of tectonic investigations indicate the Younger Alpine Orogenic genesis of the graben. During the first stage of its development, in the early Tertiary, basement structures formed (Gotowała & Hałuszczak op. cit.). These authors are of the opinion that graben development (the beginning of the second stage of graben formation) began in the form of initial hollows of the pull-apart type, and that the principal period of graben opening occurred during the cramping of the Western Carpathians to the east, which most scientists correlate with the Early Miocene (Eggenburgian according to the scheme of Paratethys, Fodor 1995). This conclusion as to the age of the graben’s formation agrees with the results of earlier palynological studies on the oldest deposits filling the bottom of the graben, which, according to Stuchlik et. al (1990) were dated as Eggenburgian (Early Miocene).

As a result of the comprehensive geological and palaeontological studies carried out on the Bełchatów Lignite Mine outcrop, a synthetic lithostratigraphic profile of Tertiary deposits filling the Kleszczów Graben was established (Stuchlik et al. 1990, Czarnecki et al. 1992, Stuchlik & Szynkiewicz 1998, Szynkiewicz 1999, 2000, Matl 2000). Division of this profile was based on distinct differences in its lithological formation, the presence of characteristic correlatable horizons, and above all numerous kaolinized tuffite horizons: paratonsteins (Matl op. cit.). The practical lithostratigraphical division into so-called “units” was proposed by Kasza (1985). This division was subsequently corrected and completed. After Czarnecki et al. (1992), Stuchlik and Szynkiewicz (1998), and Matl (2000) in the current lithostratigraphical profile of the Tertiary deposits from Bełchatów, four main lithological units are distinguished (Fig. 2): subcoal unit (PW), coal unit (W) including the main seam (PG) and seams B(II) and C(III), clayey-coal unit (I-W) with seam A(I) and the youngest clayey-sandy unit (I-P).

Within the deposits of the subcoal unit, mostly sandy and only secondarily (particularly in the upper part) containing silt-clayey intercalations, 2–3 m thick lignite layers dated as Eggenburgian occur locally (Stuchlik et al. 1990). The floor of the subcoal unit marks the contact with the Mesozoic basement formations (Matl 2000). Locally, at the base of this unit, between the Mesozoic basement and Neogene deposits Palaeogene regolith may be found (Matl op. cit.). The upper limit of the subcoal unit is marked by the lowest paratonstein of correlatable importance (TS-7 according to Czarnecki et al. (1992), TS-5 according to Szynkiewicz (1999), TS-10 according to Matl (2000) and Wagner (2000). Above this paratonstein lie 3 economic coal seams (PG, C(III), B(II). Within the main seam (PG), between two (TS-5 and TS-6, Czarnecki et al. (1992) and five (from TS-5 to TS-9, Wagner op. cit.) paratonstein horizons have been recognized.

A subsequent paratonstein overlies the

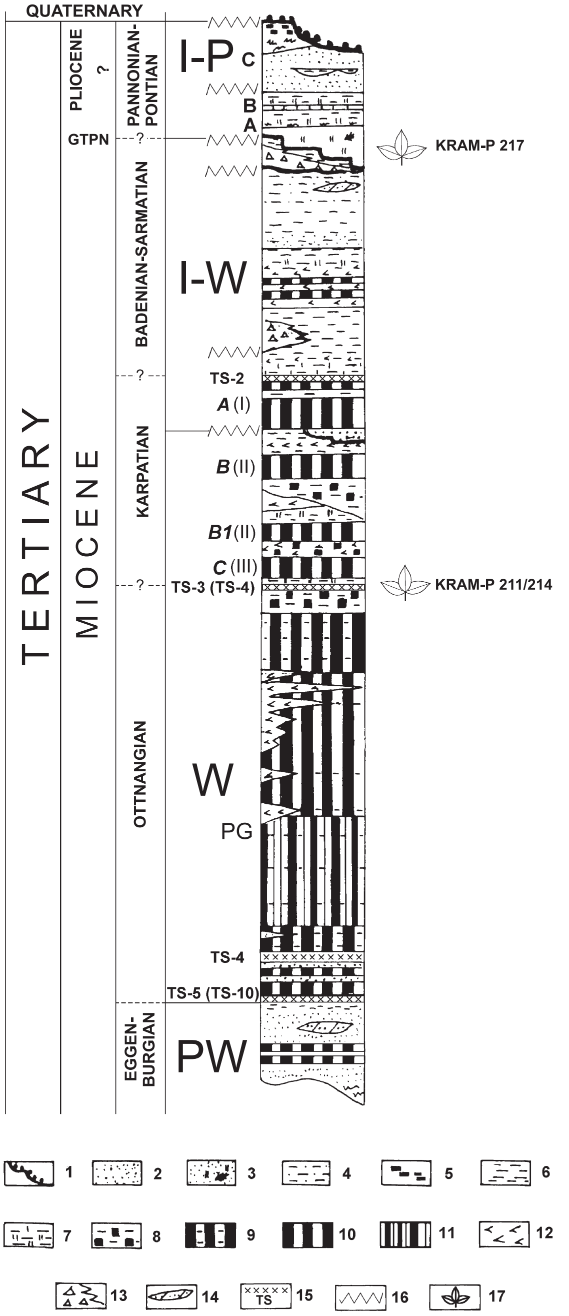

Fig. 2. Lithostrartigraphic profile of the Tertiary deposits in the Bełchatów Lignite Mine (after Stuchlik et al. 1990, Stuchlik & Szynkiewicz 1998, Szynkiewicz 1999, 2000, slightly changed)

1 – erosional boundary of the Tertiary and Quaternary (Q) sediments, **2** – sands, **3** – coaled sands with plant detritus, **4** – clayey sands, **5** – peat, **6** – clays, **7** – coaled clays, **8** – humic coals (“cuboidal clays”), **9** – xylite-sapropelic brown coals or coals with clay, **10** – xylite brown coals, **11** – bituminous-pyropissite brown coals, **12** – lacustrine limestones, **13** – weathered mesozoic rocks with silica or ferruginous cement, **14** – silicated sands or quartzitic sandstones, **15** – tuffogenous layers (paratonsteins), **16** – distinct erosion borders and discordance, **17** – position of the described fossil floras

PW – subcoal unit; **W** – coal unit; **I-W**-clayey-coal unit; **I-P** – clayey-sandy unit; **PG** – main coal seam; **A(I)**, **B(II)**, **B1(II)**, **C(III)** – symbols of remaining coal seams; **A**, **B**, **C** – units distinguished in clayey-sandy unit (Wilczyński 1992), **GTPN** – the Main Tertiary Surface of Discordance (Hałuszczak 1995)

main seam on the so-called “cuboidal clays” layer, which in the opinion of Wagner and Drobniak (2000) represents a rarely occurring variety of completely gelified humic coal. Stuchlik et al. (1990) regard this paratonstein as TS-3, Czarnecki et al. (1992) and Wagner (2000) as TS-4. The paratonstein under discussion is an important correlation horizon as it separates the main seam from the overlying deposits with seams C(III) and B(II). Using fission track analysis (FT) it was first dated at 18.1 ± 1.7 Ma BP (Burchart 1985), then at 17. 25 ± 0.4 Ma BP (Burchart et al. 1988). A greyish-green clay (named the “leaf clay” by Wagner and Drobniak (2000) directly overlies the paratonstein, and contains remains of KRAM-P 211/214 fossil flora. Above it are several metres thick coal seams C(III) and B(II) and lacustrine limestones. Within coal unit (W) alluvial fan sediments occur (Słomka et al. 2000). The top of the coal unit is marked by the dichotomous paratonstein horizon (TS-3 according to Czarnecki et al. 1992 and Wagner 2000, Wagner et al. 2000, fig. 1).

The overlying clayey-coal unit is built of gravel, sand, silt, clay and lacustrine limestone layers and a coal seam A(I). Within the clayey-coal unit are two paratonstein horizons, TS-1 and TS-2 (Wagner 2000); using fission track analysis, the latter (TS-2) that lies in the top or near-top parts of seam A(I), was first dated at 16.5 ± 1.3 Ma BP (Burchart 1985), then at 17.05 ± 0.69 Ma BP (Burchart et al. 1988). Above, lies the last clayey-sandy unit, separated by a distinct erosional discordance marked by an extensive layer of siliceous flints (in the mine this layer is named “the surface of washing”). This layer is often discordant with different lithological members of the clayey-coal unit (Matl 2000). Hałuszczak (1995) identifies this boundary as the Main Tertiary Surface of Unconformity (GTPN). According to this author it has a regional character and goes far beyond the Kleszczów Graben. GTPN is a turning point for the second stage of the structural development of the Kleszczów Graben (Gotowała & Hałuszczak 1999). Within the clayey-sandy unit, just over the erosional discordance, deposits with the KRAM-P 217 fossil flora were found. The clayey-sandy unit has a characteristic lithology; it consists of poorly sorted quartzite sands, and in the upper part of variegated clayey-silt deposits with sand layers (Matl 2000). Locally there are very thin intercalations of coal or peat. The top of the clayey-sandy unit is marked by an erosive contact overlain by Quaternary deposits (Q).

According to Krzyszkowski (1993) the subcoal unit, most of the clayey-coal unit (except for its lower part under paratonstein TS-2) and the whole clayey-sandy unit are of alluvial origin, whereas the coal unit together with the lower part of the clayey-coal unit may be lacustrine or swampy in origin.

Within the coal unit Wagner et al. (2000) have distinguished deposits of lacustrine origin (lacustrine limestones), phytogenic swamp deposits (coals) formed by bog vegetation, and fluvial deposits of the alluvial fan. Szynkiewicz (1999) assumes that formation of the upper part of the main seam was connected with the sedimentary environment of a meandering river (including ox-bow lakes) in the active tectonic zone.

GEOLOGICAL CHARACTERISTICS OF THE EXPOSURE CONTAINING THE KRAM-P 211/214 LEAF FLORA

The stratigraphic position of the clays containing the leaf flora KRAM-P 211/214 in the lithostratigraphic profile of the Tertiary deposits of the Bełchatów Lignite Mine have been established on the basis of the exposure observed in July 1994 (Szynkiewicz 1994).

The exposure with the flora was located on coal escarpment no. 1 on the sixth mining level from the surface recorded on the western slope of the Bełchatów Lignite Mine open pit. This occurs at 61.3–75.0 m a.s.l. and is situated between boreholes 74.5/14.5 and 74/15 NS (90–110 span of conveyors belt B-602). The lithostratigraphic profile of the exposure is described below. In the lower part of the escarpment lacustrine limestone (so-called lacustrine chalk) occurs interbedded with thin lignite intercalations, which to the north and to the bottom grade into the main seam (PG). The layers mentioned dip at a shallow angle to the N and NE. To the north intercalations of lacustrine limestones become increasingly thinner and the coals merge into a single seam. Overlying these deposits, almost along the whole length of the escarpment investigated, a layer of black, completely gelified humic coal (the so-called “cuboidal clays”) occurs that ranges up to 2.0 m in thickness but thins to 0.5 m northwards. In its top occurs a layer of 2–3 cm laminated pyroclastic deposits (paratonstein). In older papers this paratonstein was referred to as TS-3 (Stuchlik et al. 1990), and subsequently as TS-4 (Czarnecki et al. 1992, Wagner 2000). The paratonstein is overlain by laminated grey clays containing a leaf flora. This layer varies in thickness from 0.5 m to 1.5 m. In addition to fossil leaf remains it also includes fragments of fish skeleton and bone remains belonging to Megachiroptera (Kowalski 1995). Above this occur lignites of the 3–9 m xylitic-clay seam C(III). Over seam C occurs a layer of lacustrine limestone that is approximately 2–2.5 m thick, which to the north grades into lacustrine limestones with intercalations of silt, next into silts and farther to the top even into sand layers. These formations were covered by the xylite-clayey lignite seam B(II) with intercalations of lacustrine limestone and standing trunks.

The clay horizon that contains the KRAM-P 211/214 flora was deposited in a large lake, as shown by lacustrine limestone deposits. Large concentrations of lacustrine limestones indicate that the depth of the lake increased to the south.

GEOLOGICAL CHARACTERISTICS OF THE EXPOSURE CONTAINING THE KRAM-P 217 LEAF FLORA

The stratigraphic position of the clays containing the KRAM-P 217 leaf flora in the Bełchatów Lignite Mine was established on the basis of the exposure as observed in July 1995 (Szynkiewicz 1997).

The exposure containing the fossil flora was on overburden escarpment 3 on the western slope of the Bełchatów Lignite Mine open pit, near spans 90–120 of conveyor belt B-302. The lithostratigraphic profile of the exposure is described below. In the lower part of the escarpment formations were assigned to the clayey-coal unit. These were dusty quartzite sands, white in places, covered by the 2–3 m thick A(I) lignite seam. This seam was locally covered by paratonstein TS-2. Above, were fine-grained dusty sands and two thin (up to 1 m) layers of xylitic-clayey lignites and a few fossil soil horizons. In this part of the exposure a boundary between the clayey-coal unit and clayey-sandy unit was found; it has an erosion character. In the lower part of the Tertiary clayey-sandy unit an erosional depression was found filled with grey sands and sheets of striped flints. These sands were covered by greyish-brown clayey-silts and above them lay an approximately 10 cm thick layer of grey-white claystone, most probably paratonstein (TS-1). Above, this lay an approximately 12 cm thick layer of grey clays with many leaf remains (the KRAM-P 217 fossil flora). Upwards these deposits graded into a rather thick layer (approx. 25 cm) of leaf litter compressions, which when fresh looked exactly like xylite-clayey lignites. These deposits were covered by a 25 cm thick layer of grey-brown clay, grading upwards into clayey sands and grey silts, and then into a layer of fine-grained quartzite sands. On these sands lay a thin layer of dusty sands with the quartzite gravel in the floor, underlying grey quartzite sands with a large amount of striped flints and plant detritus.

Deposits containing the KRAM-P 217 flora were deposited in an eroded depression at the boundary between the clayey-coal unit and clayey-sandy unit. According to Wilczyński (1992) deposits belonging to the floor part of the clayey-sandy unit formed in a fluvial environment that was transitional from a braided to meandering river system. In the roof part of unit A distinguished by this author (the lowest part of the clayey-sandy unit) laminated deposits with leaf macrofossils were found. Wilczyński (op. cit.) is of the opinion that they originated as the result of filling of stagnant water bodies (ox-bow lakes?) in a decadent phase of the development of the meandering river environment. Therefore, it can be hypothesised that the lacustrine sediments containing the KRAM-P 217 flora probably represent an ox-bow lake.

MATERIAL AND METHODS

The study material was collected from the Bełchatów Lignite Mine between 1993–1995. In 1993, 48 specimens of the KRAM-P 211 leaf flora from clays overlying paratonstein TS-3 were collected. In 1994, 193 specimens of the KRAM-P 214 leaf flora were collected from clays overlaying paratonstein TS-3, and in 1995, 262 specimens of the KRAM-P 217 leaf flora. In total 503 fossil specimens were collected.

The state of preservation of the fossil leaves was generally very good (categories A or B according to the classification proposed by Mädler 1952) and enabled isolation of leaf compressions from the claystone. In the case of the KRAM-P 211/214 flora, preservation within bituminous clay made it necessary to adopt the method described by Knobloch and Kvaček (1976), where leaves are separated in hydrofluoric acid (HF). A fragment of claystone with a leaf impression was placed on a plastic Petri dish in a small amount of concentrated HF for a few hours. The claystone fragment with the leaf was then carefully transferred to a large plastic pot containing water, where the leaf was separated from the clay with preparatory needles. The prepared specimen was then ready for clearing.

To isolate leaves of the flora KRAM-P 217 from the claystone and to separate leaf from coalfied leaf layers, a 30% solution of H_2O_2 was used (Worobiec 2003). This methodology was based on techniques used by Huard (1966) to isolate leaf compressions. The action of H_2O_2 on the clay or silt causes their decomposition as a result of generation of oxygen bubbles inside the matrix. To make use of this property of H_2O_2, the author sprayed leaf compressions, uncovered on the surface of claystone or mudstone fragments, with small amounts (approx. 1 ml) of 30% H_2O_2 which was then spread carefully over the whole surface of a specimen with a brush-pencil with plastic hair. After a short time (usually 1–2 minutes), the rock fragment under a leaf would swell visibly, and the specimen would be carefully transferred to a large pot filled with tap water. While in the water the leaf usually became freed from the matrix and would often float to the surface. However, it was sometimes necessary to detach the leaf using a preparatory needle. The separated leaves were then caught on a plastic spatula and transferred to a pot where they were kept immersed in water. Before clearing they were treated with HF for a few hours, and finally rinsed thoroughly in tap water. Small fragments of leaves were isolated for cuticular analysis.

The isolated leaves of the two floras were cleared to show their venation. To this aim the author's own two-stage method was applied. First, specimens were steeped in a mixture of diluted (approx. 1%) hydrogen peroxide (H_2O_2) with an addition of 10% KOH solution. To clear coriaceous leaves a mixture of 15 ml of H_2O_2 to 1 ml 10% KOH solution was used. In the case of delicate leaves the proportion used was 25–30 ml H_2O_2 to 1 ml 10% KOH solution. This solution cleared the leaves by outwashing the humic substances from the tissues; the leaf blade assumed a brown colour. The duration of this process was dependent on the leaf type but generally lasted for about a few hours.

Temporarily cleared leaves, after rinsing in tap water, were transferred to very diluted solution of NaClO (a commercial bleach, called "Bielnar", prepared using 1 ml of bleaching substance to 10 ml of tap water). Leaves were kept in this solution for between 2–20 minutes, being removed the moment the black-brown venation became distinct against a bright leaf blade. It was noticed that this solution damaged the margins of dentate leaves (mainly of the family Betulaceae), and for this reason the second stage of the procedure was sometimes avoided. The cleared leaves were rinsed in water for between 12–24 hours to stabilize the colouring and remove the residual reagents, and were then mounted in glycerine jelly between glass slides following the method described by Hummel (1983). Altogether 100 preparations of isolated fossil leaves were made.

Different methods were used to prepare leaf epidermis for microscopy. Leaf fragments were placed on watch glasses for maceration, rarely specimens were macerated directly on microscopic slides. Leaves from the KRAM-P 211/214 flora were macerated for a few hours in a solution of 2 ml of 30% H_2O_2, 2 ml of 10% KOH and 40 ml of tap water (modification of a method described by Kvaček 1966), in most cases this produced good results. To obtain satisfactory epidermal preparations of the coriaceous leaves of *Daphnogene polymorpha* (Al.Braun) Ettingshausen maceration in Schulze's solution (saturated solution of $KClO_3$ in concentrated HNO_3) was required.

Leaves from the KRAM-P 217 flora were macerated for between 30 minutes to several hours (dependent on taxa) using a solution of NaClO (commercial bleach "Bielnar") prepared as 1 ml of bleach and 10–20 ml of tap water (Dilcher 1974). Usually the ratio 1:10 was used, but in the case of *Fagus* 1:20. The macerated epidermis was then transferred to a small drop of glycerine on a glass slide and a drop of melted glycerine jelly added (avoiding the formation of air bubbles) and was in turn placed under a cover glass. After approximate one week the margins of the cover glass were coated with transparent varnish. As the fossil epiderms was usually of yellowish colour, they were only rarely stained with safranin (e.g. leaves of *Laurophyllum pseudoprinceps* Weyland & Kilpper). Altogether 189 slides of leaf epiderms were prepared.

All drawings were made using a Carl Zeiss stereomicroscope with *camera lucida* attachment. Bright field, dark field and phase contrast microphotography of the fossil leaf epiderms using Optiphot (NIKON) microscope fitted with an FDX-35 camera and a Nikon H-III lens cap for microphotography were made by the author. Fossil leaf epidermal structures were measured with an Amplival (Carl Zeiss Jena) microscope fitted with a ×12.5 ocular equipped with a 5:100 micrometric scale. Small morphological elements of fossil leaves were measured with a Carl Zeiss Jena stereoscopic microscope fitted with a micrometric ×16 ocular.

The method of measuring the size of anatomical structures depended on their shape. In case of round or broadly elliptical structures, their diameter was measured, while in elongate, tetragonal their length and width. Structures with irregular or variable shape (mainly epidermal cells) had their longest dimension measured (size).

In this elaboration the taxonomical system used by Hutchinson (1973) and Takhtajan (1987) was used. Morphological descriptions of fossil leaves were based on the nomenclature proposed by Hickey (1973, 1979). Features of anatomical structure were interpreted on the basis of papers by Dilcher (1974), Wilkinson (1979) and Theobald et al. (1979).

In these studies the author made use of the herbaria at the Władysław Szafer Institute of Botany PAS, Kraków, and of the reference herbaria in the Department of Palaeobotany and the Museum of the Earth PAS, Warszawa. For comparative purposes the author used collections of epidermal preparations from fossil and recent leaves kept in the Władysław Szafer Institute of Botany PAS, Kraków, the Museum of the Earth PAS, Warszawa and the Charles University, Prague (Czech Republic).

All the examined fossil specimens marked with symbols KRAM-P 211 (nos 1–48), KRAM-P 214 (nos 1–193), KRAM-P 217 (nos 1–262) are kept in the Władysław Szafer Institute of Botany PAS, Kraków. The total number of specimens from all taxa is greater than the total number of fragments of stones with plant remains because on some specimens (fragments of stones) several taxa have been preserved. In this case a specimen number is accompanied by a Roman numeral.

Because some of the localities of fossil floras in territory of Poland changed their names after Second World War, below are put together new and old names. On the right side are old names present in papers published before 1945 year (after Łańcucka-Środoniowa et al. 1983).

Bluszczów = Bluschau
Brzeg Dolny = Dyhernfurth
Chroślice = Hennersdorf
Dzierżysław = Dirschel
Kokoszyce = Kokoschütz
Koronowo = Crone a. Br
Kunice Żarskie = Kunzendorf
Malczyce = Maltsch
Nowogród Bobrzański = Naumberg a. Bober
Pierusza = Peruschen
Popowice = Pöpelvitz
Rataje = Rataj bei Posen
Rozewie = Rixhoeft
Smogorzówek = Klein Schmograu
Sośnica = Schoßnitz
Stróża = Striese (W.)
Trzebnica = Trebnitz
Węgliniec = Kohlfurt
Wołów = Wohlau
Wyszonowice = Ruppersdorf
Zielona Góra = Grünberg

SYSTEMATIC DESCRIPTIONS

Pterophytina

Osmundaceae

Osmunda L.

Osmunda parschlugiana (Unger) Andreánszky

Fig. 3: 1, 2; Pl. 1, figs 4, 4a

1847 *Pteris parschlugiana* Unger; Unger, p. 122, Pl. 36, fig. 6.
1959 *Osmunda parschlugiana* (Unger) Andreánszky; Andreánszky, p. 45, Fig. 2., Pl. 7, fig. 4.

Material. KRAM-P 214: 36, 64, 95, 180.

Morphological description. Fragments of leaflets of fern frond up to 2.0 cm long and 1.3–1.5 cm wide. Leaflet margin dentate, teeth very small, tooth apex acute to rounded, apical sides of teeth mostly short. Venation dichotomous, very regular. Secondary

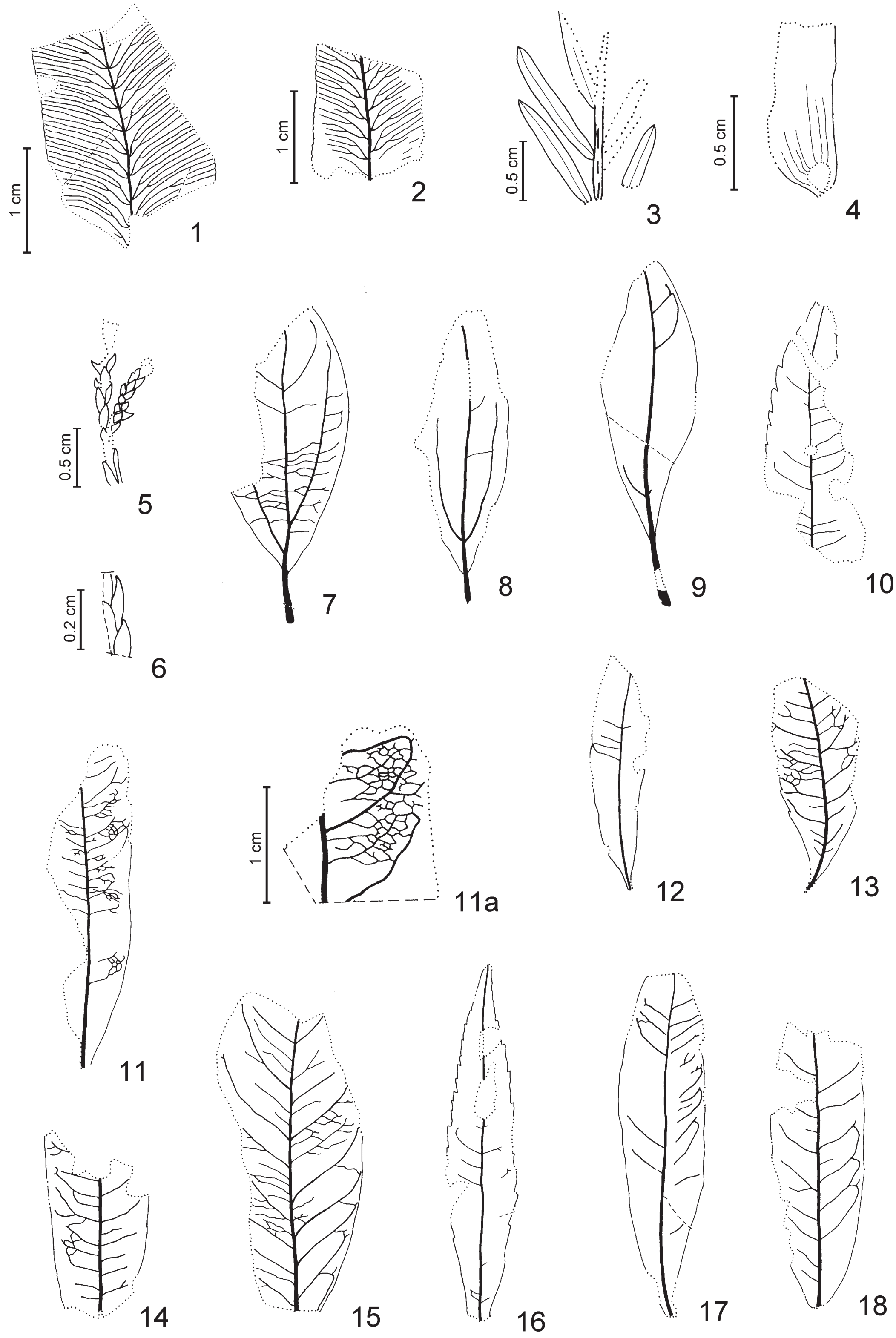

Fig. 3. **1–2** – *Osmunda parschlugiana* (Unger) Andreánszky: 1 – specimen KRAM-P 214/64, 2 – specimen KRAM-P 214/95; **3** – *Taxodium dubium* (Sternberg) Heer – specimen KRAM-P 211/27; **4** – *Pinus* sp. – specimen KRAM-P 214/161; **5–6** – *Glyptostrobus europeus* (Brongniart) Unger: 5 – specimen KRAM-P 214/136, 6 – specimen KRAM-P 214/105; **7–8** – *Daphnogene polymorpha* (Al.Braun) Ettingshausen: 7 – specimen KRAM-P 214/93, 8 – specimen KRAM-P 214/78; **9 –** *Laurophyllum pseudoprinceps* Weyland & Kilpper – specimen KRAM-P 214/162; **10–11a, 13–18** – *Myrica lignitum* (Unger) Saporta sensu lato: 10 – specimen KRAM-P 217/104, 11 – specimen KRAM-P 217/210/I, 11a – specimen KRAM-P 217/210/I, enlargement of leaf venation, 13 – specimen KRAM-P 214/131, 14 – specimen KRAM-P 217/109, 15 – specimen KRAM-P 214/62, 16 – specimen KRAM-P 217/215/IV, 17 – specimen KRAM-P 217/188, 18 – specimen KRAM-P 217/46/IV; **12**. cf. *Myrica lignitum* (Unger) Saporta sensu lato – specimen KRAM-P 217/110. Specimens without scale were reduced 15% from natural size

veins arranged mostly alternate, depart the primary vein at the angle of 50–70° (mostly 60°). Secondaries first branched near primary vein for two branches and each of them once more branched for another two branches which reach the leaflet margin. Due to the poor state of preservation it is impossible to determine whether the secondary veins terminate in the tooth apex or in the sinuses between teeth.

Anatomical description. Lower epidermis composed of isodiametrical, sometimes elongate cells, 80–100 µm in size. Anticlinal cell walls undulate and thick. Stomata (Pl. 1, fig. 4a) anomocytic, surrounded by ca. 5 cells, wide elliptic to roundish, 40–60 µm in size with indistinct polar T-shaped cuticular thickness. Outer stomatal ledge aperture spindle-shaped, 20–28 µm long and 4–8 µm wide. Stomatal pore poorly visible and thin.

Remarks. The anatomical structure of fern leaves from Bełchatów corresponds with that of the genus *Osmunda* L. Large (40–60 µm) anomocytic stomata and epidermal cells with undulate anticlinal walls are typical. The specimens described have been assigned to *Osmunda parschlugiana* (Unger) Andreánszky (Worobiec 1995). Large leaflets with fine dentate margins are characteristic of this species. The other fossil species, *O. lignitum* (Giebel) Stur, differs in the morphology of its leaflets. Andreánszky (1959) placed *Pteris parschlugiana* Unger as described by Unger (1847) in the genus *Osmunda*. Bůžek (1971) expanded the concept placing *Osmunda heeri* Gaudin, *Osmunda strozzi* Gaudin, *Asplenium neogenicum* Ettingshausen and *Osmunda schemniciensis* (Pettko) Stur (pro parte) and *Pteris bilinica* Ettingshausen (pro parte) in synonymy with *Osmunda parschlugiana* because there were no significant morphological differences between them.

Modern *Osmunda regalis* L. is very similar to fossil *Osmunda parschlugiana*. The species is a natural component of the flora of Poland and represents the Atlantic element in it (Czeczott 1926). This fern occurs almost exclusively in areas with a mild climate showing distinct marine influences. In Poland *Osmunda regalis* is found mainly in the north-west, and rarely in other parts of the country (e.g. in the Niepołomice Forest near Kraków), mostly in swamp forest (association *Carici elongate-Alnetum*, Szafer et al. 1972). In North America *Osmunda regalis* L. grows in swamp forest with *Osmunda cinnamomea* L. (Kearney 1901).

Occurrence in the fossil floras of Poland. Lower Miocene – Bełchatów (Worobiec 1995); Miocene – Chroślice (Kräusel 1920, as *Pteris parschlugiana* Unger).

Pinophytina (= Coniferophytina)

Pinopsida (= Coniferopsida)

Pinaceae

Pinus L.

Pinus cf. ***spinosa*** Herbst

Pl. 1, figs 2, 8, 8a

? 1844 *Pinus spinosa* Herbst; Herbst, p. 567–568.
? 1965 *Pinus spinosa* Herbst; Mai, p. 40–43, Pl. 3, fig. 2–6.

Material. KRAM-P 217: 15, 20, 75/II, 93/II, 118/I, 144/III, 206/III.

Morphological description. Beside numerous fragments of needles, leaf fascicles joining three needles were found. Fragments of needles up to 5.0 cm long and 0.6–1.0 mm (mostly 1 mm) wide. Dentate or crenate margin seen only in few needles.

Anatomical description. Epidermal cells of very elongate rectangular shape up to 250 µm long and 22–24 µm wide. Short walls of cells oblique or perpendicular to the longer walls of cells and to midvein. A few stomatal bands found, all of them composed of single row of stomata. Longer axes of stomata parallel to the midvein. Stomata cyclocytic, surrounded by six subsidiary cells, wide elliptic, 56–60 µm long 32–36 µm wide. Outer stomatal ledge aperture (or possibly stomatal pore) 22–26 µm long and ca. 6 µm wide. Polar T-shaped cuticular thickness always visible, strongly developed.

Remarks. The fragments of needles and leaf fascicles, described above, correspond to *Pinus spinosa* Herbst from Kranichfeld (Mai 1965) and Gozdnica (Dyjor et al. 1992). This identification is justified by the following features: presence of three needles in leaf fascicles, stomata surrounded by 6 cells, of which 2 are at the poles and 4 on both sides of the stomata, and the size of aperture formed by outer stomatal ledges is 22–26 µm. The author did not managed to obtain cross-sections of the needles of this pine, which are necessary to identify univocally fossil pine species. He also did not managed to establish the number of stomatal bands. Hence, the identification is only provisional.

The needles, leaf fascicles and cones of *Pinus spinosa* Herbst are found in the fossil Tertiary floras from the Early Miocene to the Pliocene, most often in lignite deposits over almost the whole of Europe and East Siberia (Mai 1986). *Pinus spinosa* resembles recent pines from the section *Pinaster* Loudon (Mai, op. cit.).

Occurrence in the fossil floras of Poland. Middle Miocene – Węgliniec, (Kräusel 1920, as *Pinus spinosa*), Stare Gliwice (Szafer 1961, as *Pinus spinosa*), Bełchatów (Stuchlik et al. 1990), Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997), Rzędów near Staszów (Zastawniak, archiv.); Upper Miocene – Gozdnica (Dyjor et al. 1992).

Pinus hampeana (Unger) Heer

Pl. 1, fig. 1

1847 *Pitys hampeana* Unger; Unger, p. 76–78, Pl. 20, figs 1–3.
1855 *Pinus hampeana* (Unger) Heer; Heer, p. 56–57, Pl. 20, fig. 4.
1995 *Pinus* cf. *hampeana* (Unger) Heer; Worobiec, p. 245.

Material. KRAM-P 214: 158, 163.

Morphological description. Completely preserved cones, strongly compressed and contracted, presumed length ca. 5.4 cm, width 2.0–2.6 cm. The cone scales, helically arranged and with polygonal apophyses, 0.7 cm long and 1.0 cm wide. Umbo clearly visible on tops of apophyses.

Remarks. The morphology of fossil cones from Bełchatów corresponds with that of *Pinus hampeana* (Unger) Heer. In Europe this species occurred from the Late Oligocene to the Late Miocene, and was common in the Middle Miocene (Mai 1986). The recent counterpart of the fossil species is *Pinus massoniana* Sieb. & Zucc. from Japan (Mai op. cit.).

Occurrence in the fossil floras of Poland. Lower Miocene – Rozewie, (Heer 1869), Bełchatów (Worobiec 1995, as *Pinus* cf. *hampeana* (Unger) Heer); Middle Miocene – Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997); Upper Miocene – Bełchatów (Stuchlik et al. 1990).

Pinus sp. div.

Fig. 3: 4; Pl. 1, figs 3, 5–7, Pl. 2, figs 1, 1a

Material. KRAM-P 214: 16, 89, 90, 91 (needles), 161 (seed wing); KRAM-P 217: 49, 103/III, 112/II (seeds wings).

Morphological description. Needle fragments, up to 6.0 cm long and 0.10–0.12 cm wide, straight and linear with acute apex. A few needles with very fine serrate margins, teeth lying every 0.5 mm with rounded apex, basal sides of teeth always much more longer then apical sides.

Wings of seeds of elongate shape, up to 1.5 cm long and 0.35–0.55 cm wide. Seeds not preserved.

Anatomical description. Needles amphistomatic. Both epidermal cells and stomata very cutinized. Cuticle of periclinal cell walls with distinct granulate ornamentation. Epidermal cells between stomatal bands (Pl. 2, fig. 1) very elongate, 300–500 µm long and 15–22 µm wide. The longer anticlinal walls of cells mostly straight, 1–2 µm thick. Short anticlinal cell walls mostly oblique to the midvein. Epidermal cells from stomatal bands as wide as other cells, but much shorter (30–40 µm). Stomatal bands always composed of one row of stomata. Stomata (Pl. 2, fig. 1a) cyclocytic, surrounded by few subsidiary cells (square to rectangular, 16–30 µm in size, often with rounded anticlinal cell walls), elliptic, 50–60 µm long and 40 µm wide. Outer stomatal ledge aperture 22–28 µm long and 4–12 µm wide with two strongly developed crests surrounding the aperture. Polar T-shaped cuticular thickness strongly developed, the upper branches of thickening goes up in the shape of letter Y.

Remarks. Due to the poor preservation of the remains (none of the needles was preserved as a whole; the absence of leaf fascicles and whole seeds) the identification of the described remains to species was impossible.

Taxodiaceae

Taxodium Rich.

Taxodium dubium (Sternberg) Heer

Fig. 3: 3; Pl. 3, fig. 3

1823 *Phyllites dubius* Sternberg; Sternberg, p. 37, Pl. 36, fig. 3.
1853 *Taxodium dubium* (Sternberg) Heer; Heer, p. 136.

1855 *Taxodium dubium* (Sternberg) Heer; Heer, p. 49, Pl. 17, figs 5–15.

Material. KRAM-P 211: 27.

Morphological description. Fragmentary shoot with few needles attached (Fig. 3: 3). Needles entire-margined, 1.0–1.2 cm long and 0.15 cm wide, apex acute, base cuneate or obtuse, decurrent. Midvein clearly visible. Needles arise from the axis of shoot at an angle of ca. 40°. Distance between needles 0.2–0.4 cm.

Anatomical description. Epidermal cells mostly rectangular or square, sometimes slightly deformed, 30–60 µm in size. Anticlinal cell walls thick (1–2 µm), mostly rounded sometimes slightly undulate. Hypodermis composed of cells of similar dimensions as epidermis but anticlinal cell walls thinner and pitted. Surface of epidermis (cuticle on the periclinal cell walls) slightly granulate, most probably due to presence of epicuticular wax and not of ornamentation. Stomata irregular-elliptic, 35–40 µm long and 24–30 µm wide. Polar T-shaped cuticular thickness always present. Outer stomatal ledge aperture elongate-elliptic, 12–14 µm long. In the course of maceration needles underwent distinct overmaceration. This points to a low rate of cutinization of *Taxodium* needles. The same phenomenon was observed by Z. Kvaček (pers. comm.). Low rate of cutinization of *Taxodium* epidermis could suggest that fossil bald cypress likewise recent *Taxodium distichum* (L.) Rich. had deciduous shoots.

Remarks. The shoots of *Taxodium* Rich. are morphologically similar to the shoots of *Sequoia abietina* (Brongniart) Knobloch, from which they differ by slightly narrower and shorter needles. As both *Sequoia* and *Taxodium* are characterized by the highly variable morphology of leaves, their identification is based on the structure of the epidermis of needles. In *Taxodium* needles the longer axis of stomata is oblique to the axis of a needle, while in *Sequoia* Endl. (taxodioid form) shoots the axes of stomata are always parallel to the needle axis. In addition, the epidermis of *Taxodium* needles is delicate and fragile (it is easily damaged during maceration), while the epidermis of *Sequoia abietina* needles is strongly cutinized and resistant to overmaceration.

Taxodium dubium (Sternberg) Heer was a common component of European Neogene swampy forest and together with *Glyptostrobus* Endl. was one of the important coal-forming plants. The fossil species is comparable with two recent species from North America: *Taxodium distichum* (L.) Rich. and *T. mucronatum* Tenore. According to Hummel (1983) both taxa are very similar in respect of both the morphological and anatomical structure. *Taxodium mucronatum* differs from *T. distichum* by having slightly larger stomata, while *T. dubium* and *T. distichum* have similar stomata in size (comp. Walther 1964, Christensen 1975). *Taxodium distichum* today grows in swamps and on river banks in the south-western USA. *Taxodium mucronatum* is associated with wet habitats on the banks of mountain rivers and streams in Mexico where it occurs at altitudes up to 2300 m a.s.l. (Krüssmann 1972).

Occurrence in the fossil floras of Poland. Lower Miocene – Rozewie (Heer 1869, as *Taxodium distichum miocenicum* Heer), Turów (Zalewska 1959), Bełchatów (Worobiec 1995); Middle Miocene – Koronowo (Menzel 1910, as *Taxodium distichum miocenicum* Heer), Nowogród Bobrzański, Popowice, Zielona Góra, (Reichenbach 1919, as *Taxodium distichum miocenicum*), Dobrzyń on the Vistula (Kownas 1956, as *Taxodium distichum miocenicum*), Swoszowice (Ilinskaya 1962, 1964), Zatoka Gdowska (Łańcucka-Środoniowa 1966, as *Taxodium distichum miocenicum*), Trzcianka near Piła (Raniecka-Bobrowska 1970), Mirostowice Dolne (Zastawniak 1980), Bełchatów (Stuchlik et al. 1990), Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997), Mrozów, Karnków (Zastawniak, archiv.); Upper Miocene – Brzeg Dolny, Sośnica (Reichenbach 1919, as *Taxodium distichum miocenicum*), Malczyce (Kräusel 1921, as *Taxodium distichum miocenicum*), Wołów (Kräusel 1920, Juhnke 1931, as *Taxodium distichum miocenicum*), Bełchatów (Stuchlik et al. 1990, Worobiec & Lesiak 1998), Gozdnica (Dyjor et al. 1992), Gnojna (Krajewska 1998); Lower Pliocene – Ruszów (Hummel 1983); Pliocene – Bełchatów (Wójcicki & Zastawniak 1998).

Sequoia Endl.

Sequoia abietina (Brongniart) Knobloch

Pl. 2, figs 2–8, Pl. 3, figs 1, 2, Pl. 18, fig. 2(B)

1822 *Phyllites abietina* Brongniart; Cuvier 1822, p. 360, Pl. 11, fig. 14.

1964 *Sequoia abietina* (Brongniart) Knobloch, Knobloch, p. 601.

Material. KRAM-P 217: 7, 21, 22, 31, 32, 33/I, 34, 46/III, 64, 73, 77, 80, 81, 98/III, 99/II, 106/II, 119/II, 120/II, 123/III, 126/II, 129/II, 132/II, 137/II, 144/I, 159/II, 162/II, 163, 165, 170/II, 171/II, 172, 173, 181/II, 184/II, 186, 187, 197, 199/I, 201/III, 212, 213, 215/III, 218, 219, 220/II, 222/II, 223, 225/I, 231/II, 236/III, 237/I, 244/I, 245/II, 259, 261, 262.

Morphological description. Shoots trimorphous. Taxodioid shoots (Pl. 2, figs 3, 4, 6, 8) bear entire-margined needles up to 3.0 cm long (mostly 2.0 cm) and 1.4–2.7 mm (mostly 2.0 mm) wide, straight, apex mainly acute sometimes attenuate or rounded, base acute and decurrent. Cryptomerioid shoots (Pl. 2, fig. 5) bear smaller entire-margined needles, sabre-shaped, upwardly curved, 0.4–0.9 cm long and 0.1–0.4 mm wide with acute apex. Cupressoid shoots (Pl. 2, fig. 2, 7) bear small (0.1–0.4 cm long) entire-margined needles with upwardly curved, acute apex and decurrent base. These needles are often more or less parallel to the axis of the shoot.

Anatomical description. Epidermal cells of all morphological types of *Sequoia* are similar. They are predominantly rectangular, often very elongate, 70–200 μm long (only cryptomerioid shoots up to 150 μm) and 14–30 μm wide. Cuticle distinctly granulate. Hypodermis consists of mainly square or rectangular cells, 30–40 μm in size. Stomata of all morphological types cyclocytic, elliptic, surrounded by 4–5 subsidiary cells (taxodioid type mostly 4 cells). Differences between the above mentioned morphotypes could be found in the stomatal orientation and network. Taxodioid shoots (Pl. 3, fig. 2) on the adaxial side of needles have two wide stomatal bands composed of several stomatal rows. Stomata 45–60 μm (mostly 52–53 μm) long and 26–40 μm (mostly 33 μm) wide, longer axes of these stomata more or less parallel to the midvein of needle. Cryptomerioid type (Pl. 3, fig. 1) stomata 50–56 μm long and 30–36 μm wide, arranged in narrow bands (2–3 rows), axes of stomata oblique to midvein. Stomatal bands of cupressoid type less regular than cryptomerioid, stomata slightly smaller, 40–50 μm long and 24–32 μm wide. Outer stomatal ledge aperture of all morphotypes narrow-elliptic, 15–28 μm (mostly 20 μm) long. Polar T-shaped cuticular thickness always present, distinct.

Remarks. These fragments of twigs of a coniferous tree represent *Sequoia abietina* (Brongniart) Knobloch. The detailed morphological description of the shoots of *Sequoia abietina* was included in the monograph of the fossil flora from Gozdnica (Kvaček in: Dyjor et al. 1992), in which three morphological types were distinguished, similarly as in Bełchatów. In the investigated material the taxodioid and cupressoid types prevail.

A distinction between the fossil taxodioid shoots of *Sequoia* Endl. and morphologically similar shoots of *Taxodium* Rich. is not difficult if the epidermis is preserved. In *Taxodium dubium* (Sternberg) Heer the longer axes of stomata are perpendicular or slightly oblique to the longer axis of a needle, while in the taxodioid shoots of *Sequoia abietina* the longer axes of stomata are parallel to the needle axis. Certain slight differences of little taxonomical value can also be observed in the morphology of needles belonging to these taxa. In *Sequoia* needles the ratio of length to width is on average smaller than in *Taxodium* (comp. Ferguson 1971, Hummel 1983).

One problem is how to distinguish the glyptostroboid shoots of *Sequoia abietina* from the twigs of *Glyptostrobus europaeus* (Brongniart) Unger (Meller et al. 1999). The morphological and anatomical features, mentioned by Zalewska (1959) as useful to differentiate *Sequoia* from *Glyptostrobus* in the flora from Turów, are vague and not always noticeable. Sveshnikova (1963) considers the proportion of length to width in the epidermal cells as a feature allowing one to tell the shoots of *Sequoia* from those of *Glyptostrobus*. In *Sequoia* the length of a cell exceeds its width as much as 7–12 times, while in *Glyptostrobus* the length of epidermal cells is only 3–4 times greater than their width. This difference is noticeable also in *Sequoia abietina* and *Glyptostrobus europaeus* from Bełchatów. In *Sequoia* the length of epidermal cells is 6–8 times greater than width, while in *Glyptostrobus* only 4 times. Meller et al. (1999) point to the presence of transitional forms in respect of the proportion of length to width in the epidermal cells of *Sequoia abietina* and *Glyptostrobus europaeus* from the Neogene of Austria and the Czech Republic.

Sequoia abietina occurs in Tertiary deposits from central Europe, and is particularly abundant in the Middle Neogene (Dyjor et al. 1992).

It is accepted that this tree grew mostly in the last stage of the succession of the coal-forming vegetation (raised bog, facies M, Schneider 1992), showing preference for drier places. The remains of *Sequoia* are also found in fossil alluvial sediments (Dyjor et al. 1992).

The fossil *Sequoia abietina* is comparable to recent *Sequoia sempervirens* (D. Don) Endl. from North America. This species grows on the slopes of the Sierra Nevada in California, in an area with a warm and humid climate, and summer droughts mitigated by abundant fogs (Podbielkowski 1991). Also the recent species is characterized by shoot polymorphism; it can have both long (*Taxodium* type) and short needles, scale-like ones, on one twig.

Occurrence in the fossil floras of Poland. Lower Miocene – Turów (Zalewska 1959, as *Sequoia langsdorfii* (Brongniart) Heer), Osieczów (Raniecka-Bobrowska 1962b, as *Sequoia langsdorfii*); Middle Miocene – Rypin (Łańcucka-Środoniowa 1957, as *Sequoia langsdorfii*), Bełchatów (Stuchlik at al. 1990, as cf. *Sequoia abietina* (Brongniart) Knobloch), Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997); Upper Miocene – Gozdnica (Dyjor et al. 1992).

Glyptostrobus Endl.

Glyptostrobus europaeus (Brongniart) Unger

Fig. 3: 5, 6; Pl. 3, fig. 5

1833 *Taxodium europaeum* Brongniart; Brongniart, p. 168–176, Pl. 3, Pl. 12.
1850 *Glyptostrobus europaeus* (Brongniart) Unger; Unger, p. 434–435.

Material. KRAM-P 214: 104, 105, 136, 181.

Morphological description. Fragmentary shoots, up to 1.5 cm long and 0.15–0.20 cm wide, bearing dense, scale-like needles, 0.1–0.2 cm long and 0.05–0.10 cm wide with acute, upwardly curved apex and decurrent base. Needles polymorphous, at the upper part of shoot short and wide, in lower part long and narrow.

Anatomical description. Epidermal cells tetragonal, mostly elongate, sometimes square, 20–50 µm long and 15–18 µm wide. Anticlinal cell walls straight, sometimes slightly rounded, 1–2 µm thick and with irregular thickenings. Surface of epidermis (cuticle) distinctly granulate. The hypodermis has cells of similar shape, 25–50 µm long and 20–25 µm wide. Hypodermal cells walls are thinner than epidermal (1 µm thick) are mainly straight, sometimes rounded, short wall of cells perpendicular or oblique to the longer walls of hypodermal cells. Irregularities in the epidermal and hypodermal anticlinal cell walls visible mainly in cells of the stomatal bands. Stomata cyclocytic, narrow-elliptic, 44–55 µm long and 24–30 µm wide, surrounded by 4–6 subsidiary cells. Longer axes of stomata mainly oblique to midvein, stomata arranged in stomatal bands of variable length. Outer stomatal ledge aperture distinctly cutinized, 22–24 µm long and 5–6 µm wide. Polar T-shaped cuticular thickness present, strongly cutinized.

Remarks. Both the morphology of shoots and the structure of stomata corresponds to the fossil species *Glyptostrobus europaeus* (Brongniart) Unger. Characteristic features include scale-like needles and the structure of stomata, which are usually surrounded by 4–6 subsidiary cells (according to Zalewska (1959) – 4 to 7 cells). One of the shoot types of *Sequoia abietina* (Brongniart) Knobloch is morphologically similar to the taxon under discussion; but differs in having a higher ratio of length to width in the epidermal cells (see page 14).

Glyptostrobus europaeus was a very common component of the Tertiary vegetation in Europe from the Eocene to the Pliocene; it was most common in the Miocene (Zastawniak et al. 1996). In the Tertiary fossil floras it represented the Arctotertiary element. This species, in addition to *Taxodium* Rich., was a dominant component of swamp forest where the genera *Alnus* B.Ehrh. and *Nyssa* L. were also important (Mai 1995). Swamp forest with *Glyptostrobus europaeus* contributed much to the formation of lignite deposits (so-called facies K, Schneider 1992).

Glyptostrobus pensilis (Staunton) K. Koch is a modern counterpart of *Glyptostrobus europaeus*, growing in a small area in southern China and in Vietnam on river banks, often in swampy places (Henry & McIntyre 1926, Hiêp & Vidal 1996). According to Zalewska (1953, 1955, 1959) and the authors she quoted, this taxon is a Tertiary relic, which since that time has not changed significantly.

Occurrence in the fossil floras of Poland. *Glyptostrobus europaeus* is a common component of Neogene floras from Poland. It has been reported from many localities in Miocene floras (Zalewska 1959, Zastawniak et al. 1996) and from one locality of Early Pliocene age (Ruszów, Baranowska-Zarzycka 1988).

Cupressaceae

Tetraclinis Masters

Tetraclinis salicornioides (Unger) Z. Kvaček

Pl. 3, figs 4–4b

1838 *Hellia salicornioides* Unger; Unger, p. 101, nomen illegit.
1841 *Thuytes salicornioides* Unger; Unger, p. 11, Pl. 4, figs 1–4.
1847 *Libocedrites salicornioides* (Unger) Endlicher; Endlicher, p. 275.
1855 *Libocedrus salicornioides* (Unger) Heer; Heer, p. 47, Pl. 21, fig. 2.
1989 *Tetraclinis salicornioides* (Unger) Z. Kvaček; Kvaček, p. 48, Fig. 1, Pl. 1, fig. 11, Pl. 2, figs 2–14, Pl. 3, figs 3–4.

Material. KRAM-P 214: 20.

Morphological description. Fragment of shoot composed of two bulgy-shaped flattened leaf whorls. At the apical part of the whorl outlines are visible of three apices of leaves. Whorls about 0.5 cm long.

Anatomical description. Epidermis of leaf whorls composed of rectangular, elongate cells (Pl. 3, fig. 4a), 36–82 μm long and 18–30 μm wide with 1–2 μm thick, rounded anticlinal cell walls. On the anticlinal cell walls irregular thickenings are visible. Cuticle markedly granulate. Stomata cyclocytic (Pl. 3, fig. 4b), elliptic, 42–50 μm long and 26–30 μm wide, surrounded by single circle of 4–6 subsidiary cells. Outer stomatal ledge aperture very narrow-elliptic to oblongate, about 20 μm long. Polar T-shaped cuticular thickness clearly visible. Up to a dozen or so papillae may be visible on epidermal periclinal cell walls.

Remarks. The fragment described has been placed in *Tetraclinis salicornioides* (Unger) Z. Kvaček. The shoot is characterized by the shape of the flattened leaf whorls. This identification is confirmed by the structure of the epidermis.

Twigs of this fossil plant, described for the first time by Unger (1838) as *Hellia salicornioides*, were next mentioned under various generic names from the family Cupressaceae (among others, *Callitris* Vent., *Callitrites* Endl., *Calocedrus* Kurz, *Libocedrites* Endl., *Libocedrus* Endl.). Among the investigated macroremains of the family Cupressaceae, Mai and Walther (1978, 1985) distinguished the genus *Tetraclinis* Mast. and the species *T. brachyodon* (Brongniart) Mai & Walther. Later on, Kvaček (1989) decided that part of the fossils represented the another species *Tetraclinis salicornioides* (Unger) Z. Kvaček, which differs from *T. brachyodon* in the morphology of the twigs and the location of the stomata (Kvaček op. cit.). In *T. salicornioides* clear polymorphism of the twigs is observed, which seems to be an effect of environmental conditions, principally light intensity (Kvaček op. cit.).

Tetraclinis salicornioides was an accessory coniferous tree often found in subtropical or moderately warm and humid forest communities. It was more frequently found in the so-called “Younger Mastixioid Floras”, while in the younger Neogene it became relatively rare, which was most probably connected with the deterioration of climatic conditions (Kvaček 1989).

A modern counterpart of *Tetraclinis salicornioides* is *Tetraclinis articulata* (Vahl.) Mast. occurring in the western Mediterranean basin (among others in Morocco, Malta and south-eastern Spain), whose climates are characterized by dry summer periods, annual precipitation of 250–700 mm, mean annual temperatures ranging from 15 to 18°C and winters with rare frost. It forms more or less single-species stands or forms communities with *Ceratonia*, *Juniperus*, *Olea*, *Pistacia*, *Rhamnus*, *Chamaerops*, and *Smilax*; it usually grows up to altitude of 1300 m a.s.l., showing a preference for warm and dry habitats, e.g. on limestone (Kvaček 1989).

Occurrence in the fossil floras of Poland. Lower Miocene – Osieczów (Raniecka-Bobrowska 1962b, as *Libocedrus salicornioides* (Unger) Heer), Bełchatów (Worobiec 1995); Middle Miocene – Kokoszyce (Kräusel 1920, 1921, as *Libocedrus salicornioides*), Stare Gliwice (Szafer 1961, as *Libocedrus salicornioides*), Zatoka Gdowska (Łańcucka-Środoniowa 1966, as *Hellia salicornioides* Unger), Młyny (Zastawniak 1980, as *Libocedrites salicornioides* (Unger) Endlicher), Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997); Upper Miocene – Sośnica (Goeppert 1855, as *Liboce-*

drites salicornioides), Bełchatów (Stuchlik et al. 1990, as *Libocedrites salicornioides*), Gozdnica (Dyjor et al. 1992).

Magnoliophytina (= Angiospermae)

Magnoliopsida (= Dicotyledones)

Lauraceae

Daphnogene Unger

Daphnogene polymorpha (Al. Braun) Ettingshausen

Fig. 3: 7, 8; Pl. 4, figs 2–7, Pl. 5, figs 1–1b, Pl. 6, fig. 1

1845 *Ceanothus polymorphus* Al. Braun; Al. Braun, p. 171.
1851 *Daphnogene polymorpha* (Al. Braun) Ettingshausen; Ettingshausen, p. 16, Pl. 2, fig. 23–25.

Material. KRAM-P 211: 2, (8, 9 – twin specimens), 24, (40, 41 – twin specimens); KRAM-P 214: 5/I, 9, 13, 21, 25, 35, 39, 59, 69, 75, 78, 93, 174, 175.

Morphological description. Several fragments of entire-margined coriaceous leaves, elliptic or lanceolate, symmetric, up to 5.2 cm long and 1.0–2.7 cm wide. Leaf apex acute/attenuate, base acute or obtuse. One of the preserved petioles, 0.7 cm long, is characteristically curved. Venation acrodromous. Primary vein branched above leaf base forming two main branches at an angle of 25–30°. Branches curve upward. The branches give rise to outer, loop forming veins. Between primary vein and its two main branches run more or less percurrent tertiary veins, mostly forked, produce dense network. Higher-order venation orthogonal reticulate. Areoles well developed, 0.2–0.3 mm in size. Veinlets rarely present. Marginal ultimate venation forms a fimbrial vein.

Anatomical description. Leaves hypostomatic. Upper epidermis (Pl. 4, fig. 4, Pl. 5, fig. 1) composed of polygonal, isodiametric or slightly elongate cells, 15–35 µm in size. Anticlinal cell walls undulate and thick. Cuticle most probably covered by the rest of epicuticular wax. The hypodermis below the upper epidermis is composed of variable-shaped cells, 16–18 µm in size, with thin, rounded or straight walls. Lower epidermis (Pl. 5, fig. 1a) composed of variable-shaped cells, 16–35 µm (mostly 22 µm) in size, with undulate anticlinal cell walls. The cells over veins are of more regular shape, rectangular, mostly elongate, up to 35 µm long. The hypodermis below the lower epidermis has thin and rounded anticlinal cell walls, 15–30 µm in size. Stomata mostly paracytic (Pl. 5, fig. 1b), sometimes tetracytic with characteristics of *Daphnogene* having wide elliptic-rhomboid shape, 17–20 µm in size. Outer stomatal ledge aperture mostly poorly visible, sometimes very narrow, oblong, 7–10 µm long. Stomata occur only on the intercostal areas and there randomly distributed. On the upper epidermis scattered, unicellular trichome bases are present, trichomes not preserved. On the lower epidermis the same type of trichome bases are present but there they are very numerous (Pl. 5, figs 1a, 1b). Trichome bases, 7–12 µm in diameter, surrounded by 5–6 radially arranged cells.

Remarks. The characteristic venation of the leaf remains allowed their identification as *Daphnogene* (syn. *Cinnamomophyllum* and *Cinnamomum*) *polymorpha* (Al. Braun) Ettingshausen. The generic name *Daphnogen*e Unger is an artificial name (morpho-genus) given to fossil leaves with acrodromous venation and belonging to the family Lauraceae, but otherwise similar to the recent genus *Cinnamomum* Schaeffer (Cinnamomoid type, Kvaček 1971). According to Kvaček (op. cit.) it is impossible to determine fossil leaf taxa of the family Lauraceae to genus on the basis of both the morphology or the anatomy. For that reason the name *Daphnogene* is more correct than *Cinnamomophyllum* Kräusel & Weyland, or *Cinnamomum*, the more so as the epidermis of *Daphnogene* fossil leaves differs distinctly from that of leaves of the latter (Kvaček 1971). *Daphnogene polymorpha* (Al. Braun) Ettingshausen shows great morphological and anatomical variability of leaves, which is reflected in the species name. According to Kvaček and Walther (1978) this variability is an effect of the environment, which is reflected in the occurrence of different ecological forms (differing slightly in their morphology) in sunny, shaded or intermediate places. In the opinion of these authors other ecological factors, such as humidity or microclimatic conditions in stands with *Daphnogene polymorpha* may have contributed to the high variability of this taxon. According to Kvaček and Walther (op. cit.) and Knobloch and Kvaček (1976) one may distinguish 3 basic groups of forms within the taxon

Daphnogene polymorpha, similar in respect of morphology and anatomy:

– form scheuchzeri (from *Cinnamomum scheuchzeri* (Heer) Kräusel & Weyland),

– form polymorphum (from *Cinnamomum polymorphum* (Al. Braun) Ettingshausen),

– form spectabile (from *Cinnamomum spectabile* Heer).

Anatomical differences between these forms relate to the density of trichomes on the epidermis, the degree of undulation of the epidermal anticlinal cell walls and the degree of their cutinization; e.g. in the form *C. polymorphum* the upper epidermis has undulate cell walls and at the lower epidermal trichomes are almost completely absent.

The leaf morphology of *Daphnogene polymorpha* from Bełchatów is also variable. Specimen no. 214/39 (Pl. 4, fig. 2) resembles the form *C. scheuchzeri*, while specimen 214/9 (Pl. 4, fig. 3) the form *C. polymorphum*. The problem of morphological variability in the fossil leaves of *Daphnogene* was discussed by, among others, Givulescu et al. (1996).

According to Kolakovsky (1958) and Kvaček (1971) the fossil leaves of *Daphnogene* may have belonged to different genera of the family Lauraceae, among others to *Cryptocarya* R.Br., *Litsea* Lam., *Lindera* Thunb., and *Neolitsea* (Benth.) Merrill, whose leaves were most similar in respect of morphology.

The leaves of *Daphnogene polymorpha* have been reported from many fossil floras, but mainly those of Miocene age. In central Europe this taxon is frequently found in floras from the Early Miocene, particularly from its oldest part, for example at Osieczów (Raniecka-Bobrowska 1962b). In the Middle Miocene this species is rarer; in Poland it has so far only been found in Swoszowice (Ilinskaya 1962) and Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997); these are the youngest localities of this taxon in the Polish Neogene (Łancucka-Środoniowa & Zastawniak op cit.). *Daphnogene polymorpha* did not occurred in Poland in the Late Miocene. In Pliocene fossil floras it has been found only in the south of Europe (e.g. in the south of France, Roiron 1979). Its disappearance from central Europe at the end of the Miocene was undoubtedly connected with climate cooling.

Occurrence in the fossil floras of Poland. Lower Miocene – Rozewie (Heer 1869, as *Cinnamomum scheuchzeri* (Heer) Kräusel & Weyland), Bluszczów, Dzierżysław (Kräusel 1920, as *C. polymorphum* (A. Br.) Kräusel & Weyland), Osieczów (Raniecka-Bobrowska 1962b, as *Cinnamomum scheuchzeri*, *C. polymorphum* and *C. spectabile*), Turów (Czeczott & Skirgiełło 1975, as *C. lanceolatum* (Unger) Kolakovsky), Bełchatów (Worobiec 1995); Middle Miocene – Swoszowice (Unger 1849, Ilinskaya 1962, as *Cinnamomum polymorphum*), Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997, as *Daphnogene* sp.).

Laurophyllum Goepp.

Laurophyllum pseudoprinceps Weyland & Kilpper

Fig. 3: 9; Pl. 4, fig. 1, Pl. 5, figs 2–2b

1950 *Laurophyllum princeps* (Heer) Kräusel & Weyland; Kräusel & Weyland, p. 58, Figs 20, 21, Pl. 13, figs 1–9, Pl. 14, figs 1–4.

1963 *Laurophyllum pseudoprinceps* Weyland & Kilpper; Weyland & Kilpper, p. 100, Fig. 6, Pl. 23, figs 14–19.

Material. KRAM-P 214: (40, 162 – twin specimens).

Morphological description. Fragment of one entire-margined leaf, elliptic/ovate, coriaceous, 5.0 cm long and 1.6 cm wide. Leaf base cuneate, preserved rest of petiole 1.2 cm long. Venation brochidodromous. Primary vein stout, slightly bent. Preserved are 5 pairs of secondary veins which run off the primary vein at intervals of about 0.8 cm and form an angle of ca. 40^o with it. Secondaries curve upward, especially near leaf margin, their ends join together by means of loops. Intersecondary veins present, reach half of the distance from the primary vein to leaf margin. Tertiary venation percurrent (or weakly percurrent), not too regular. Higher-order venation reticulate.

Anatomical description. Leaf hypostomatic. Upper epidermis (Pl. 5, fig. 2) composed of mostly tetragonal, often elongate cells, 16–30 μm in size. Over veins the cells are more elongate, rectangular and are arranged in rows. Anticlinal cell walls often very thick, rounded or undulate with knobs (Pl. 5, fig. 2). Lower epidermis composed of polygonal cells, on the intercostal areas isodiametric or rectangular, 20–40 μm (mostly 25 μm) in size, over the veins rectangular, elongate, arranged in few rows (Pl. 5, fig. 2a). Anticlinal cell walls thick, straight or rounded. Under the lower epidermis the probable remains of hypodermal cells occur. Stomata (Pl. 5, fig. 2b) paracytic, wide elliptic, sometimes roundish, 16–24 µm in size. Stomata distributed only in the intercostal areas. Outer stomatal ledge aperture rather distinct, 12–14 µm long.

Remarks. The character of the leaf venation (brochidodromous venation and the characteristic higher order venation pattern) points to the family Lauraceae. Through analyses of this leaf's epidermal structure it was possible to confirm conclusions resulting from the morphological analyses and to place it within *Laurophyllum pseudoprinceps* Weyland & Kilpper (Worobiec 1995). Morphologically and anatomically, it corresponds to the specimens reported under this name by Weyland and Kilpper (1963), Kvaček (1971) and Knobloch and Kvaček (1976). According to Kvaček (1971), it is impossible to unequivocally determine the affinity of the fossil representatives of the Lauraceae to genus. Therefore, fossil leaves from this family, which have brochidodromous venation, were assigned to the form-genus *Laurophyllum* Goeppert. Recently Bůžek et al. (1996) pointed that stomata of *Laurophyllum pseudoprinceps* are very similar to that of genus *Ocotea*; Uzunova and Stojanova (1999) assigned this fossil species to genus *Ocotea* and made a new combination *Ocotea pseudoprinceps* (Weyland & Kilpper) Uzunova & Stojanova. On the other hand Kräusel and Weyland (1950) considered that *Litsea varians* Hemsl. and *Beilschmiedia zenkeri* Engl. have similar epidermal structure to *Laurophyllum pseudoprinceps* and according to Kvaček (1971) *Cryptocarya acuminata* Schinz too. However, in his opinion, this is not sufficient to unequivocally explain the systematic position of *Laurophyllum pseudoprinceps* among recent Lauraceae.

Laurophyllum pseudoprinceps is the commonest representative of the family Lauraceae in the Tertiary of the north-western Czech Republic and its occurrence testifies to the relatively warm climate in that period (Kvaček 1971). Beyond the Czech Republic this taxon has been reported from many European localities from the Palaeogene and the older part of the Neogene (Early Miocene). In the Middle Miocene this species was rare and in the Late Miocene very rare. In the Pliocene *Laurophyllum pseudoprinceps* occurred only in southern Europe. It has been recorded in the Pliocene flora of Kodor, Abkhazia (Kolakovsky 1964). In Poland it was mentioned from Osieczów (Raniecka-Bobrowska 1962b) and Sobniów near Jasło (Zastawniak & Worobiec 1997). In both cases these were only leaf impressions; hence both identifications are uncertain.

Occurrence in the fossil floras of Poland. Oligocene – Sobniów near Jasło (Zastawniak & Worobiec 1997); Lower Miocene – Osieczów (Raniecka-Bobrowska 1962b, as cf. *Laurophyllum princeps* Weyland & Kilpper), Bełchatów (Worobiec 1995).

Altingiaceae

Liquidambar L.

Liquidambar sp.

Pl. 6, fig. 4

Material. KRAM-P 214: 60.

Morphological description. Compressed, rounded fructification, 2 cm in diameter, composed of numerous polygonal nests, 0.3–0.4 cm in size.

Remarks. The compressed fructification has been assigned to *Liquidambar* L. The state of its preservation (specimen is strongly compressed) does not allow for more precise identification.

Salicaceae

Populus L.

Populus sp.

Fig. 4: 9; Pl. 6, fig. 2

Material. KRAM-P 214: 130.

Morphological description. Small fragment of a simple serrate leaf. Teeth curved upwards, apical sides very short, concave, basal sides convex or acuminate, tooth apex rounded. Preserved fragment of leaf venation shows secondary veins branched, one of these branches terminates in the sinus between teeth. Because of the state of preservation it is impossible to find if this branch prolongates to the tooth apex. The higher-order venation forms a characteristic reticulum of polygonal-shaped meshes.

Remarks. The characteristic structure of the leaf margin, the shape and venation of the teeth and the pattern of the third and fourth order venation shows unequivocally that the fragment belongs to *Populus*. Due to the small size of the specimen, its determination to species is impossible.

Myricaceae

Myrica L.

Myrica lignitum (Unger) Saporta sensu lato

Fig. 3: 10–11a, 13–18; Pl. 6, figs 3, 5–7, Pl. 7, figs 1–3a

1847 *Quercus lignitum* Unger; Unger, p. 113, Pl. 31, figs 5–7.
1865 *Myrica lignitum* (Unger) Saporta; Saporta, p. 102.

Material. KRAM-P 211: 48; KRAM-P 214: 19, 26, 31, 44, 62, 131; KRAM-P 217: 46/IV, 50/II, 65/II, 104, 109, 137/III, 144/II, 147, 164, 180, 181/III, 183, 188, 190/I, 203, 210/I, 215/IV, 217, 237/II, 246.

Morphological description. More or less fragmentary, very narrow-elliptic or lanceolate, symmetric, sometimes coriaceous leaves, up to 6.5 cm long and 1.0–2.7 cm (mostly 1.7 cm) wide. Apex acute or attenuate, base acute or decurrent. On the surface of a few impressions numerous minute scales of peltate trichomes are visible. Both entire-margined and simple serrate leaves were found. Teeth of variable size, apical sides of teeth very short, convex or acuminate, basal sides convex or acuminate, tooth apex acute or rounded. Serrate leaves with semicraspedodromous venation, entire-margined leaves with brochidodromous venation. Primary vein straight or slightly curved, moderately thick/stout. Numerous thin secondary veins run off primary vein at intervals of 0.2–0.6 cm and form an angle of 60–80^{o} (mostly 70^{o}) with it in the middle part of lamina and of 50^{o} near the leaf base. Secondaries curve upward and near leaf margin interconnect in loops. In case of serrate leaves teeth are supplied by fine veins running from secondary vein loops. Intersecondary veins always present, reach half the distance from primary vein to leaf margin. Tertiary venation forms a composite network with intersecondary veins. Higher-order venation is randomly reticulate. Areoles imperfect, variable in size (0.4–0.8 mm). Veinlets always present, branched. Marginal ultimate venation looped.

Anatomical description. Leaves hypostomatic. Upper epidermis (Pl. 6, fig. 6, Pl. 7, figs 2, 2a) composed of mostly isodiametric cells, 14–30 µm in size. Anticlinal cell walls straight or rounded, thin. Unilayered hypodermis (Pl. 6, fig. 6) composed of isodiametric, rounded, thin-walled cells, 8–16 µm in diameter. Lower epidermis (Pl. 6, fig. 7, Pl. 7, figs 3, 3a) consists of polygonal cells, 14–30 µm (mostly 20–24 µm) in size. Anticlinal cell walls rounded or undulate, of moderate thickness. Stomata (Pl. 6, fig. 7, Pl. 7, fig. 3a) anomocytic, rounded or widely elliptic, 18–26 µm (mostly 22 µm) in diameter. Outer stomatal ledge aperture wide elliptic or rounded, 6–12 µm (mostly 8 µm) in size. On the lower epidermis numerous glandular, peltate trichomes (scales) were found (Pl. 7, fig. 2b). Two-celled trichome base, ovate-rectangular, 17–29 µm (mostly 21–24 µm) in size. Trichome shield multicellular, composed of radiately arranged cells, 80–125 µm in diameter. Inside a few trichomes the shield preserved the remains of resin (Pl. 6, fig. 5).

Remarks. The leaf fragments are morphologically and anatomically most similar to *Myrica lignitum* (Unger) Saporta sensu lato. They have its characteristic shape, leaf margin and venation pattern and in addition, epidermal peltate glandular trichomes with two-celled bases and round stomata. Due to differences in the anatomical structure between the leaves of *Myrica* L. from Bełchatów (mainly the presence of hypodermis) and the leaves of *Myrica lignitum* (Unger) Saporta sensu stricto, in which the hypodermis has not been found (comp. Knobloch & Kvaček 1976; Hummel 1983), the specimens from Bełchatów have been assigned to the collective species *Myrica lignitum* (Unger) Saporta sensu lato. One of the specimens (KRAM-P 211/48) shows certain morphological similarity to *Myrica joannis* Ettingshausen emend. Kovar-Eder reported by, among others, Kovar-Eder (1996) from the Early Miocene of Köflach-Voitsberg (Styria, Austria). However, the leaves of *Myrica* from Bełchatów differ from the leaves of *Myrica joannis* in the shape of the epidermal anticlinal cell walls. In *Myrica joannis* the cell walls of the upper epidermis are usually slightly undulated, while in *Myrica lignitum* from Bełchatów they are mostly curved

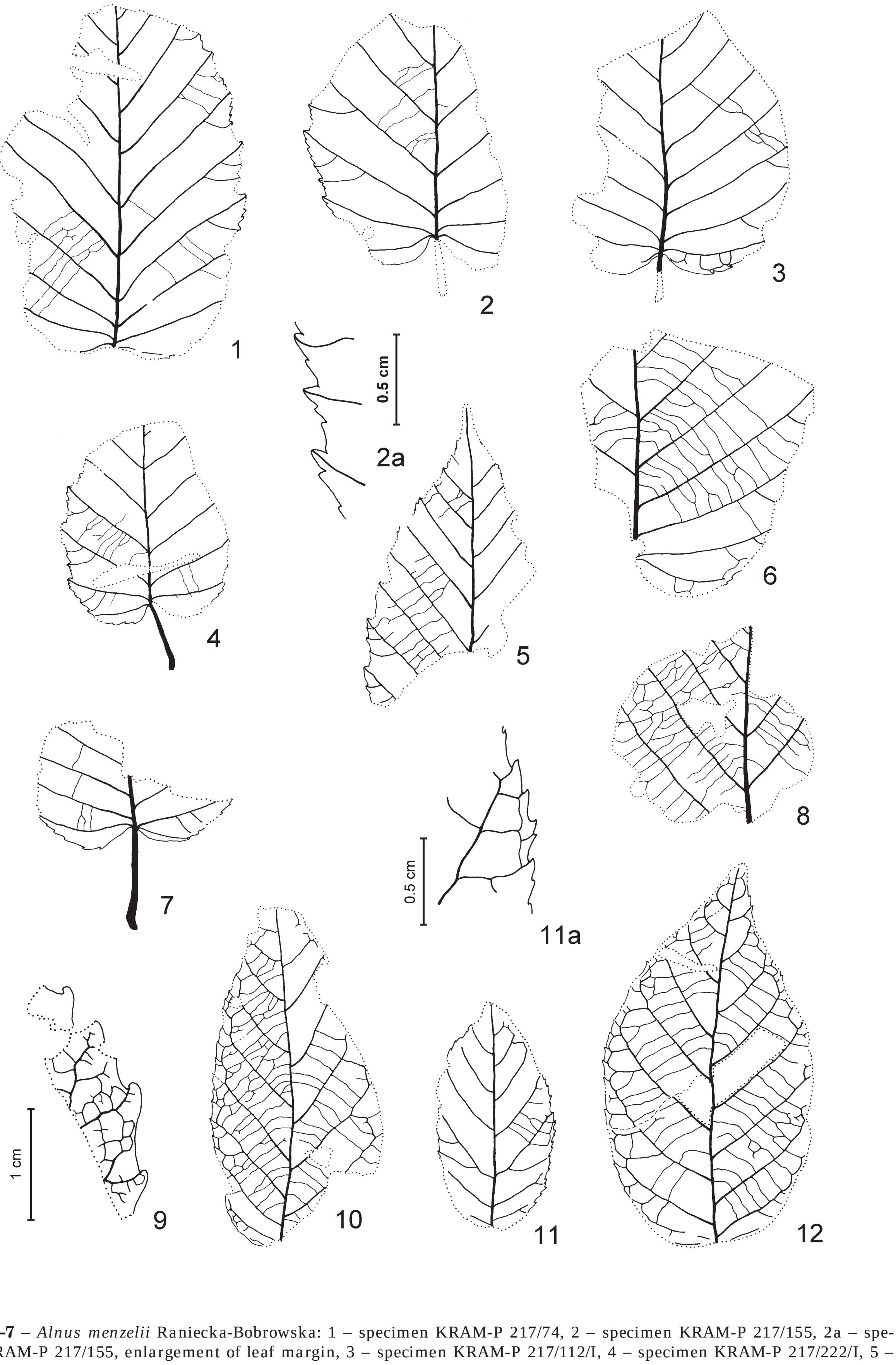

Fig. 4. **1–7** – *Alnus menzelii* Raniecka-Bobrowska: 1 – specimen KRAM-P 217/74, 2 – specimen KRAM-P 217/155, 2a – specimen KRAM-P 217/155, enlargement of leaf margin, 3 – specimen KRAM-P 217/112/I, 4 – specimen KRAM-P 217/222/I, 5 – specimen KRAM-P 217/126/I, 6 – specimen KRAM-P 217/88, 7 – specimen KRAM-P 217/75/I; **8** – *Alnus sp.* – specimen KRAM-P 217/39; **9** – *Populus* sp. – specimen KRAM-P 214/130; **10–12** – *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček: 10 – specimen KRAM-P 217/53/II, 11 – specimen KRAM-P 217/121, 11a – specimen KRAM-P 217/121, enlargement of leaf margin, 12 – specimen KRAM-P 217/176. Specimens without scale were reduced 15% from natural size

(rounded). The same concerns the cell walls of the lower epidermis; however, in this case this feature is not so well-marked. The leaf margin in *Myrica joannis* is always serrate according to Ettingshausen's diagnosis (in: Kovar-Eder 1996), while some of the *Myrica* specimens from Bełchatów have entire-margined leaves.

Fossil leaves of *Myrica* are morphologically very similar to fossil leaves of the genus *Engelhardia* Lesch. ex Bl. (Juglandaceae), for which they are often mistaken. They may only be distinguished by comparing the bases of the peltate glandular trichomes. In *Myrica* these bases are always two-celled, while in *Engelhardia* one-celled (just as in leaves of other genera belonging to the family Juglandaceae).

The leaves of *Myrica lignitum* occur in the both investigated fossil floras. Despite differences in age they are very similar to each other.

Myrica lignitum is a common element of Neogene fossil floras, an indicator of the presence of swampy vegetation. In respect of morphology the species resembles several representatives of the genus *Myrica* L. from North America, East Asia, and even tropical mountain forest from Africa (Ilinskaya 1964, Knobloch 1969). On the basis of his own observations, the author has found that among several recently analysed species (*Myrica carolinensis* Mill., *M. gale* L., *M. javanica* Blume, *M. rubra* Sieb. & Zucc.), the leaf epidermis of *Myrica rubra* Sieb. & Zucc. is most similar to that of fossil *Myrica lignitum*. *Myrica rubra* has a very similar structure of the upper and lower epidermis and it has the hypodermis. Its natural localities are in southern China and Japan (Krüsmann 1972).

Occurrence in the fossil floras of Poland. Lower Miocene – Bełchatów (Worobiec 1995); Middle Miocene – Swoszowice (Ilinskaya 1962, 1964); Upper Miocene – Bełchatów (Stuchlik et al. 1990); Lower Pliocene – Ruszów (Hummel 1983); Pliocene – Bełchatów (Wójcicki & Zastawniak 1998). In the opinion of Knobloch and Kvaček (1976) fossil leaves reported as *Myrica pseudolignitum* Kräusel & Weyland from Stare Gliwice by Szafer (1961) belong to *Buxus pliocenica* Saporta. Leaves of *Myrica* from Dobrzyń on the Vistula (Kownas 1956) reported as *Myrica amissa* Heer and *Myrica studeri* Heer most probably belong to *Myrica lignitum*.

cf. ***Myrica lignitum*** (Unger) Saporta sensu lato

Fig. 3: 12

Material. KRAM-P 217: 110, 151.

Remarks. Fragments of leaves similar to *Myrica lignitum*. Their poor state of preservation precludes unequivocally assigning them to this species.

Betulaceae

Alnus Miller

Alnus gaudinii (Heer) Knobloch & Z. Kvaček

Fig. 4: 10–12; Pl. 8, figs 1–7, Pl. 9, figs 1, 2, Pl. 24, fig. 4(A)

1856 *Rhamnus gaudinii* Heer; Heer, p. 79–80, Pl. 124, figs 4–15, Pl. 125, figs 1, 7, 13.

1976 *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček; Knobloch & Kvaček, p. 33–35, Fig. 11, 12, Pl. 6, figs 1, 3, Pl. 7, figs 1, 5, Pl. 13, fig. 4, Pl. 15, figs 1–4, 7, 8, 10, 11, 13, 15, 17, Pl. 16, figs 1–5, Pl. 19, fig. 15, Pl. 20, fig. 10.

Material. KRAM-P 217: 5, 6, 26, 44/II, 46/II, 50/I, 52, 53/II, 60/II, 63, 89/II, 97, 98/II, 101/II, 108/II, 121, 124/I, 130, 138/II, 140, 143, 149/II, 176, 185/II, 195, 201/II, 206/II, 215/II, 227, 235, 236/II, 243/II, 251, 256.

Morphological description. Elliptic or ovate leaves, up to 7.5 cm long and 2.1–4.3 cm wide. Leaf apex attenuate, leaf base predominantly cordate, sometimes rounded. Leaf margin simple serrate, teeth small, apical sides of teeth very short, concave or rounded, basal sides straight, convex or acuminate, tooth apex acute or attenuate. Preserved fragment of petiole 1.6 cm long. Venation semicraspedodromous. Primary vein straight, moderately thick. Up to 10 pairs of secondary veins run off the primary vein at intervals of 0.2–1.2 cm (0.2–0.4 cm near leaf base) and form an angle of about 60–90° with it near the leaf base and 40–60° (mostly 50–55°) in the middle of the leaf blade. Secondaries curve upward, near leaf margin interconnected in loops, but sometimes loops are indistinct. Fine veins run off secondary vein loops and terminate in apices of teeth. Tertiary venation percurrent, veins simple or forked, perpendicular or oblique in relation to secondary veins and oblique to primary vein, form an angle of 120–140° (mostly 130°) with primary vein. 4 to 8 tertiary veins occur per 1 cm of secondary vein length. Higher-order venation more or less orthogonally reticulate. Areoles imperfectly developed, 0.5–0.9 mm in size. Veinlets both simple and branched. Marginal ultimate venation looped.

Anatomical description. Leaves hypostomatic. Upper epidermis (Pl. 8, fig. 6) composed of isodiametric or tetragonal cells, over the veins cells more elongate, 12–40 µm (mostly 20–30 µm) in size with undulate cell walls. Cuticle striate. Lower epidermis (Pl. 9, fig. 1) composed of more or less isodiametric cells, 12–40 µm (mostly 24–25 µm) in size, over the veins more elongate, up to 44 µm long and 6–10 µm wide. Stomata (Pl. 9, fig. 2) anomocytic or cyclocytic, wide elliptic to rounded and of different size (heterostomata). Large stomata 24–30 µm, small stomata 16–20 µm in diameter. Outer stomatal ledge aperture mainly spindle-shaped, 12–18 µm long and 5–8 µm wide, surrounded by perpendicular cuticular striations. On the lower epidermis are found four-celled trichome bases (Pl. 9, fig. 1a), 24–30 µm in size. Only one peltate trichome (scale) was preserved and measured ca. 60 µm in diameter.

Remarks. The venation pattern, serrate leaf margin and epidermal structure of the specimens is characteristic of *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček. The leaves of this taxon are characterized by semicraspedodromous venation, often with a slightly asymmetric base, a simple serrate leaf margin and small, acute teeth (Zastawniak & Walther 1998). The leaves of this species differ from those of *Alnus julianiformis* (Sternberg) Z. Kvaček & Holý (see page 24). Other central European Neogene fossil leaf species belonging to *Alnus* Miller, such as *A. adscendens* (Goeppert) Zastawniak & Walther, *A. cecropiaefolia* (Ettingshausen) Berger, *A. ducaulis* (Gaudin) Knobloch, *A. suborientalis* Czeczott & Skirgiełło and *A. menzelii* Raniecka-Bobrowska differ from *Alnus gaudinii* above all, by the simple craspedodromous venation, the shape of leaves and the type serration.

Alnus gaudinii was described for the first time by Heer (1856) from the Swiss Tertiary as *Rhamnus gaudinii* Heer. Knobloch and Kvaček (1976) assigned this taxon to the genus *Alnus*.

Alnus gaudinii has been found in Tertiary central European floras as far back as the Late Oligocene (Mai & Walther 1988, 1991) and Early Oligocene (Kvaček & Walther 1998). According to Mai and Walther (1988) and Knobloch and Kvaček (1976) the fossil leaves of this taxon are most similar to those of the recent East Asiatic species *Alnus nitida* (Spach) Endlicher of the subgenus *Clethropsis* (Spach) Endlicher. Alders representing this subgenus are characterized by the semicraspedodromous or even brochidodromous leaf venation; all other species of the remaining subgenera of *Alnus* always have simple craspedodromous venation (Furlow 1979).

Occurrence in the fossil floras of Poland. Lower Miocene – Rozewie (Heer 1869, as *Rhamnus gaudinii* Heer); Middle Miocene – Kokoszyce (Steger 1883, as *Rhamnus gaudinii*), Zielona Góra (Engelhardt 1892, as *Rhamnus gaudinii*), Konin (Raniecka-Bobrowska 1954, as *Rhamnus gaudinii*); Upper Miocene – Sośnica (Zastawniak & Walther 1998).

cf. ***Alnus gaudinii*** (Heer)
Knobloch & Z. Kvaček

Fig. 5: 2

Material. KRAM-P 217: 122, 123/II, 135/I, 245/I.

Remarks. Leaf fragments resembling *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček. However, their poor preservation precludes their confident placement in this species.

Alnus julianiformis (Sternberg)
Z. Kvaček & Holý

Pl. 9, figs 3, 4

1823 *Phyllites julianaeformis* Sternberg; Sternberg, pp. 37, 39, Pl. 36, fig. 2.
1974 *Alnus julianaeformis* (Sternberg) Z. Kvaček & Holý; Kvaček & Holý, p. 367, Fig. 1, Pl. 1–3, Pl. 4, fig. 1.
1998 *Alnus julianiformis* (Sternberg) Z. Kvaček & Holý; Zastawniak & Walther, p. 100, Figs 5: 1–17, Figs 6: 1–4, Pl. 7, figs 2–5, 7, 9–10, Pl. 8, figs 1–4, 8, 10

Material. KRAM-P 211: 13; KRAM-P 214: 28, 52, 77, 94, 123, 148, 149, 189, 190, 191.

Morphological description. Leaves elliptic or ovate, up to 7.5 cm long and 2.6–3.7 cm wide, with acute apex and obtuse base. Leaf margin simple serrate, teeth small, upwardly curved, apical sides very short, basal sides mostly acuminate. Branches of veins terminate at the tooth apex. Venation simple craspedodromous. Primary vein straight, of moderate thickness. Secondary veins straight or slightly upwardly curved, preserved in 8–9 pairs, distributed at intervals of 0.9–1.3 cm in the middle of the leaf blade and 0.3–0.5 cm near the leaf base. Secondaries form an angle of 30–50° (mostly 40°) with primary vein, this angle decreases towards leaf apex. Close to the leaf margin secondary veins produce short branches that form tri-junctions with the tertiary veins. Fine branching from this junction supplies the nearest tooth. Tertiary venation percurrent, tertiaries perpendicular, at the upper part of leaf slightly oblique to the secondary veins, 6 to 7 tertiary veins occur per 1 cm of secondary vein length. Tertiary venation forms an angle of 100–120° with the primary vein. Higher-order venation mostly orthogonally reticulate, venation network is rather regular. Areoles well developed, polygonal, 0.3–0.5 mm in size. Veinlets always present, branched. Marginal ultimate venation looped.

Anatomical description. Leaves hypostomatic. Upper epidermis mostly composed of isodiametric cells, 20–24 µm in size with undulate and medium thickness anticlinal cell walls. Lower epidermis (Pl. 9, fig. 3a) consists of diversiform cells, 24–40 µm in size, cells over veins elongate, 40–65 µm long and 8–16 µm wide. Anticlinal cell walls straight or rounded, sometimes slightly undulate, moderate thickness and distinctly cutinized. Stomata anomocytic, elliptic or widely elliptic and of different size (heterostomata). Large stomata 28–34 µm in size and small stomata 20–27 µm in size. Outer stomatal ledge aperture elliptic. Mostly four-celled trichome bases are found on the lower epidermis and formed part of a glandular trichome (Pl. 9, figs 3b, 3c). The bases of the trichomes are nearly round to slightly elongate and 22–24 µm in size. Only one unicellular trichome base found, ca. 15 µm in diameter. The lower epidermis of one specimen (KRAM-P 214/28) revealed a high density of the above mentioned four-celled trichome bases in comparison with other specimens examined. It is probable that this is a sun leaf from a tree which grew in a sunny locality, as for example on the edge of a forest (Kürschner 1996).

Remarks. The specimens, with their characteristic type of serration, venation pattern and epidermal structure, have been assigned to *Alnus julianiformis* (Sternberg) Z. Kvaček & Holý. The leaves of this species described for the first time by Sternberg (1823) as *Phyllites julianaeformis*, were placed within *Fagus* by Unger (1845), who described them from Bílina as *Fagus feroniae* Unger. For many years this classification was considered dubious (e.g. Heer 1868, Lesquereux 1878), and ultimately Czeczott (1934), on the basis of the type of serration of the leaf margin and venation pattern, recognized them as alder leaves, creating a new combination *Alnus feroniae* (Unger) Czeczott. Czeczott (op. cit.) also produced a detailed morphological description of this taxon. Kvaček and Holý (1974) on the basis of the priority of Sternberg's (1823) description recombined the leaves of *Phyllites julianaeformis* Sternberg as *Alnus julianaeformis* (Sternberg) Z. Kvaček & Holý, completing its morphological description with characteristics of the structure of the epidermis. According to the principles of the Code of Botanical Nomenclature, the species epithet has recently been corrected at "*julianiformis*" (Zastawniak & Walther 1998). Morphologically, the leaves of *Alnus julianiformis* are similar to *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček. According to Zastawniak and Walther (1998) the differences between them are as follows:

– *Alnus gaudinii* has semicraspedodromous venation, while *A. julianiformis* simple craspedodromous venation;

– leaves of *A. gaudinii* have distinctly asymmetric bases;

– teeth in both species are morphologically similar but in *A. julianiformis* they are more scattered than in *A. gaudinii*;

– the cuticle of *A. gaudinii* is ornamented with perpendicular cuticular striations around the stomata (Pl. 9, fig. 1, 2);

According to Knobloch and Kvaček (1976) the epidermis is more cutinized in *A. gaudinii*, which is confirmed by the author's own observations.

Alnus julianiformis is a common species in the Neogene floras from Europe (Hummel 1991).

With respect to morphology, the most similar recent species to *Alnus julianiformis* is *Alnus japonica* Sieb. & Zucc. growing in Japan, China and in the east of Russia (Czeczott 1934). However, it differs from *A. juliani-*

formis in the structure of the epidermis (Kvaček & Holý 1974, Hummel 1991). According to Kvaček and Holy (op. cit.) *Alnus* species of the subgenus *Alnaster* (Spach) Endlicher are most similar to the taxon under discussion in respect of epidermal structure. The epidermal structure of *Alnus trabeculosa* Hand.-Mazz. is also similar. Hummel (1991) noticed only small differences in the structure of the epidermis between these two species (they concern a size of the shields of the peltate glandular trichomes). However, *A. trabeculosa* differs slightly in the morphology of the leaves which have rounded or cordate asymmetric bases and more numerous lateral veins. This species grows in mixed mesophytic forest in the Yangtze Valley in China (Wang 1961).

Occurrence in the fossil floras of Poland. Lower Miocene – Bełchatów (Worobiec 1995); Middle Miocene – Młyny (Zastawniak 1980); Upper Miocene – Sośnica (Knobloch 1971, Zastawniak & Walther 1998); Lower Pliocene – Ruszów (Hummel 1991). Fossil leaves reported from Domański Wierch as *Alnus feroniae* (Unger) Czeczott (Zastawniak 1972) do not represent *Alnus julianiformis* (Sternberg) Z. Kvaček & Holý (Zastawniak 1980).

Alnus menzelii Raniecka-Bobrowska

Fig. 4: 1–7; Pl. 10, figs 1–10, Pl. 11, figs 1–6, Pl. 12, figs 2, 3, Pl. 24, fig. 4(B)

1954 *Alnus menzelii* Raniecka-Bobrowska; Raniecka-Bobrowska p. 11, Fig. 4, Phot. 11–13.

Material. KRAM-P 217: 1, 2, 3, 8/I, 9/I, 10, 11, 12, 13, 14, 16, 25, 29, 30, 35, 36, 37, 38/I, 41, 42, 43, 44/I, 45, 46/I, 48/I, 51, 53/I, 54/I, 55, 56, 60/I, 65/I, 66/I, 68/I, 70/I, 71, 74, 75/I, 85, 86, 88, 89/I, 91, 92, 93/I, 95, 96, 98/I, 99/I, 100, 101/I, 102, 103/I, 105/I, 106/I, 108/I, 112/I, 115, 119/I, 120/I, 123/I, 125/I, 126/I, 127/I, 128, 129/I, 132/I, 133, 134/I, 136, 137/I, 138/I, 139, 141, 145/I, 149/I, 150, 152/I, 153, 154, 155, 156, 157, 158, 159/I, 160, 161, 162/I, 167, 168, 170/I, 171/I, 175, 178, 179/I, 181/I, 184/I, 185/I, 189, 196/I, 200, 202, 204, 205, 206/I, 207, 209, 211, 215/I, 216, 220/I, 221, 222/I, 226, 228, 230, 231/I, 233, 234/I, 236/I, 242, 243/I, 247, 249/I, 252/I.

Morphological description. Elliptical or ovate leaves up to 9.0 cm long and 3.2–7.0 cm wide, leaf apex acute or attenuate, base always cordate. Leaf margin doubly serrate, primary teeth large and so resemble lobes, secondary teeth much more smaller. Apical sides of teeth convex or acuminate, basal sides acuminate or convex, tooth apex of primary teeth acute, tooth apex of secondary teeth mostly rounded. Preserved petioles up to 3 (4) cm long. Venation simple craspedodromous, only above leaf base often semicraspedodromous. Primary vein straight, of moderate thickness. Up to 13 pairs of secondary veins found. First pair of secondary veins form an angle of 90–120° with primary vein, next pair 70–90°. In the middle part of leaf this angle decreases to 40–60° (mostly 50°). Secondaries straight or curve upward, arranged at intervals ranging from 0.1–0.4 cm near leaf base to 0.2–1.1 cm in the middle part of leaf, close to the leaf margin forked, forming junctions with tertiary veins. Secondaries terminate in primary teeth, branches of secondaries terminate in secondary teeth. Tertiary venation percurrent, perpendicular or oblique to the secondary veins forming an angle of 120–140° (mostly 130°) with primary vein, tertiaries simple or forked. 4 to 8 tertiaries occur per 1 cm of the secondary vein length. Higher-order venation orthogonal reticulate. Areoles well developed, often tetragonal, 0.3–0.6 mm (mostly 0.4 mm) in size. Veinlets present, both simple and branched. Marginal ultimate venation looped. At the junctions formed by the primary and secondary veins on the KRAM-P 217/4 and 217/12 specimens domatia composed of tufts of large trichomes occur. Domatia of this type have been described, among others, in *Alnus glutinosa* (L.) Gaertn. (Wilkinson 1979).

Anatomical description. Leaves hypostomatic. Upper epidermis (Pl. 11, figs 4, 5) composed of isodiametric to elongate cells, 12–42 μm (mostly 24–26 μm) in size, over the veins cells more elongate (up to 44 μm). Anticlinal cell walls mainly straight, rarely rounded. Cuticle of upper epidermis usually distinctly striated (Pl. 11, fig. 5). Cells of lower epidermis (Pl. 11, figs 4a, 6) of similar dimensions as upper epidermis (12–40 μm, mainly 26 μm in size), over the veins more elongate, up to 60 μm long and 10–12 μm wide, anticlinal cell walls straight or rounded, sometimes undulate. Stomata anomocytic (Pl. 11, figs 4a, 6), wide elliptic to elliptic and of different size (heterostomata). Large stomata 24–30 μm,

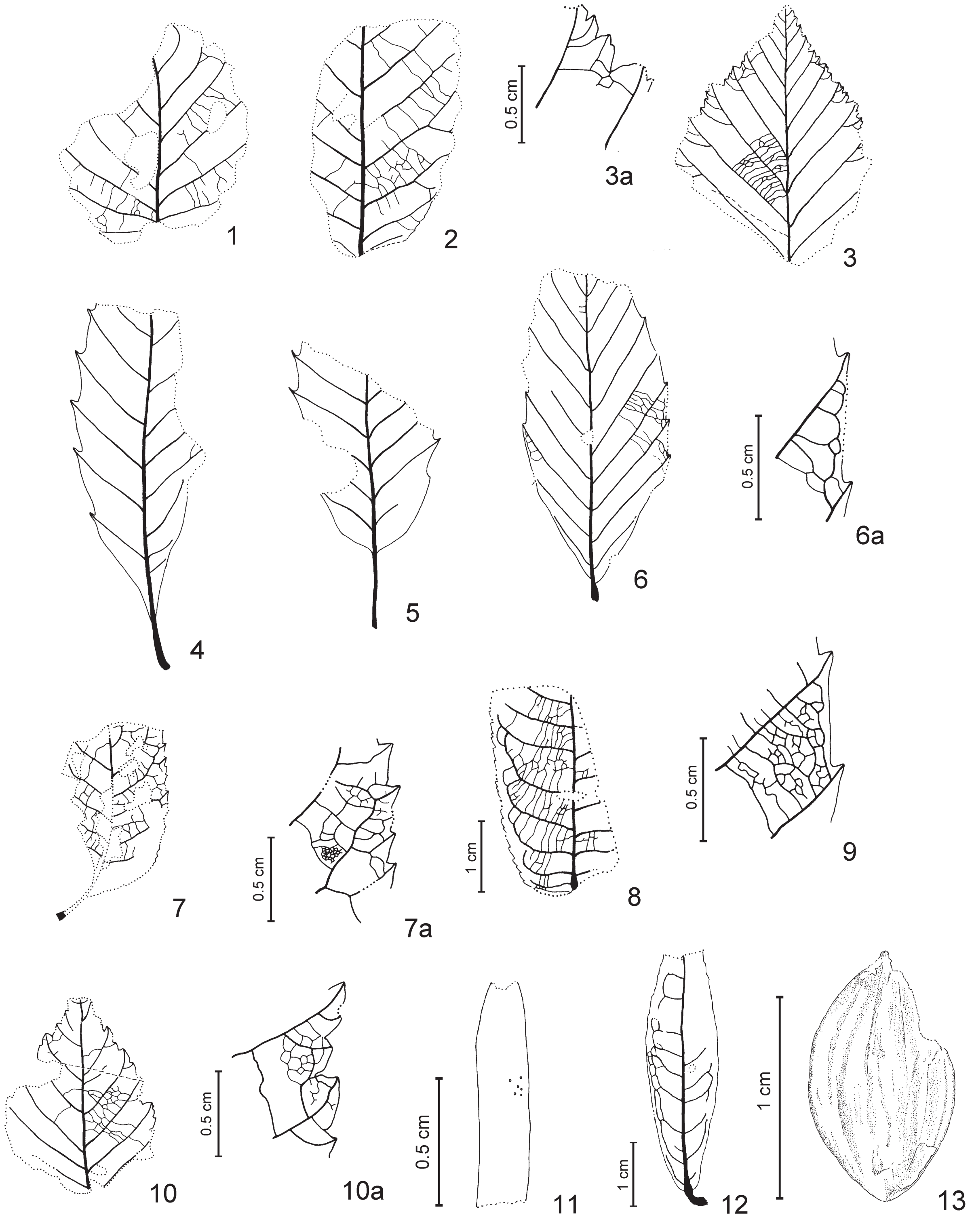

Fig. 5. 1 – cf. *Alnus menzelii* Raniecka-Bobrowska – specimen KRAM-P 217/113/I; **2** – cf. *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček – specimen KRAM-P 217/122; **3–3a** – *Carpinus* sp.: 3 – specimen KRAM-P 217/94, 3a – specimen KRAM-P 217/94, enlargement of leaf margin; **4–5** – "*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček: 4 – specimen KRAM P 214/114, 5 – specimen KRAM-P 214/71; **6, 6a**, **9** – *Fagus silesiaca* Walther & Zastawniak: 6 – specimen KRAM-P 217/103/IV, 6a – specimen KRAM-P 217/103/IV, enlargement of leaf margin, 9 – specimen KRAM-P 217/107, enlargement of leaf margin**; 7–7a** – cf. *Carya serrifolia* (Goeppert) Kräusel: 7 – specimen KRAM-P 214/133, 7a – specimen KRAM-P 214/133, enlargement of leaflet margin; **8 –** *Pterocarya paradisiaca* (Unger) Ilinskaya – specimen KRAM-P 217/125/II, **10–10a –** *Ulmus* sp., specimen KRAM-P 214/173a & b, 10a – specimen KRAM-P 214/173a & b, enlargement of leaf margin; **11** – *Viscophyllum pliocenicum* (Engelhardt) Mädler – specimen KRAM-P 217/258, **12** – *Kalmia* cf. *saxonica* Litke – specimen KRAM-P 217/28; **13 –** *Nyssa ornithobroma* Unger – specimen KRAM-P 214/65. Specimens without scale were reduced 15% from natural size

small stomata 16–20 µm in size. Outer stomatal ledge aperture spindle-shaped, rarely elliptic, 11–20 µm long and 5–10 µm wide. On the lower epidermis, four to five-celled trichome bases, sometimes with preserved peltate trichomes (Pl. 12, figs 2, 3), may be found. Trichome shield ca. 70 µm in size (it is deformed because of fossilization), trichome bases 20–32 µm in size.

Remarks. *Alnus menzelii* Raniecka-Bobrowska is characterized by elliptic or ovate leaves, always having cordate and sometimes slightly asymmetric bases, with a doubly serrate leaf margin and well-marked branches of lateral veins at the leaf base. The leaves of this taxon show a large size variability. Morphologically, the leaf remains correspond exactly with the description of *Alnus menzelii* from the Miocene of Konin (Raniecka-Bobrowska 1954), for which, data on the structure of the epidermis are absent. The leaf fragment described as *Alnus* sp. (cf. *kefersteini* Unger) by Kräusel and Weyland (1954) may serve as the first illustration of the epidermis in this species. Features of the upper epidermis of this leaf are typical of *Alnus menzelii* from Bełchatów; it has a similarly striate cuticle. Hummel (1983), Belz and Mosbrugger (1994), Worobiec and Lesiak (1998) and Kovar Eder and Wójcicki (2001) enumerated features, characterizing the epidermis in this taxon. The size of the upper epidermal cells given by Hummel (1983) and Belz and Mosbrugger (1994) is similar to data gathered from the Bełchatów specimens. Belz and Mosbrugger (op. cit.) and Kovar Eder and Wójcicki (2001) also mention the occurrence of striate ornamentation on the cuticle of the upper epidermis, this is characteristic of the specimens of *Alnus menzelii* from Bełchatów. Also the type and size classes of stomata are similar. The specimens of *Alnus menzelii* reported by Worobiec and Lesiak (1998) from locality Stawek-1A from the Bełchatów Lignite Mine correspond in respect of the morphology and anatomy of the lower epidermis to *Alnus menzelii* from locality KRAM-P 217.

Alnus menzelii has only been recorded from a few Tertiary fossil floras outside of Poland, though according to Zastawniak and Walther (1998) this taxon was rather common. In last years *Alnus menzelii* have been recorded from several localities outside of Poland. Knobloch (1986) mentioned this species from the Miocene of Achldorf, Bůžek et al. (1992) from the Miocene of Bílina, Belz and Mosbrugger (1994) from the Neogene of the Lower Rhine Embayment, Kovar-Eder et al. (1995) from the Pannonian of Burgeland in south-eastern Austria, Krenn (1998) from the Pannonian of Paldau in Austria, Kvaček and Hurník (2000) from the Lower Miocene of northern Czech (Lajsník and Želénky) and recently Kovar-Eder and Wójcicki (2001) from Upper Miocene of Austria (Hinterschlagen).

Alnus menzelii was a typical component of riparian forest and swampy forest, particularly in the Middle Miocene (Zastawniak & Walther 1998).

Raniecka-Bobrowska (1954) compares *Alnus menzelii* to two recent alder species: *Alnus serrulata* (Ait.) Willd. from forest growing in the eastern part of North America and *Alnus subcordata* C.A. Mey. from Asia Minor (Transcaucasia, Iran). The former grows in wet, periodically flooded riparian forest and on lake shores, the latter in river bank forest and those growing on elevations. Raniecka-Bobrowska (op. cit.) is of the opinion that both species slightly differ morphologically from *Alnus menzelii*. Comparing the epidermis of *Alnus menzelii* from Bełchatów with that of both recent *Alnus serrulata* and *Alnus subcordata*, the former appears most similar, the upper epidermis having a striate cuticle as in *A. menzelii*, a feature not observed in *A. subcordata*. Other epidermal features of the fossil species are also more similar to *Alnus serrulata*. The leaf margin of *A. serrulata* is doubly serrate (Callier 1918), as in *A. menzelii*, while that of *A. subcordata* is simple serrate. These shared features indicate that *Alnus menzelii* is closer to *Alnus serrulata* than to *Alnus subcordata*, despite certain differences, mostly in the morphology of the leaves (e.g. the shape of the leaf blade and its base).

Occurrence in the fossil floras of Poland. Middle Miocene – Koronowo (Menzel 1910, as *Corylus mac quarri* (Forbes) Heer), Konin (Raniecka-Bobrowska 1954); Upper Miocene – Bełchatów (Stuchlik et al. 1990), Gnojna (Krajewska 1998), Sośnica Zastawniak & Walther (1998); Upper Miocene/ Lower Pliocene – Bełchatów (Worobiec & Lesiak 1998), Lower Pliocene – Ruszów (Hummel 1983).

cf. ***Alnus menzelii*** Raniecka-Bobrowska

Fig. 5: 1

Material. KRAM-P 217: 113/I, 135/II, 194, 201/I, 229, 240, 241.

Remarks. Fragments of leaves similar to *Alnus menzelii* Raniecka-Bobrowska but due to their poor state of preservation identification is uncertain.

Alnus sp.

Fig. 4: 8

Material. KRAM-P 217: 4, 39, 166.

Remarks. Fragments of *Alnus* leaves that can not be assigned to a given species.

Carpinus L.

Carpinus sp.

Fig. 5: 3, 3a; Pl. 12, figs 1, 1a

Material. KRAM-P 217: (68/II, 94 – twin specimens).

Morphological description. Leaf fragment, 5.0 cm long and 4.6 cm wide. Leaf margin doubly serrate, apical sides of teeth acuminate, sometimes concave, basal sides acuminate, tooth apex acute. Venation simple craspedodromous. 9 pairs of secondary veins preserved, arranged oppositely in lower part and alternately in upper part of leaf, they depart the primary vein at intervals of 0.4–0.7 cm and form an angle of 35–40° with it. Close to leaf margin secondaries forked, veins and their branches enter teeth and reach their apex. Tertiary venation percurrent, tertiaries oblique to primary vein, closely arranged (10 tertiary veins per 1 cm of secondary vein length), form an angle of ca. 120° with the primary vein. Higher-order venation orthogonal reticulate. Areoles well developed, polygonal, about 0.3–0.5 mm in size.

Anatomical description. Upper epidermis (Pl. 12, fig. 1) composed of polygonal, sometimes tetragonal cells, over the veins these are more elongate, up to 40 µm in size. Anticlinal cell walls straight. Lower epidermis (Pl. 12, fig. 1a) consists of isodiametric or over the veins elongate cells, up to 40 µm (mostly 30 µm) in size with rounded sometimes slightly undulate anticlinal cell walls. Stomata wide elliptic or rounded and of different size (heterostomata). Large stomata 25–30 µm and small stomata ca. 20 µm in diameter. Outer stomatal ledge aperture wide, spindle-shaped or elliptic 17–20 µm (large stomata) and ca. 12 µm (small stomata) long. Most of stomata surrounded by cuticular striations perpendicular to them. On the upper epidermis is found simple, unicellular trichome base, about 15 µm in diameter. On the lower epidermis is found what are probably the rest of multicellular glandular trichome base.

Remarks. The leaf fragment probably belongs to the genus *Carpinus* L., as indicated by the venation pattern and structure of epidermis. Due to the poor state of preservation a more precise identification is not possible.

Fagaceae

Fagus L.

Fagus silesiaca Walther & Zastawniak

Fig. 5: 6, 6a, 9; Pl. 12, figs 4–4b

1991 *Fagus silesiaca* Walther & Zastawniak; Walther & Zastawniak, p. 156–160, Fig. 1, Pl. 1, figs 1–6, Pl. 2, fig. 1.

1991 *Fagus menzelii* Z. Kvaček & Walther; Kvaček & Walther, p. 485–487, Fig. 9–10, Pl. 17, figs 1–5, Pl. 18, figs 1–5.

Material. KRAM-P 217: 103/IV, 107, 249/II.

Morphological description. Leaves elliptic, up to 7.0 cm long and 3.0–3.5 cm wide with cuneate leaf bases. Leaf margin simple serrate, teeth upwardly curved, apical sides of teeth concave, basal sides convex or straight, tooth apex acute or rounded. Venation simple craspedodromous. Primary vein thin. Secondary veins, preserved in 9 pairs, straight or slightly upwardly curved, arranged mostly oppositely, run off primary vein at intervals of 0.5–0.8 cm and form an angle of 40–45° (mostly 40°) with it. Close to the leaf margin before entering a tooth secondary veins forked, one branch terminates in the tooth and the other, upwardly curved, joins with tertiary veins superadjacent secondary veins. Tertiary venation percurrent, mostly perpendicular, sometimes oblique to the secondary veins and oblique to the primary vein, tertiaries closely arranged, 8 to 10 tertiary veins per 1 cm of the secondary vein length. Tertiary veins form an angle of 125–150° with primary vein.

Anatomical description. Leaves hypostomatic. Intercostally the upper epidermis (Pl. 12, fig. 4) is composed of isodiametric or slightly elongate cells, 20–40 μm in size with distinctly undulate anticlinal cell walls, while over the veins they are elongate, measuring about 30–40 μm long. Lower epidermis (Pl. 12, fig. 4a) is composed of variable-shape cells, 16–24 μm in size with rounded anticlinal cell walls. Stomata (Pl. 12, fig. 4b) cyclocytic, rounded, 16–24 μm (mostly 20 μm) in diameter, surrounded by 5–7 (mostly 5) subsidiary cells. Outer stomatal ledge elliptic-oblongate, 8–10 μm long. On the lower epidermis are found rounded, unicellular trichome bases, 8–12 μm in diameter. The preserved rests suggest that the trichomes were simple (unbranched).

Remarks. The fragments of fossil beech leaves described above belong to *Fagus silesiaca* Walther & Zastawniak. Their morphological and anatomical features correspond to the description given by Walther and Zastawniak (1991). It differs from the similar fossil species *Fagus kraeuselii* Z. Kvaček & Walther in having a greater number of secondary (lateral) veins (9 pairs in an incomplete specimen were preserved) and in its elongate, elliptic-ovate shape (comp. Kvaček & Walther 1991). The length-width ratio of the leaves of *Fagus silesiaca* from Bełchatów is approx. 2.0, while that of *Fagus kraeuselii* is 1.8–1.9, a very small difference. Statistical analyses, to establish distinct differences between these species were not possible due to the scarcity of *Fagus silesiaca* at Bełchatów (3 fragmentary leaves).

The fragments of *Fagus silesiaca* from Bełchatów differ from *Fagus saxonica* Z. Kvaček & Walther (Middle Oligocene-Early Miocene, Walther 1994), in apparently having fewer lateral veins (*F. saxonica* has 12–16). However, the morphology and epidermal structure of *Fagus menzelii* Z. Kvaček & Walther as described by Kvaček and Walther (1991) is very similar to that of *Fagus silesiaca*. These authors compared leaves of *Fagus silesiaca*, *Fagus menzelii* and *Fagus kraeuselii* from the Tertiary of central Europe. They concluded that, differences in the structure of the epidermis, such as variation in the size of the stomata between *Fagus silesiaca* and *Fagus menzelii* can only be observed when the specimens for comparison are large. However, other differences in the structure of the epidermis, such as the degree of undulation of the cell walls, do not necessarily have taxonomic value, this character often depending on environmental conditions (Stace 1965). The epidermal cells of plants growing in wet habitats are often undulate. Significant taxonomic differences, at least on a species level, do not exist between *Fagus silesiaca* and *F. menzelii*. Only a comparison of beech cupules found with the leaves of these species (Kvaček & Walther 1991) indicates that *Fagus silesiaca* and *F. menzelii* could be separate species. These cupules differ markedly in the length of the pedicel. However, it is not known whether the cupules and leaves under discussion are organs of the same beech species because they were found separately. Most probably the leaves of *Fagus menzelii* and *F. silesiaca* belong to the same taxon.

Fagus silesiaca occurs frequently in fossil floras from the Late Miocene to the Early Pliocene of central Europe (Walther 1994) and is most often reported under the incorrect names *Fagus attenuata* Goeppert and *Fagus haidingeri* Kováts sensu Knobloch. According to Kvaček and Walther (1991) this plant grew in mesophytic deciduous or mixed forest.

The morphology and epidermal structure of *Fagus silesiaca* (Kvaček & Walther 1991, 1992) is comparable to that of the recent *Fagus hayatae* Palibin ex Hayata that grows in the Mixed Mesophytic Forests of central China (Dyjor et al. 1992). *Fagus grandiflora* Ehrh. (= *Fagus ferruginea* Ait.) from the eastern USA is morphologically very similar to *Fagus silesiaca*, but differs in having anomocytic stomata (Kvaček & Walther 1992).

Occurrence in the fossil floras of Poland. Middle Miocene – Kokoszyce (Reichenbach 1919, as *Fagus attenuata* Goeppert); Upper Miocene – Sośnica (Goeppert 1855, Reichenbach 1919, Walther & Zastawniak 1991), Bełchatów (Stuchlik et al. 1990, as *Fagus attenuata*), Worobiec & Lesiak (1998), Gozdnica (Dyjor et al. 1992, as *Fagus silesiaca* Walther & Zastawniak var. *gozdnicensis* Zastawniak & Kvaček), Stare Bystre (Worobiec 1994, as *Fagus haidingeri* Kováts sensu Knobloch); Miocene – Trzebnica (Pax 1907, as *Fagus attenuata*), Smogorzówek (Juhnke 1931, as *Fagus attenuata*); Lower Pliocene – Ruszów (Hummel

1983, as *Fagus attenuata* Goeppert); Pliocene – Domański Wierch (Zastawniak 1972, as *Fagus haidingeri*), Bełchatów (Wójcicki & Zastawniak 1998).

(?) ***Castanea*** Miller

"*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček

Fig. 5: 4, 5, Pl. 13, figs 1–11, Pl. 14, figs 1–4

1851 *Castanea kubinyi* Kováts; Kováts, p. 178, nomen nudum.
1852 *Castanea kubinyi* Kováts; Ettingshausen, p. 6, Pl. 1, fig. 12.
1976 *Castanea kubinyi* Kováts ex Ettingshausen; Knobloch & Kvaček, p. 35–38, Fig. 13, 14, Pl. 16, figs 7–9, Pl. 18, figs 1, 4–10, Pl. 23, figs 4, 6, 8–11, Pl. 31, fig. 7.
1995 *Castanea* sp.; Worobiec, p. 245, Pl. 1, fig. 5, Pl. 2, fig. 3.
1996 *Quercus kubinyii* (Kováts ex Ettingshausen) Czeczott; Knobloch & Kvaček, p. 51–52, Fig. 1, 2, Pl. 7, figs 3, 6, Pl. 8, figs 1, 2.

Material. This taxon has two morphotypes: A and B.

Morphotype A: KRAM-P 211: 5, 7, 10, 14, 19, 34, 35, 38, 42, 46; KRAM-P 214: 1, 2, 6, 11, 12, 17, 22, 24, 37, 38, 45, 48, 54, 55, 68/I, 81, 83, 85, 86, 87/I, 96, 97, 98, 99, 100, 103, 108, 110, 111, 113, 115, 116, 118, 120/I, 126, 135, 141, 146, 147, 154, 166, 167, 169, 170, 176, 177.

Morphotype B: KRAM-P 211: 20, 22, 25, 30, 47; KRAM-P 214: 4, 7, 8, 23, 27, 29, 32, 33, 41, 46, 47, 49, 50, 51, 56, 57, 58, 66, 71, 72, 109, 114, 121, 137, 138, 140, 152, 157, 168, 178, 186.

Specimens of transitional morphology between the two morphotypes: KRAM-P 211: 4, 11, 12, 31; KRAM-P 214: 3, 10, 14, 34, 76, 79, 82, 88, 92, 119, 124, 125, 151, 153, 155, 156, 160, 164, 165, 183, 184, 185.

Description of morphotype A (Pl. 13, figs 2, 6, 9–11, Pl. 14, figs 3, 4)

Morphological description. Leaves narrow-elliptic to lanceolate, up to 7.3 cm long and 0.8 to 3.0 cm (mostly 2.0 cm) wide. Leaf apex normally attenuate, base cuneate, obtuse or decurrent. Leaf margin simple serrate, teeth upwardly curved, apical sides of teeth concave, often very short, basal sides convex or acuminate, rarely straight, never concave, tooth apex mostly rounded. The longest preserved petiole 0.4 cm long. Venation mixed craspedodromous: near leaf base brochidodromous (lowermost secondary veins do not reach leaf margin), in the upper part of leaf simple craspedodromous. Primary vein mostly straight or slightly curved, of moderate thickness. Leaves of this form have up to 11 pairs of secondary veins. Secondaries depart primary vein at intervals ranging from 0.3–0.4 cm near leaf base to 1.2 cm (mostly 0.5–0.8 cm) in the middle part of leaf. Secondary veins form an angle of 45–60^o (mostly 50^o) with primary vein. Close to the leaf margin secondaries often upwardly curved and forked, terminate in the tooth apex. Lowermost secondary veins interconnected in loops. Intersecondary veins, rarely present, generally short (up to half distance between primary vein and leaf margin). Tertiary venation percurrent, less regular than in morphotype B, perpendicular to the secondary veins and oblique to primary vein, form an angle of 135–140^o with primary vein. Higher-order venation orthogonal reticulate. Areoles well developed, variable in size, 0.3–0.5 mm. Veinlets present, mostly simple or once branched. Marginal ultimate venation form fimbrial vein.

Anatomical description. Leaves hypostomatic. Upper epidermis composed of mostly tetragonal, sometimes slightly elongate cells, 22–38 µm (mostly 30 µm) in size. Anticlinal cell walls thick, irregularly pitted, mostly straight, sometimes rounded. Below upper epidermis lies a unilayered hypodermis, composed of rounded, thin-walled, small cells, 7–20 µm (mostly 12–14 µm) in diameter. Lower epidermis (Pl. 14, fig. 3) consists of variably shaped and arranged cells, 15–45 µm (mostly 23 µm) in size. Anticlinal cell walls mostly rounded, rarely straight, sometimes distinctly cutinized. Hypodermis composed of polygonal cells, 20–36 µm in size with rounded or slightly undulate anticlinal cell walls, thinner than lower epidermis cell walls. Stomata anomocytic, wide elliptic, rarely roundish, 15–25 µm (mostly 20 µm) in size. Outer stomatal ledge aperture often poorly visible, elliptic-oblong, 6–8 µm long. Polar T-shaped cuticular thickness present.

Description of morphotype B (Pl. 13, figs 1, 3–5, 8, Pl. 14, figs 1, 1a, 2, 2a)

Morphological description. Leaves, mostly fragmentary, up to 8.5 cm long and 1.6–4.5 cm (mostly 3.0–3.5 cm) wide, narrow-elliptic to lanceolate, symmetric. Leaf base of variable shape: mostly acute or cuneate, rarely obtuse or rounded. Leaf margin simple serrate, teeth moderate or large, apical sides of teeth always concave, basal sides straight or acuminate, sometimes concave, tooth apex always acute, often passing into a bristle which constitutes a spinose tooth termination. Petioles up to 1.8 cm long. Venation generally simple craspedodromous, only close to leaf base lowermost pair of secondary veins interconnected in loops. Primary vein straight or curved, of moderate thickness, sometimes stout. Up to 11 pairs of secondary veins run off primary vein at intervals ranging from 0.3–0.4 cm near leaf base to 0.6–1.1 cm in the middle part of leaf and form an angle of 40–60^o (mostly 50^o) with it. This angle increases to 70^o towards the leaf base and generally decreases towards the leaf apex. Secondaries straight or close to leaf margin slightly upwardly curved, forked, one branch terminates in tooth apex and the other, upwardly curved joins with a tertiary vein and with a superadjacent secondary vein. Intersecondary veins not observed. Tertiary venation percurrent, 6–12 tertiary veins occur per 1 cm of secondary vein length, tertiaries oblique to primary vein forming an angle of 120–140^o (mostly 130^o) with primary vein. Higher-order venation orthogonal reticulate. Areoles well developed, 0.3–0.5 mm in size. Veinlets mostly multiply branched (two or three times), rarely simple branched. Marginal ultimate venation forms an imperfect fimbrial vein, which is not so distinct as in morphotype A.

Anatomical description. Leaves hypostomatic. Upper epidermis (Pl. 14, figs 1, 1a) composed of tetragonal cells, 17–40 µm in size. Anticlinal cell walls straight, sometimes slightly rounded, of moderate thickness. Below upper epidermis lies a hypodermis composed of rounded, thin-walled cells, 7–14 µm (mostly 11 µm) in diameter. Lower epidermis (Pl. 14, figs 2, 2a) composed of polygonal, often elongate cells, 15–36 µm (mostly 25 µm) in size. Anticlinal cell walls mostly rounded, rarely undulate. Hypodermis consists of variably-shaped cells, 20–30 µm in size with rounded or slightly undulate anticlinal cell walls. Stomata (Pl. 14, fig. 2a) anomocytic, mainly wide elliptic or roundish, 17–24 µm (mostly 20 µm) in size. Outer stomatal ledge aperture poorly visible, elliptic-oblongate, 4–7 µm long. Polar T-shaped cuticular thickness mostly clearly visible, but sometimes indistinct or absent. Scattered unicellular trichome bases, 10–12 µm in diameter are very rarely found on the lower epidermis. One specimen shows a pair of that type trichome bases closely connected (comp. Knobloch & Kvaček 1976).

Differences in the morphology and anatomy between the two forms are listed in Table 1**.**

Remarks. The leaves have a venation pattern and leaf margins characteristic of the genera *Castanea* Mill. and *Quercus* L. In comparison with fossil material, the following morphologically similar taxa are here considered: *Castanea atavia* Unger, *Castanea gigas* (Goeppert) Ilinskaya, *Castanea kubinyii* Kováts ex Ettingshausen, *Quercus kubinyi* (Kováts ex Ettingshausen) Czeczott, and *Quercus gigas* Goeppert emend. Walther & Zastawniak. The leaves from Bełchatów are morpho-

Table 1. Differences between the two morphotypes of "*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček

Morfology of leaf	
Form A	Form B
1. Teeth obtuse, hook-shaped	1. Teeth acute, often spinose
2. Leaves usulally narrow (ca. 2 cm)	2. Leaves wider (3–3,5 cm)
3. Tertiary venation network less regular	3. Tertiary venation network rather regular
4. Intersecondary veins rarely present	4. Intersecondary veins absent
5. Venilets simple or once branched	5. Veinlets twice or three times branched
Anatomy of leaf	
Form A	Form B
1. Hypodermal cells (below upper epidermis) larger, 7–20 µm in diameter (mostly 12–14 µm)	1. Hypodermal cells (below upper epidermis) smaller, 7–14 µm in diameter (mostly 11 µm)

logically very similar to *Quercus gigas* (Walther & Zastawniak 1991) but differ in their epidermal structure, this species having both single and stellate trichomes on the lower leaf epidermis. However, "*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček has either single trichomes or none, and as such, the study material has been assigned to this species. The epidermal structure, particularly the presence of a hypodermis in "*Castanea*" *kubinyii* is shared with *Quercus mediterranea* Unger from the Early Miocene of Aliveri, Greece, Velitzelos et al. (1992). However, this species differs in having stellate, multicellular trichomes.

The specimens of "*Castanea*" *kubinyii* from Bełchatów show morphological and epidermal variability. However, this variability is too small to justify two separate species, instead two ecological forms within a single taxon are proposed (morphotypes A and B, Table 1), both respectively representing leaves from trees growing in sunny and shady places (e.g. a dense stand). Differences in the features of the leaves listed in Table 1 correspond to variability recorded in other plant species resulting from differences in the ambient light conditions (Kürschner 1996, Ashton & Berlyn 1994). Other factors such as the age of the plant, the position of the leaves on the shoot and in the crown, or the origin of the leaves from offshoots may also have influenced leaf variability (Jentys-Szaferowa 1955, Kvaček & Walther 1978). Anisophylly in fossil leaf taxa has been reported by Kvaček and Walther (1978) in *Acer tricuspidatum* Bronn, *Daphnogene polymorpha* (Al. Braun) Ettingshausen and *Castanopsis toscana* (Bandulska) Kräusel & Weyland and by Givulescu et al. (1996) in *Daphnogene polymorpha* (Al. Braun) Ettingshausen.

As to the generic affinity of "*Castanea*" *kubinyii* it is not possible to distinguish the fossil leaves of the genera *Quercus* and *Castanea* on the basis of either morphology or anatomy (Ferguson 1971, Knobloch & Kvaček 1976). For this reason, it is unclear whether the leaves of "*Castanea*" *kubinyii* belong to oak or chestnut.

The occurrence of "*Castanea*" *kubinyii* has so far been proved by anatomical studies of leaves from the following Tertiary localities in Europe: the Early Miocene of Wackersdorf (Knobloch & Kvaček 1976), western Czech (Bůžek et al. 1996), the Miocene of southern Czech (Knobloch & Kvaček 1996), the Pliocene of Hungary (Hably & Kvaček 1997) and the Late Miocene of Hinterschlagen in Austria (Kovar-Eder & Wójcicki 2001). Fossil leaves described by Ferguson (1971) from Kreuzau (as form XIV, type *Castanea atavia* Unger), which later on were assigned by Knobloch and Kvaček (1976) to the species "*Castanea*" *kubinyii*, represent *Quercus gigas* Goeppert emend. Walther & Zastawniak, as indicated by the presence of stellate trichome bases on their epidermis.

The range of occurrence of "*Castanea*" *kubinyii* in the Neogene of Europe may have been much larger because this species is easily mistaken for other fossil species of the family Fagaceae, particularly *Castanea atavia* Unger, *Castanea gigas* (Goeppert), *Quercus kubinyi* (Kováts ex Ettingshausen) Czeczott, and *Quercus gigas* Goeppert emend. Walther & Zastawniak. In almost all older elaborations of fossil floras from the 19th century and the earlier part of the 20th century (comp. Kováts 1851, Czeczottowa 1951, Berger 1952) the epidermis of these leaves was not analysed, and without anatomical studies the differentiation of "*Castanea*" *kubinyii* from *Quercus gigas* Goeppert emend. Walther & Zastawniak seems to be impossible.

Oak (mostly from the section *Cerris* Oersted) and chestnut leaves are most similar to "*Castanea*" *kubinyii* (Knobloch & Kvaček 1976). According to Czeczottowa (1951) and Berger (1952) leaves of this type are most similar in respect of morphology to the leaves of *Quercus libani* Oliv., growing in south-eastern and eastern Asia Minor and in the surrounding areas of Iraq and Syria on warm calcareous soils in mountain areas at elevations of 900–1500 m a.s.l.

Occurrence in the fossil floras of Poland. Species earlier reported for fossil floras of Poland only from the Lower Miocene of Bełchatów (Worobiec 1995).

Quercus L.

Quercus rhenana (Kräusel & Weyland) Knobloch & Z. Kvaček

Pl. 15, figs 1–3

1950 *Illicium rhenanum* Kräusel & Weyland; Kräusel & Weyland p. 50, Fig. 14, Pl. 9, figs 5–7, Pl. 10, figs 1–2, Pl. 11, fig. 6.

1976 *Quercus rhenana* (Kräusel & Weyland) Knobloch & Z. Kvaček; Knobloch & Kvaček, p. 41, Pl. 17, figs 6, 8, 14, Pl. 21, figs 5–6, Pl. 24, fig. 10.

Material. KRAM-P 214: 18, 42, 171, 188.

Morphological description. Fragments of entire-margined, very coriaceous, symmetric leaves, up to 6.9 cm long and 2.5–4.1 cm wide, most probably narrow-elliptic or lanceolate (Pl. 15, fig. 1). Venation brochidodromous. Primary vein straight, stout. Secondary veins, curve upward, up to 7 pairs preserved, arranged at intervals of 0.6–1.2 cm, depart primary vein at an angle of 60–70°. Close to the leaf margin secondary veins interconnected in loops. Generally short intersecondary veins (or possible distinct tertiary veins) found only in one specimen. Tertiary venation percurrent, 5–6 tertiary veins occur per 1 cm of secondary vein length, tertiaries perpendicular or slightly oblique to the secondary veins and oblique to primary vein, form variable angle of 120–150° with primary vein. Some of tertiary veins curved towards primary vein and directly connect with it. Higher-order venation orthogonal reticulate. Areoles well developed, rather regular, tetragonal or polygonal, 0.5–0.6 mm in size. Veinlets very rarely observed, simple. Marginal ultimate venation forms an imperfect fimbrial vein.

Anatomical description. Leaves hypostomatic. Upper epidermis (Pl. 15, fig. 3) composed of predominantly tetragonal cells, variably arranged, ca. 40–50 µm in size (cells not clearly visible). Anticlinal cell walls undulate, moderate thickness. Cuticle very thick, often separates during maceration. Below upper epidermis lies a hypodermis composed of very regular, isodiametric, mostly rounded cells, 16–30 µm in diameter with thin, rounded or straight anticlinal cell walls. Lower epidermis (Pl. 15, figs 2a, 2b) composed of variably-shaped cells, 60–70 µm in size with thick and distinctly undulate anticlinal cell walls. Cuticle is slightly granulate (due to ornamentation or the rest of epicuticular wax). Hypodermis consists of variably-shaped cells, 40–50 µm in size with thin and rounded, sometimes undulate anticlinal cell walls. Stomata (Pl. 15, fig. 2b) cyclocytic, surrounded by 5–6 subsidiary cells, wide elliptic or rounded, distinctly cutinized, 28–36 µm in diameter. Outer stomatal ledge aperture very distinct, 15–16 µm long and about 8 µm wide. Polar T-shaped cuticular thickness present. A characteristic epicuticular wax ring (Pl. 15, fig. 2b) resembling a cuticular peristomatal rim is preserved around stomata. On the lower epidermis a single unicellular trichome base, 24 µm in size was found.

Remarks. The fossil leaves from Bełchatów are identical to those of *Quercus rhenana* (Kräusel & Weyland) Knobloch & Z. Kvaček reported by Knobloch and Kvaček (1976) from the Miocene of Wackersdorf. These authors revised fossil leaves described by Kräusel and Weyland (1950) as *Illicium rhenanum* Kräusel & Weyland, classifying them in the genus *Quercus* L. According to Knobloch and Kvaček (1976) the same species is also represented by leaves described by Jähnichen (1966) as Q*uercus lusatica*. Palamarev and Mai (1998) classify *Quercus rhenana* in *Quercus lyellii* Heer group related to recent oaks of the subgenus *Erythrobalanus* Loud.

According to Rüffle and Palamarev (1979) *Quercus rhenana* was most frequently found in the Oligocene and Miocene; in the Pliocene it became extinct in Europe, and the nearest known locality from this period is in Abkhazia (Kolakovsky 1959) which in the opinion of Rüffle and Palamarev (op. cit.) was the last refuge of this fossil oak. Its occurrence in the Early Miocene was most often associated with swamp forest.

Recent equivalents of *Quercus rhenana* are, according to Jähnichen (1966), oaks with entire-margined leaves, such as *Quercus laurifolia* Michx. and *Q. virginiana* Mill. from North America, and according to Rüffle and Palamarev (1979) *Quercus flagelifera* Trel., *Q. imbricaria* Michx. and *Q. laurifolia*. from North and Central America. These conclusions were based on comparative morphological and anatomical analyses of the leaves of *Quercus rhenana* and the mentioned recent species.

Quercus imbricaria occurs as a component of the swampy vegetation in the south-eastern states of the USA (Kearney 1901).

Occurrence in the fossil floras of Poland. Lower Miocene – Osieczów (Raniecka-Bobrowska 1962b, as Q*uercus apocynophylllum* Ettingshausen), Bełchatów (Worobiec 1995). Leaves reported from Lower Miocene of Turów as *Qurecus lusatica* Jähn., *Quercus* sp. and *Castanopsis* sp. (Juchniewicz 1975) belong to *Quercus rhenana* (Rüffle & Palamarev 1979).

Quercus sp. sect. ***Cerris*** Oersted vel sect. ***Dentata*** C.K. Schneid.

Pl. 15, figs 4–6

1995 *Qurecus* cf. *cerrisaecarpa* Kolakovsky; Worobiec, p. 245.

Material. KRAM-P 214: 127, 128, 129.

Description. Flattened cupules, about 2.2 cm in diameter, their margins surrounded by radiate-distributed scales. These scales of lanceolate shape and acute apex, up to 2.5 mm long and about 1.0 mm wide.

Remarks. The cupules found in the investigated material represent *Quercus* L. of the section *Cerris* Oersted or the section *Dentata* C.K. Schneid., as shown by the acute scales visible on the margin of the cupules. Comparing specimens from Bełchatów with other fossil species with similar morphology it has been found that all *Qurecus cerrisaecarpa* Kolakovsky, *Q. microcerrisaecarpa* Kolakovsky, *Q. sapperi* (Menzel) Mai ex Hummel and *Q. variabiliformis* Hummel have longer and wider scales on the margins of the cupules. Therefore, the specimens from Bełchatów may represent a new taxon.

Occurrence in the fossil floras of Poland. Fossil cupules of the *Quercus* species of section *Cerris* occur in the Pliocene of Domański Wierch (Zastawniak 1972) and Ruszów (Hummel 1983).

Juglandaceae

Pterocarya Kunth

Pterocarya paradisiaca (Unger) Ilinskaya

Fig. 5: 8; Pl. 16, figs 1, 1–1b

1849 *Prunus paradisiaca* Unger; Unger, p. 7, Pl. 14, fig. 22.

1962 *Pterocarya paradisiaca* (Unger) Ilinskaya; Ilinskaya, p. 104.

Material. KRAM-P 217: 125/II.

Morphological description. Fragment of one leaflet about 3 cm long (width estimated to reach about 2.0–2.5 cm). Leaf margin simple serrate, apical sides of teeth very short, concave, basal sides convex or acuminate. Venation semicraspedodromous. Secondary veins, preserved in 7 pairs, distributed at intervals of 0.3–0.5 cm form an angle of 70–90° with the primary vein. Near leaf margin secondary veins strongly upwardly curved and interconnected in loops. These loops give fine branches terminating in teeth. Tertiary venation percurrent, tertiaries numerous, oblique to primary vein forming an angle of 150–170° with it. Higher-order venation orthogonal reticulate.

Anatomical description. Leaflet hypostomatic. Upper epidermis (Pl. 16, fig. 1) composed of cells about 30–40 μm in size with slightly undulate anticlinal cell walls. Over the veins cells elongate, rectangular, about 50 μm long and ca. 12 μm wide. Lower epidermis very badly preserved and only the outlines of stomata were visible. Stomata (Pl. 16, fig. 1a) elliptic, 18–20 μm in size. Outer stomatal ledge aperture elliptic-oblongate. On the fragments of lower epidermis are found unicellular, strongly cutinized trichome bases (Pl. 16, fig. 1a), 16–20 μm in diameter.

Remarks. This fragment has been assigned to *Pterocarya paradisiaca* (Unger) Ilinskaya on account of the semicraspedodromous venation, the large angle between the primary vein and secondary veins, the pattern of higher order venation and the shape of the teeth. A comparison of the structure of the upper epidermis of *Pterocarya paradisiaca* from Bełchatów and Wackersdorf (Knobloch & Kvaček 1976) reveals a difference in the size of cells, those from Bełchatów being almost twice as large (Wackersdorf: 15–25 μm, Bełchatów: 30–40 μm). Otherwise, no other significant differences between the leaflets of *Pterocarya* from the two sites were observed.

Carya serrifolia (Goeppert) Kräusel is morphologically similar to *Pterocarya paradisiaca* from Bełchatów but differs in having craspedodromous venation and normally a smaller angle (45–70°) between the primary vein and secondary veins (in *Pterocarya paradisiaca* 70–90°, comp. Palamarev & Petkova 1987, Knobloch 1969, Hummel 1983). *Pterocarya* differs from the leaflets of the other fossil species of the family Juglandaceae, *Cyclocarya cyclocarpa* (Schlecht.) Knobloch, in the venation pattern of the leaflet margin.

Pterocarya paradisiaca is a frequent component of the Tertiary fossil vegetation in Eurasia, known from the Late Oligocene to the Late Pliocene (Zastawniak et al. 1996).

The fossil species *Pterocarya paradisiaca* is similar to recent *Pterocarya pterocarpa* (Michaux) Kunth (= *P. fraxinifolia* Spach), occurring in the forest of Transcaucasia and the adjacent coast of the Caspian Sea (Ilinskaya 1968, Knobloch 1969). This tree grows on wet alluvial or swampy soils, mostly in lowlands and in lower mountains up to 600–700 m a.s.l. It is a component of mixed riparian forest *Alnetum*, growing in river and stream valleys (Boratyński & Boratyńska 1975).

Occurrence in the fossil floras of Poland. Lower Miocene – Turów (Czeczott & Skirgiełło 1961, as *Pterocarya castaneifolia* (Goeppert) Schlecht.); Middle Miocene – Swoszowice (Ilinskaya 1962), Trzcianka (Raniecka-Bobrowska 1970, as *Pterocarya* sp.), Młyny, Stawiany, Stare Gliwice (Zastawniak 1980); Upper Miocene – Sośnica (Meyer 1919, as *Pterocarya castaneifolia*), Wołów (Kräusel 1920, as *Pterocarya castaneifolia*), Bełchatów (Stuchlik et al. 1990), Stare Bystre (Worobiec 1994); Pliocene – Domański Wierch (Zastawniak 1972), Bełchatów (Wójcicki & Zastawniak 1998).

Carya Nuttal

cf. ***Carya serrifolia*** (Goeppert) Kräusel

Fig. 5: 7, 7a, Pl. 16, fig. 3

? 1855 *Quercus serraefolia* Goeppert; Goeppert, p. 17, Pl. 5, fig. 14.

? 1920 *Carya serraefolia* (Goeppert) Kräusel; Kräusel, p. 389, Pl. 5, fig. 2.

Material. KRAM-P 214: (133, 134 – twin specimens), 143.

Morphological description. Only two leaflets were preserved. The larger measured 3.5 cm long, both measured 1.7–2.0 cm wide. Petioles up to 1 cm long. Leaf margin simple serrate, teeth small, apical sides acuminate, rarely straight, basal sides acuminate, apex acute, sinuses between teeth angular. Venation simple craspedodromous, partly semicraspedodromous. Primary vein straight or curved, of moderate thickness. About 9 pairs of secondary veins preserved, arranged mostly alternately at intervals of 0.3–0.6 cm, form an angle of 55–60° with the primary vein. Secondaries curve upward, close to the leaf margin forked, branches enter the teeth. Uppermost branch or secondary vein joins with the superadiacent secondary vein and could be considered as loops. Intersecondary veins imperfectly developed, sometimes not present. Tertiary venation percurrent, oblique to the primary vein and perpendicular to secondary veins, tertiary veins straight or slightly twisted. Higher order venation orthogonal reticulate, very regular. Areoles well developed, mostly tetragonal, small 0.1–0.2 mm in size. Veinlets rarely present, mostly simple.

Remarks. The serration type, the venation pattern (simple craspedodromous with admixture of semicraspedodromous) and the branching character of the secondary veins at the leaf margin indicate that these specimens belong to *Carya* Nutt. and most probably to *Carya serraefolia* (Goeppert) Kräusel. These specimens differ from *Pterocarya paradisiaca* (Unger) Ilinskaya found at Bełchatów in the predominance of craspedodromous secondary veins (*Pterocarya* only has semicraspedodromous venation), the absence of characteristic loops connecting secondary veins with each other and a smaller angle between the primary vein and secondary veins. Both leaflets were most probably the apical leaflets of a compound leaf, as indicated by their long petioles.

Carya serrifolia is common in Neogene European floras (Knobloch 1969, Palamarev & Petkova 1987). This taxon is a representative of the Arctotertiary, warm-temperate element. *Carya serrifolia* is comparable to some recent North American species of *Carya*: *Carya cordiformis* (Wangh.) K. Koch, *C. pecan* (Marsh.) Engl. & Graebn. and *C. tomentosa* Nutt. (among others Knobloch 1961).

Occurrence in the fossil floras of Poland. Middle Miocene – Dobrzyń on the Vistula (Kownas 1956), Młyny (Zastawniak 1980); Upper Miocene – Sośnica (Kräusel 1920), Bełchatów (Stuchlik et al. 1990, Worobiec 1995); Miocene – Wyszonowice (Kräusel 1920); Lower Pliocene – Ruszów (Hummel 1983).

Ulmaceae

Ulmus L.

Ulmus sp.

Fig. 5: 10, 10a

Material. KRAM-P 214: 173 a and b.

Morphological description. Leaf fragment 4.0 cm long and 3.0 cm wide with doubly serrate margin. Teeth large, characteristically upwardly curved, 0.10–0.15 cm high and 0.2–

0.3 cm wide at the base. Both apical and basal sides of teeth mostly acuminate or concave. Tooth apex acute, sinuses between teeth angular. Venation simple craspedodromous. Primary vein straight, of moderate thickness. About 8 pairs of secondary veins preserved, arranged at intervals of 0.3–0.7 cm, form an angle of 45–50° with primary vein. Secondaries curve upward, close to the leaf margin forked. Secondary vein and vein branches enter nearest teeth and terminate in tooth apex. Some branches reach sinuses between teeth. Tertiary venation percurrent, and form an angle of ca. 130° with the primary vein. About 7–8 tertiary veins occur per 1 cm of secondary vein length. Higher-order venation more or less randomly reticulate. Areoles well developed, polygonal, 0.3–0.5 cm in size. Veinlets mostly branched.

Remarks. The characteristic shape of teeth of this leaf fragment allows it to be placed in *Ulmus* L.

Occurrence in the fossil floras of Poland. Fossil leaves of *Ulmus* (*U. carpinoides* Goeppert, *U. pyramidalis* Goeppert, *U. ruszovensis* Hummel) are known from many Neogene fossil floras of Poland (Zastawniak et al. 1996), among others from Lower and Upper Miocene of Bełchatów (Stuchlik et al. 1990, Worobiec 1995).

Nyssaceae

Nyssa L.

Nyssa ornithobroma Unger

Fig. 5: 13

1861 *Nyssa ornithobroma* Unger; Unger, p. 16, Pl. 8, figs 15–18.

Material. KRAM-P 214: 65.

Morphological description. Endocarp impression of elliptic-ovate shape, 1.1 cm long and 0.7 cm wide with remains of compressed seed preserved. Surface of endocarp impression shows longitudinal parallel furrows.

Remarks. The characteristic shape of the fruit allows it to be assigned to *Nyssa ornithobroma* Unger. This taxon is common in the Neogene of central Europe. The occurrence of *Nyssa* L. fruits indicates a swamp vegetation. *Nyssa ornithobroma* has no recent counterpart, it shows only general similarity to *Nyssa sinensis* Oliv. and *N. ogeche* Marsch. (Mai & Gregor 1982).

Occurrence in the fossil floras of Poland. Lower Miocene – Bełchatów (Stuchlik et. al. 1990, Worobiec 1995); Miocene – Zielona Góra (Engelhardt 1892); Pliocene – Bełchatów (Wójcicki & Zastawniak 1998).

Malvaceae sensu lato Judd & Manchester (1997)

Byttneriophyllum Givulescu ex Knobloch & Z. Kvaček

Byttneriophyllum tiliaefolium (Al. Braun) Knobloch & Z. Kvaček

Pl. 16, fig. 4, Pl. 17, figs 1, 2–2d

1845 *Cordia tiliaefolia* Al. Braun; Al. Braun, p. 170.
1965 *Byttneriophyllum tiliaefolium* (Al. Braun) Knobloch & Z. Kvaček; Knobloch & Kvaček, p. 128, Pl. 1, figs 1–3, Pl. 2, figs 1–2, Pl. 3, fig. 2, Pl. 4, figs 1–2, Pl. 5, figs 1–6, Pl. 6, figs 1–3.

Material. KRAM-P 217: 17, 18, 19, 23, 40, 260.

Morphological description. Fragments of entire-margined leaves preserved with remains of petioles. Venation actinodromous. Primary vein branched into between 5 and 7 branches. Secondary veins curve upward, arranged at wide intervals of about 2.5 cm and form an angle of 60–70° with the branches of the primary vein. Secondary veins and primary vein branches interconnected in loops. Tertiary venation percurrent, perpendicular or oblique to the primary vein branches or secondary veins, tertiaries mostly branched. About 3–6 (mostly 5) tertiary veins occur per 1 cm of secondary vein length. Higher-order venation orthogonal reticulate. Areoles well developed, small 0.15–0.20 mm in size. Veinlets rare, mostly simple. Marginal ultimate venation looped.

Anatomical description. Leaves hypostomatic. Upper epidermis (Pl. 17, figs 2, 2d) consists of isodiametric, polygonal, rather regular cells, 12–26 (mostly 16–20 µm) in size. Over the veins cells are elongate, rectangular. Anticlinal cell walls straight. Lower epidermis (Pl. 17, fig. 2a) composed of cells about 14–18 µm in size with rounded to undulate anticlinal cell walls. Stomata (Pl. 17, fig. 2a) rounded, rarely elliptic, 14–20 µm (mostly 17–18 µm) in diameter. Type of stomata unknown. Outer stomatal ledge aperture narrow, spindle-shaped or elliptic, ca. 10 µm long. On the lower epidermis three types of trichome can be found: simple (unbranched), up to 200 µm long; stellate, composed of several arms (Pl. 17, fig. 2b) of diverse size; and simple, glandular, clavate-forms (Pl. 17, fig. 2c), composed of few (mostly 6) cells. The glandular trichomes measure: 32–36 µm long and 12–21 µm wide.

Remarks. The shape and the venation of these leaves are characteristic of the extinct taxon *Byttneriophyllum tiliaefolium* (Al. Braun) Knobloch & Z. Kvaček, which has entire, suborbiculate to nearly orbiculate leaves, often with a cordate, asymmetric base, actinodromous venation and a regular network of tertiary veins. The lower epidermis of these leaves bear both stellate, branched trichomes and simple, glandular, clavate trichomes. The fossil species *Dombeyopsis lobata* Unger is similar to *Byttneriophyllum tiliaefolium*; however, it has mostly lobate leaves with a less dense and not so regular network of tertiary veins and areoles approximately twice as large. Anatomical differences also exist and these have been detailed by Knobloch and Kvaček (1976).

Byttneriophyllum tiliaefolium has been included in the family Sterculiaceae (Givulescu 1979, Sitár & Takač 1993). However, according to Knobloch and Kvaček (1965) it may belong to either the Sterculiaceaae or the Tiliaceae, leaves with a similar morphology and epidermal structure occurring in both families. The results of contemporary taxonomic studies on representatives of the order Malvales indicate that the families Tiliaceae, Sterculiaceae (including Byttneriaceae) and Bombacaceae are of paraphyletic origin, and that they are poorly delimited (Judd & Manchester 1997). Judd and Manchester (op. cit.) connected these families and the family Malvaceae sensu stricto in the complex family Malvaceae sensu lato.

Fossil *Byttneriophyllum tiliaefolium* are morphologically similar, particularly with regards their venation pattern, to the recent genera *Byttneria* Loefling, *Dombeya* Cavanilles and *Pterospermum* Schreber of the Sterculiaceae, *Burretiodendron* Rheder and *Grewia* L., of the Tiliaceae, *Alangium* Lam. of the Alangiaceae, and even *Artocarpus* J.R. & Foster of the Moraceae (Knobloch & Kvaček 1965, Czeczott 1967, Givulescu & Rüffle 1971 and author's own observations).

Byttneriophyllum tiliaefolium has been recognised as a component of swampy vegetation in the Neogene flora of central Europe (Knobloch & Kvaček 1965). The species is known to occur in coal-forming communities and has been found in association with *Glyptostrobus europaeus* (Brongniart) Unger and species of the genera *Acer*, *Alnus*, *Betula*, *Cercidiphyllum*, *Osmunda*, *Populus* and *Salix* (Mai 1995). *Byttneriophyllum tiliaefolium* occurred commonly in central Europe in the Middle and Late Miocene (Zastawniak et al. 1996).

Occurrence in the fossil floras of Poland. Lower Miocene – Turów (Czeczott 1967, as "*Ficus*" *tiliaefolia* Heer); Middle Miocene – Koronowo (Menzel 1910, as *Ficus tiliaefolia* A. Br. sp.), Pierusza (Kräusel 1921, as *Büttneria aequalifolia* (Goeppert) Fr. Meyer), Wichów (Kräusel 1921, as *Büttneria aequalifolia*), Zielona Góra (Kräusel 1920, as *Büttneria aequalifolia*), Smogorzówek, Trzcianka (Raniecka-Bobrowska 1970), Bełchatów (Stuchlik et al. 1990); Upper Miocene – Rataje (Menzel 1910, as *Ficus tiliaefolia* A. Br. sp.), Wołów (Kräusel 1919, as *Büttneria aequalifolia*), Stróża (Kräusel 1920, as *Büttneria aequalifolia*); Miocene – Kunice Żarskie (Engelhardt 1877, as *Ficus tiliaefolia* A. Br.).

Ericaceae

Kalmia L.

Kalmia cf. ***saxonica*** Litke

Fig. 5: 12; Pl. 16, figs 2, 2a

? 1968 *Kalmia saxonica* Litke; Litke, p. 181, Fig. 32–36, Pl. 37, figs 5–9.

Material. KRAM-P 217: 28.

Morphological description. Fragment of narrow-elliptic, coriaceous leaf, 4.0 cm long and 1.2 cm wide. Leaf base rounded, leaf margin most probably revolute. Venation brochidodromous. Primary vein distinct. Secondary veins arranged at irregular intervals form an angle of ca. 50–60° with primary vein. Secondaries curve upward and interconnected in loops. Intersecondary veins present.

Anatomical description. Leaf hypostomatic. Upper epidermis composed of tetragonal or polygonal, strongly cutinized cells, 40–48 µm in size with strongly (Ω-like) undulate anticlinal cell walls. Over the veins cells distinctly elongate. Cuticle shows a fine granulation, maybe due to presence of the rest of epicuticular wax. Lower epidermis cells (Pl. 16, figs 2, 2a) about the same size as upper epidermis and have undulate anticlinal cell walls. Stomata (Pl. 16, fig. 2a) anomocytic, rounded, 21–23 µm in diameter. Outer stomatal ledge aperture wide elliptic or rounded, 8–10 µm in diameter. Stomatal pore very narrow, 8–10 µm long. Two-celled trichome bases (Pl. 16, fig. 2) are to be found on the epidermis and are surrounded by several cells, 16–30 µm in size, distinguished from other epidermal cells by their more or less rounded anticlinal cell walls.

Remarks. The epidermal structure of this specimen indicates its affinity to *Kalmia* L. a member of the Ericaceae, which is characterized by coriaceous leaves, anomocytic stomata and the presence of trichomes on the epidermis. *Kalmia* was first described by Kräusel and Weyland (1959) from Early Miocene lignites under the name *Kalmiophyllum marcodurense* Kräusel & Weyland and was compared with leaves of two recent species *Kalmia latifolia* L. and *K. angustifolia* L. The species was subsequently recombined as *Kalmia marcodurensis* (Kräusel & Weyland) Litke (Litke 1966). Both Kräusel and Weyland (1959) and Litke (op. cit.) gave scant information about the leaf morphology of this taxon, the former only mentioned that they had the entire leaf margins. Weyland et al. (1967, figs 19, 20) described two drawings of leaves within *Kalmiophyllum marcodurense* Kräusel & Weyland, their venation pattern, particularly fig. 20, being similar to that of the leaf from Bełchatów.

A comparison of the epidermis of *Kalmia* cf. *saxonica* Litke from Bełchatów with that of *Kalmiophyllum marcodurense* (= *Kalmia marcodurensis*) reveals distinct differences. The latter has an aperture formed by outer stomatal ledges that is relatively large and clearly visible, while the former has an aperture that is proportionally twice as small. The characteristic striation of the lower epidermal cuticle, always observed in *Kalmiophyllum marcodurense,* is absent in the Bełchatów *Kalmia* specimen. The epidermis of *Kalmiophyllum tectirima* Schneider differs from the Bełchatów *Kalmia* specimen in having numerous glandular trichomes. Based on the size of the aperture formed by the outer stomatal ledges as well as other epidermal features, the specimen from Bełchatów most closely resembles *Kalmia saxonica* Litke. However, the stomata of *K. saxonica* measuring approx. 18 µm in diameter are smaller than those of the specimen from Bełchatów that measure 21–23 µm diameter. *K. saxonica* also differs in having radial cuticular striations around some stomata, which in part have a double anticlinal cell wall, though this feature may be an artefact. Illustrations in Litke (1968) are unclear and do not help to resolve the problem. Excluding the size of the stomata, numerical data characterising the epidermis of *K. saxonica* were not published by Litke (op. cit.). Therefore, to precisely identify the specimen from Bełchatów examination of the holotype of *Kalmia saxonica* from the Lower Miocene of Brandis (Germany) would be necessary.

Leaves of *Kalmia* have only rarely been found in the Tertiary of central Europe. In addition to the authors mentioned above, *Kalmiophyllum marcodurense* was reported by Mai and Walther (1991) from the Lower Miocene of Bitterfeld. Leaf remains of *Kalmia* have more frequently been found as dispersed cuticle in Neogene lignites (Schneider 1969, 1992). Fossil remains of *Kalmia* have also been reported from the Upper Oligocene to the Miocene, mostly the Miocene (Kräusel & Weyland 1959, Schneider 1969).

In the Late Tertiary *Kalmia* was associated with coal-forming vegetation (Schneider 1992), occurring as a component of the vegetation of bush swamps (facies A, Schneider op. cit.) together with *Cyrilla* Gard. and other shrubs, mostly having xeromorphic leaf blade structure. Recent representatives of *Kalmia* are for the most part evergreen shrubs, growing in North America and Cuba. Among recent species, *Kalmia angustifolia* L. is most similar to *Kalmia saxonica* in respect of morphology, while *K. latifolia* L. has a very similar epidermal structure. This last species grows in the eastern part of the USA (from Quebec to Florida) on acid swampy or marshy soils (Knapp 1965) and in forest on the southern slopes of the Appalachian Mountains (Barnes 1991). However, no recent species fully corresponds to fossil *Kalmia saxonica* Litke.

Occurrence in the fossil floras of Poland. Genus and species not reported from Polish Neogene so far.

Cyrillaceae

Cyrilla Garden ex L.

Cyrilla thomsonii Kräusel & Weyland

Fig. 6: 1–4; Pl. 18, figs 1–1c, 2(A)

1954 *Cyrilla thomsonii* Kräusel & Weyland; Kräusel & Weyland, p. 151, Fig. 20, Pl. 32, fig. 6, Pl. 33, fig. 1.

Material. KRAM-P 217: 116, 117, 118/II, 119/III, 138/IV, 182, 192, 193.

Morphological description. Entire-margined, narrow or very narrow-elliptic leaves, up to 6.5 cm long and 1.0–1.8 cm wide. Apex acute, base obtuse, sometimes acute. Venation camptodromous, mostly reticulodromous. Primary vein straight, of moderate thickness or stout. Secondary veins curve upward, very closely arranged, run off primary vein at intervals of 0.1–0.3 cm and form an angle of 60–70^{o} (mostly 60^{o}) with it. Secondaries multiply forked, branches interconnected forming dense network. Close to the leaf margin secondary vein branches interconnected in small loops. Higher-order venation reticulate.

Anatomical description. Leaves hypostomatic. Upper epidermis (Pl. 18, fig. 1a) composed of isodiametric or slightly elongate cells, 22–40 µm (mostly 31–32 µm) in size with slightly undulate anticlinal cell walls. Lower epidermis (Pl. 18, figs 1b, 1c) consists of polygonal cells, 16–36 µm (mostly 27 µm) in size with undulate or rounded anticlinal cell walls. Stomata (Pl. 18, fig. 1c) anomocytic, mostly rounded, sometimes oblate, 25–36 µm (mostly 29 µm) in diameter. Outer stomatal ledge aperture (Pl. 18, fig. 1c) two-lipped (Jähnichen 1969), this feature is characteristic of *Cyrilla*. Outer rim, wide, strongly cutinized, 20–28 µm in diameter, inner rim, spindle-shaped, 14–19 µm long and ca. 7 µm wide.

Remarks. The leaves of *Cyrilla* are characterized by camptodromous venation with a very dense network of lateral veins and their junctions (comp. Valentín Arbona et al. 1992) and two-lipped stomata (Jähnichen 1969). The leaves from Bełchatów differ from *Cyrilla weylandi* Jähnichen in their epidermal structure, particularly the shape of the outer rim of the outer stomatal ledge and the shape of the anticlinal cell walls on the upper epidermis, which in *C. weylandi* are rounded or straight, while those from Bełchatów are slightly undulate. However, the periclinal cell walls of the lower epidermis also differ. *Cyrilla hungarica* Pálfalvy from the Miocene of Magyaregregy in Hungary (Pálfalvy 1957–58) cannot be compared with the Bełchatów material due to the absence of data on the epidermal structure.

Among fossil *Cyrilla* from the Tertiary of Europe, *Cyrilla thomsonii* Kräusel & Weyland, described from the Miocene of Librar (Germany) by Kräusel and Weyland (1954), is most similar to the material from Bełchatów. This species is characterized by the leaves with entire margins, up to 10 cm long and 2 cm wide, with reticulodromous venation and anomocytic stomata, 30–35 µm in diameter (Kräusel & Weyland 1954). The leaves from Bełchatów assigned to *Cyrilla thomsonii* are almost identical to the material from Librar, differing only in an absence of cuticluar striations on the lower epidermis.

Van der Burgh (1998) reported the occurrence of Cyrillaceae leaves (*Cyrilla*, *Cliftona*), wood (*Cyrilloxylon*) and pollen from the Neogene Lower Rhenish brown coal.

Leaves of *Cyrilla* have been reported relatively rarely from the Neogene of central Europe, though dispersed cuticle has been found more frequently, mostly in brown coals. The Cyrillaceae formed part of the Tertiary bog flora occurring in the so-called bog with *Pinus*, where they constituted an important component of the shrubby vegetation (Schneider 1992). Teichmüller (1958) put *Cyrilla* in a community of “Myricaceen-Cyrillaceen-Moores” together with “Sequoia-Waldes”; this stage of the development of the Tertiary peat-forming vegetation corresponds to bush swamp (phase A – “Angiospermen Buschmoor”, Schneider 1992). Palynological studies have confirmed the presence of the Cyrillaceae, from various central European brown coals the concentration of Cyrillaceae/Clethraceae often reaching 10% or more (Ziembińska-Tworzydło 1974, Sadowska 1977, Dyjor et al. 1992, Worobiec 1999).

According to Thomas (1960) the genus *Cyrilla* is now monotypic, with the species *Cyrilla racemiflora* L. According to other authors it comprises 10 species (Mai & Walther 1985). In the south-eastern USA *Cyrilla racemiflora* L. occurs as part of a swamp vegetation with

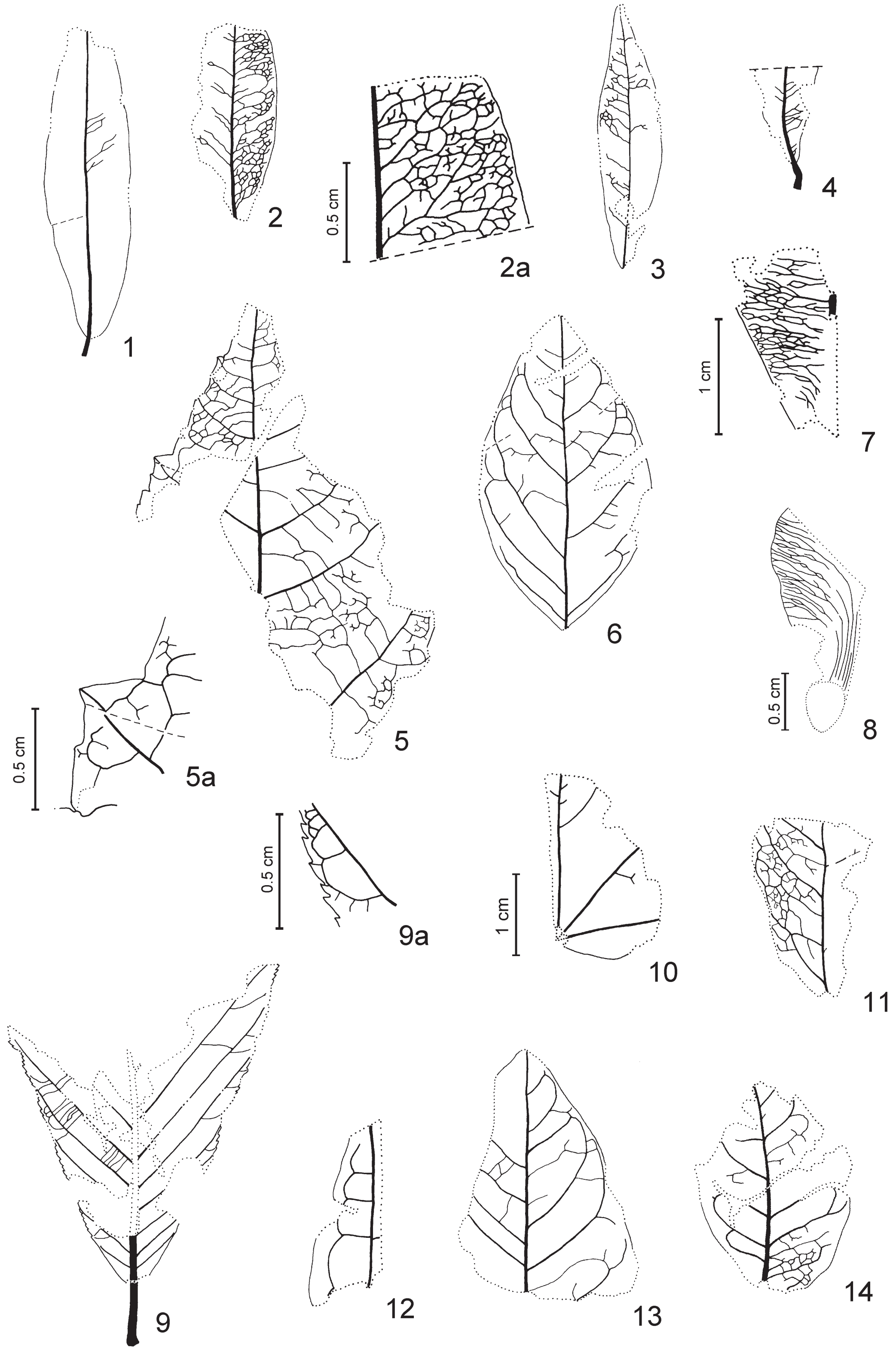

Fig. 6. 1–4 – *Cyrilla thomsonii* Kräusel & Weyland: 1 – specimen KRAM-P 217/138/IV, 2 – specimen KRAM-P 217/118/II, 2a – specimen KRAM-P 217/118/II, enlargement of leaf venation, 3 – specimen KRAM-P 217/119/III, 4 – specimen KRAM-P 217/116; **5–5a** – *Acer tricuspidatum* Bronn sensu Procházka & Bůžek: 5 – specimen KRAM-P 214/172a & b, 5a – specimen KRAM-P 214/172a & b, enlargement of leaf margin; **6 –** *Diospyros anceps* Heer – specimen KRAM-P 217/62; **7–8** – *Acer* sp. div.: 7 – specimen KRAM-P 214/132, 8 – specimen KRAM-P 217/66/II; **9–9a** – *Aesculus* cf. *hippocastanoides* Ilinskaya: 9 – specimen KRAM-P 217/257, 9a – specimen KRAM-P 217/257, enlargement of leaflet margin; **10** – cf. *Acer integrilobum* O.Weber – specimen KRAM-P 211/28; **11** – *Dicotylophyllum* sp. 2 – specimen KRAM-P 214/120/II; **12** – *Symplociphyllum breddini* (Weyland) Juchniewicz – specimen KRAM-P 214/182; **13** – cf. *Diospyros anceps* Heer – specimen KRAM-P 217/177; **14** – *Dicotylophyllum* sp. 6 – specimen KRAM-P 211/1. Specimens without scale were reduced 15% from natural size

evergreen xeromorphic shrubs (community *Persea-Magnolia*, Knapp 1965). These communities occur on acidic peaty soil which are infrequently inundated and are composed of trees and shrubs belonging to *Chamaecyparis*, *Cyrilla*, *Ilex*, *Magnolia*, *Pinus* and *Zenobia*, Ericaceae and many herbaceous plants (Kac 1975). These swamps resemble the communities of Miocene coal-forming bush swamps (Teichmüller 1958, Schneider 1992, Mai 1995).

Occurrence in the fossil floras of Poland. This species has so far not been reported from the Polish Neogene. Dispersed leaf cuticlule from the Early Miocene of Turów has been described in cf. *Cyrilla* sp. (Juchniewicz 1975).

Loranthaceae

Viscophyllum Knoll

Viscophyllum pliocenicum (Engelhardt) Mädler

Fig. 5: 11; Pl. 17, fig. 3

1908 *Potamogeton pliocenicum* Engelhardt; Engelhardt & Kinkelin, p. 225, Pl. 27, figs 25a-n, 26.
1939 *Viscophyllum pliocenicum* (Engelhardt) Mädler; Mädler, p. 20, Pl. 8, figs 8–9, Pl. 11, fig. 5.

Material. KRAM-P 217: 258.

Morphological description. Fragment of branch or entire-margined leaf, 0.9 cm long and 0.2 cm wide without any traces of venation.

Anatomical description. The epidermis is uniform over the entire specimen (Pl. 17, fig. 3). Cells more or less isodiametric, large, 80–160 μm in size, anticlinal cell walls mostly straight, rarely rounded. Cuticle most probably covered by the rest of epicuticular wax (delicate granulation on the surface of epidermis is visible). Stomata brachyparacytic more or less uniformly distributed on the epidermis, rectangular, 80–120 μm in size. Outer stomatal ledge aperture spindle-shaped, 40–50 μm long and 25–30 μm wide.

Remarks. Kräusel and Weyland (1954) listed morphological and anatomical features of six species of *Viscophyllum* Knoll: *V. bipenniferum* Kräusel & Weyland, *V. kirsti* Kräusel & Weyland, *V. miquelii* (Geyler & Kinkelin) Engelhartdt & Kinkelin (= *Viscum miquelii* (Geyler & Kinkelin) Czeczott), *V. morloti* (Unger) Knoll (= *Viscum morlotii* (Unger) Knobloch & Z. Kvaček), *V. pliocenicum* (Engelhardt) Mädler and *V. rottense* Weyland. Of these taxa, only *Viscophyllum pliocenicum* is similar to the specimen from Bełchatów. The specimens described by Kräusel and Weyland (op. cit.) were linear and elongate, and measured 50 mm in length by between 1.5 to 4.0 mm in width. The epidermal characters and leaf shape of the material from Bełchatów is similar to *Viscophyllum pliocenicum* reported by Wąs (1956) from Stare Gliwice. According to this author the fossil remain he has found is a branch fragment. Its size (11 × 4 mm) and aspect, which (as described by the author) “resembles at the first glance a wide fossil needle of the conifer, broken at both ends” corresponds strictly to the specimen of *Viscophyllum pliocenicum* from Bełchatów.

Viscophyllum pliocenicum has been considered by Jähnichen (1991) to represent fragments of strongly cutinized epidermis from the shoots of *Viscophyllum miquelii* (= *Viscum miquelii*). Both species he compared with modern *Viscum album* L. and considered that none of the recent Loranthaceae has leaves so narrow in proportion to their length (Mädler 1939). Litke (1966) recombined *Viscophyllum pliocenicum* with *Viscum miquelii*.

Viscophyllum pliocenicum has only rarely been reported from the Neogene of Europe. In addition to Mädler (1939), Wąs (1956) and Szafer (1961) reported it from the Middle Miocene sediments from Stare Gliwice (Silesia) and Givulescu (1981) from the Pliocene of Chiuzbaia in Romania.

Occurrence in the fossil floras of Poland. Middle Miocene – Stare Gliwice (Wąs 1956, Szafer 1961).

Ebenaceae

Diospyros L.

Diospyros anceps Heer

Fig. 6: 6; Pl. 18, figs 3, 4, Pl. 19, figs 1, 2, 5–5b

1859 *Diospyros anceps* Heer; Heer, p. 12, Pl. 102, figs 15–18.

Material. KRAM-P 217: 24, 27, 46/V, 47, 54/II, 57, 59, 61, 62, 67, 69, 70/II, 72, 78, 82, 87, 90, 103/II, 111, 113/II, 114, 124/II, 132/III, 138/III, 146, 148, 152/II, 179/II, 184/III, 185/III, 199/II, 208, 210/II, 214, 231/III, 232, 234/II, 238, 244/II, 245/III, 250, 252/II, 255.

Morphological description. Entire-margined, elliptic, sometimes ovate leaves, up to 7.0 cm long and 2.6–5.0 cm wide. Leaf base mostly obtuse or rounded, sporadically acute. Venation brochidodromous. Primary vein straight, of moderate thickness. Up to 7 pairs of secondary veins, upwardly curved, forked and interconnected in loops, run off primary vein at intervals of 0.2–0.5 cm near leaf base and up to 1.8 cm (mostly 1.1 cm) in the middle part of the leaf. Secondaries form an angle of 40–60° (mostly 50°, near leaf base 45°, in upper part of leaf 60°) with the primary vein. Intersecondary veins present. Tertiary venation forms a composite network with intersecondary veins. Higher-order venation random reticulate. Areoles well developed, 0.2–0.4 mm in size. Veinlets mostly branched. Marginal ultimate venation looped.

Anatomical description. Leaves hypostomatic. Upper epidermis (Pl. 19, fig. 5) on the intercostal areas composed of isodiametric, rarely slightly elongate cells, 21–55 μm (mostly 30–35 μm) in size. Over the veins these cells are elongate, up to 50 μm long. Anticlinal cell walls mostly straight, rarely rounded. Upper epidermis is distinctly and uniformly cutinized and of yellowish colour. Lower epidermis (Pl. 19, figs 5a, 5b) composed of isodiametric or elongate cells, 20–40 μm (mostly 28–30 μm) in size with straight or rounded anticlinal cell walls. Over the veins cells elongate, up to 40 μm long and 10–15 μm wide. Stomata (Pl. 19, fig. 5b) mainly anomocytic, occasionally paracytic, predominantly elliptic, 18–28 μm (mostly 20–24 μm) in size. Outer stomatal ledge aperture spindle-shaped, 9–18 μm (mostly 12–16 μm) long and 5–8 μm wide. Some of the lower epidermal cells, mostly those surrounding stomata, bear papillae. Scattered unicellular, roundish trichome bases, ca. 20 μm in diameter may be found on the upper epidermis. Similar, very numerous 18–24 μm (mostly 20 μm) diameter trichome bases may be found on the lower epidermis.

Remarks. These morphological and anatomical features indicate the inclusion of the remains in *Diospyros* L. Numerous broken trichomes stuck to the rock surface and described as glands were found associated with leaf impressions of *Diospyros brachysepala* Al. Braun sensu Hantke at Oehningen, (Hantke 1954). Hantke (op. cit.) considered this feature characteristic of the fossil leaves of *Diospyros*. Similar, separated trichomes were observed on the surface of leaf impressions from Bełchatów. This material was compared with three fossil taxa: *Diospyros lotoides* Unger, *Diospyros anceps* Heer and *Diospyros brachysepala* Al. Braun sensu Hantke.

The fossil species *Diospyros lotoides* Unger described by Unger (1861) differs markedly in their morphology and anatomy from leaves of *Diospyros* from Bełchatów. Raniecka-Bobrowska (1957) who found a leaf of *Diospyros lotoides* in Krywałd, gave its fairly detailed morphological and anatomical characteristics. The epidermis of this leaf differs from the epidermis of *Diospyros* from Bełchatów (the absence of trichomes and a slightly different shape of cells of the upper epidermis). *Diospyros anceps* and *Diospyros brachysepala* are reported to have slight morphological differences, the former having a more rounded base, leaves that are widest in their lower part and more branching of the secondary veins (Heer 1859). Kräusel (1938) identified many transitional forms between *Diospyros anceps* and *Diospyros brachysepala* and was of the opinion that they represent a single species, a claim supported by Raniecka-Bobrowska (1962b). Author of this paper, analysing variability in the leaves from Bełchatów is likewise of this opinion. Palamarev and Petkova (1987) noticed that the fossil species *Diospyros brachysepala* has been created by Braun (1836) to describe fossil flower calyces. This fact, eliminates the use of the name *Diospyros brachysepala* for leaf remains.

The epidermal structure of *Diospyros anceps* from Bełchatów was compared with that of the recent species *D. kaki* L., *D. lotus* L. and *D. virginiana* L. The leaves of all three species are characterized by the presence of simple and often rather long trichomes with unicellular bases, anomocytic stomata and striation of the cuticle. *Diospyros anceps* from Bełchatów has similar stomata and trichomes but no striations on the cuticle. Of the three comparitor species *Diospyros kaki* which grows in eastern Asia (Japan) was anatomically most similar. This accords with conclusions made about *Diospyros brachysepala* from the northern Czech Republic (Bůžek 1971).

Fossil leaves placed in either *Diospyros anceps* or *Diospyros brachysepala* have often been found in Tertiary floras in central Europe from the Early Oligocene to Early Pliocene

(Palamarev & Petkova 1987). Plants from this genus have been included in the Tertiary Mixed Mesophytic Forest community (Mai 1995), where *Diospyros kaki* grows at the present time. However, fossil *Diospyros anceps* may also have been a component of swamp and riparian forest stands. Extant *Diospyros virginiana* grows in wet habitats, including riparian forest, and sometimes in the southeastern USA in swamp forest (Barnes 1991). *Diospyros lotus* prefers wet habitats in the vicinity of rivers and streams.

Occurrence in the fossil floras of Poland. Lower Miocene – Rozewie (Heer 1869), Osieczów (Raniecka-Bobrowska 1962b, as *Diospyros* sp. cf. *D. anceps* Heer); Middle Miocene – Swoszowice (Ilinskaya 1962, as *Diospyros brachysepala*).

cf. ***Diospyros anceps*** Heer

Fig. 6: 13; Pl. 18, fig. 5

Material. KRAM-P 217: 105/II, 177, 224.

Remarks. Fossil leaf fragments similar to *Diospyros anceps* Heer but too poorly preserved to univocally assigned to this species.

Aceraceae

Acer L.

Acer integrilobum O. Weber

Pl. 20, figs 1–5

1852 *Acer integrilobum* O. Weber; O. Weber, p. 196, Pl. 22, fig. 5a.

Material. KRAM-P 211: 36 i 37; KRAM-P 214: 15, 30, 43, 53, 61, 63, 68/II, 74, 84, 87/II, 101, 112, 139, 142, 144, 150, 159, 179.

Morphological description. Leaves trilobate, lobe apex mostly acuminate rarely acute, leaf base rounded, sometimes cordate. Leaves entire-margined or simple serrate with very few teeth, apical sides of teeth rounded, basal sides mostly convex. Only one leaf with petiole preserved, petiole measures 1.5 cm long. Venation actinodromous. Primary vein branched 3 times, rarely 5 branches, these form an angle of 50–65^o with each other. Numerous secondary veins, curved towards lobe apex and forked, run off each of the primary vein branches. Secondary veins and their branches close to leaf margin interconnected in multistage loops. In case of serrate leaves, the nearest secondary vein branch enters the tooth and terminates in tooth apex. Tertiary venation random reticulate as is the higher-order venation. Areoles well developed, polygonal, 0.2–0.5 mm in size. Veinlets mostly absent if present always simple. Marginal ultimate venation looped.

Anatomical description. On a small epidermal fragment the orientation of which was indefinite were found polygonal cells, 25–35 µm in size with rounded or slightly undulate anticlinal cell walls (Pl. 20, fig. 1a). Stomata not found.

Remarks. The described above leaf remains are most similar to fossil *Acer integrilobum* O. Weber described in detail by Walther (1972) and Procházka and Bůžek (1975). From rather similar leaves of *Acer integerrimum* (Viviani) Massalongo they differ above all by the presence of teeth on lobe margins and the trilobate leaves. From the other similar fossil maple species, *Acer pseudomonspessulanum* Unger, *Acer integrilobum* differs by the acuminate apices of lobes. *Acer pseudomonspessulanum* has a lobe apex mostly obtuse or acute, and rarely acuminate.

Acer integrilobum is a taxon whose position within *Acer* is uncertain. Procházka and Bůžek (1975) are of the opinion that recent analogues of this fossil species should be searched for principally among sections *Platanoidea* Pax, *Goniocarpa* Pojark., *Saccharina* Pax and even *Rubra* Pax. According to Walther (1972) the East-Asiatic maples: *A. cappadocicum* Gleditsch and *Acer longiceps* Franch are most similar to *Acer integrilobum*.

Acer integrilobum occurred in the Tertiary fossil floras of central Europe from the Late Oligocene to the Latest Miocene (Walther 1972).

Occurrence in the fossil floras of Poland. Species reported so far only from the Lower Miocene of Bełchatów (Worobiec 1995).

cf. ***Acer integrilobum*** O. Weber

Fig. 6: 10

Material. KRAM-P 211: 28; KRAM-P 214: 70, 102, 117, 122, 145.

Remarks. Specimens similar to *Acer integri-*

lobum O. Weber but too poorly preserved for univocal identification.

Acer tricuspidatum Bronn sensu Procházka & Bůžek

Fig. 6: 5, 5a; Pl. 19, fig. 4, Pl. 20, fig. 6

1838 *Acer tricuspidatum* Bronn; Bronn, p. 865, Pl. 35, figs 10a, b.
1975 *Acer tricuspidatum* Bronn sensu novo; Procházka & Bůžek, p. 24, Figs 2, 3, 4d, 5–13, Pl. 22, figs 1–7, Pl. 23, figs 1–6, Pl. 24, figs 1–4.
1995 *Acer* sp. 1; Worobiec, p. 245.

Material. KRAM-P 214: 172a and b (the two fragments of the same leaf).

Morphological description. Description based on a single specimen preserving only the central lobe that measures 8.0 cm long and 4.5 cm wide. Lobe apex most probably attenuate. Leaf margin irregularly doubly serrate. Primary teeth large, 0.45 cm wide at the base and 0.2 cm high, secondary teeth smaller. Apical sides of teeth acuminate or convex, basal sides acuminate, longer than apical sides, tooth apex slightly roundish, sinuses between teeth angular. Venation actinodromous. Primary vein straight. Secondary veins, upwardly curved and forked, form an angle of 55–70^{o} with primary vein, the angle increases towards lobe apex. Secondary veins reach primary teeth, branches of secondaries terminate in secondary teeth. Some of the branches interconnected in loops (mostly near lobe apex). Tertiary venation perpendicular, sometimes oblique to the secondary veins, tertiaries branched, midway between secondary veins they form a characteristic network of interconnected veins. 3 to 5 tertiary veins occur per 1 cm of secondary vein length. Some of the tertiary veins connected with the primary vein of the lobe and resemble intersecondary veins. Higher-order venation more or less orthogonal reticulate. Areoles well developed.

Anatomical description. Lower epidermis (Pl. 20, fig. 6) composed of polygonal cells, 24–38 µm in size, with straight walls. Stomata anomocytic or seemingly paracytic (Hummel 1983) elliptic, 16–18 µm in size. Outer stomatal ledge aperture rather distinct and of characteristic elliptic-rectangular shape, ca. 16 µm long. On the lower epidermis are found very numerous, unicellular, simple trichomes, 50–80 µm long and ca. 8 µm wide with unicellular trichome bases 6–7 µm in size. Trichomes distributed mostly over the veins.

Remarks. The leaf fragment can be assigned to *Acer tricuspidatum* Bronn sensu Procházka & Bůžek, the identification being confirmed by the epidermal structure despite only the central lobe being preserved. Both the shape of stomata and the presence of unicellular, simple trichomes on the lower epidermis are characteristic.

Acer tricuspidatum is classified within sectio *Rubra* Pax (Walther 1972, Procházka & Bůžek 1975) and is related to recent *Acer rubrum* L. and *Acer saccharinum* L (Hantke 1954, Kräusel & Weyland 1959). The epidermal morphology and anatomy of extant *Acer rubrum*, *Acer saccharinum* and *A. hyrcanum* Frisch. & Mey are comparable with that of fossil *Acer tricuspidatum* (Walther 1972). *Acer tricuspidatum* from Bełchatów appears morphologically most similar to *Acer rubrum*. According to Kräusel and Weyland (1959) no differences in the epidermal structure exist between *Acer tricuspidatum* and *Acer rubrum*.

Acer tricuspidatum is known from central Europe from the Middle Oligocene to the Pliocene. It was most frequently found in the Miocene, at the end of this epoch it began to disappear in central Europe, and in the Pliocene it was found to occur in southern Europe, e.g. in Bulgaria and Italy (Procházka & Bůžek 1975).

Occurrence in the fossil floras of Poland. Lower Miocene – Osieczów (Raniecka-Bobrowska 1962b, as *Acer trilobatum* (Sternberg) Heer), Bełchatów (Worobiec 1995, as *Acer* sp. 1); Middle Miocene – Kokoszyce (Meyer 1919, as *Acer trilobatum*), Pierusza (Kräusel 1921, as *Acer trilobatum*), Dobrzyń on the Vistula (Kownas 1956, as *Acer* sp. (*Acer trilobatum*), Stare Gliwice (Szafer 1961, as *Acer trilobatum*), Młyny (Zastawniak 1980); Late Miocene – Sośnica (Kräusel 1921, as *Acer trilobatum*); Lower Pliocene – Ruszów (Hummel 1983).

Acer sp. div.

Fig. 6: 7, 8; Pl. 19, fig. 3

Material. KRAM-P 214: 132; KRAM-P 217: 66/II.

Morphological description. Fragment of maple samara (Fig. 6: 8) 2.2 cm long and 0.9 cm wide (in the widest place). Samara distinctly narrows towards seed, has distinct and dense venation. Veins bent towards seed and reach them in the right angle. Veins forked, branches interconnected forming dense network. The seed impression appears rounded but deformed, measuring 0.5 × 0.4 cm in size.

The second fragment of maple samara (Fig. 6: 7) measures 1.7 cm long and 0.9 cm wide (in the widest place). Samara distinctly narrows towards seed (seed not preserved) and at its narrowest measures about 0.4 cm wide. Venation distinct and dense. In the broadest place veins slightly curved towards samara margin, but in the narrowest, near impression of seed, veins curved almost right angled (from samara margin towards seed). Venation forms a dense network.

Remarks. The fruits are fragments of the maple samaras, but probably belong to different species. Identification to species is impossible due to the incompleteness of the specimens.

Hippocastanaceae

Aesculus L.

Aesculus cf. ***hippocastanoides*** Ilinskaya

Fig. 6: 9, 9a; Pl. 21, figs 1–1b

? 1968 *Aesculus hippocastanoides* Ilinskaya; Ilinskaya, p. 79–80, Pl. 24, fig. 8, Pl. 27, figs 1–3, Pl. 28, figs 4–6, Pl. 29, fig. 8, Pl. 36, figs 2, 3.

Material. KRAM-P 217: 257.

Morphological description. Fragment of leaflet, 6.0 cm long and 4.5 cm wide, basal part of leaflet cuneate but leaf base rounded. Leaflet margin simple serrate, apical sides of teeth straight, rarely convex, basal sides convex, rarely acuminate, tooth apex acute. Venation semicraspedodromous. Primary vein straight, stout. Secondary veins, preserved in 9 pairs, arranged at intervals of 0.3–0.8 cm form an angle of 35–45^{o} with primary vein. Secondaries straight, close to the leaflet margin upwardly curved and forked. One branch terminates in nearest tooth and the other joins with superadiacent secondary vein. The rest of the secondary vein branches are interconnected in loops. These loops supply teeth by fine veins. Tertiary venation percurrent, perpendicular to the secondary veins and oblique to the primary vein, closely arranged (about 10 tertiary veins occur per 1 cm of secondary vein length). Higher-order venation orthogonal reticulate.

Anatomical description. Leaflet hypostomatic. Upper epidermis (Pl. 21, figs 1, 1b) composed of isodiametric, polygonal cells, 22–34 μm in size, with characteristic wide-undulate anticlinal cell walls. Structure of lower epidermis barely visible, only the outlines of a few outer stomatal ledge apertures (Pl. 21, fig. 1a) being discernible. These apertures are narrow-elliptic or spindle-shaped, and measure 10–13 μm long. Rarely, unicellular trichome bases, ca. 16 μm in diameter were found on the lower epidermis.

Remarks. The morphology of the material, particularly the semicraspedodromous venation, the high density of secondary and tertiary veins, and the serration indicate affinity with *Aesculus*. Very similar leaflets were found by Straus (1930) in the Willershausen flora, where he described them as *Aesculus hippocastanum* L. and *A.* cf. *pavia* L. The upper epidermis of the specimen from Bełchatów has wide-undulate cell walls as in *A. hippocastanum* from Willershausen but it differs in the serration of the leaf margin.

Morphologically *Aesculus hippocastanoides* Ilinskaya described from the Pliocene of Ilnica in the Transcarpathians (Ilinskaya 1968) and the Miocene of the Precarpathians (Shvareva 1983) is most similar. Fossil leaves or single leaflets of *Aesculus* have also been reported from several Neogene localities in Europe, e.g. *Aesculus* cf. *hippocastanum* L. from the Pliocene of Thuringia (Mai & Walther 1988), *Aesculus* sp. from the Uppermost Miocene of the Lower Rhine Embayment (Belz & Mosbrugger 1994) or *Aesculus hippocastanum* L. from the Pliocene of Hambach (Van der Burgh & Zetter 1998). Velitzelos et al. (1983) found leaves and fruits of *Aesculus* in the Lower Miocene limestones in the northern part of Evia Island (Greece). All these identifications were based on the morphology of the leaflets alone; their anatomical features have not been investigated. Outside of Europe, *Aesculus* is known from the Tertiary of Japan (Tanai & Suzuki 1963), China (Hu & Chaney 1940) and North America (Axelrod 1966). The identification of the leaflet of *Aesculus* aff. *hippocastanum* from the Miocene of Zaleśce (Czeczottowa 1951) was questioned by Ilinskaya (1968) on account of the poor state of preservation of this specimen.

Aesculus hippocastanoides is comparable with *Aesculus octandra* Marsch. and *A. glabra* Willd. from North America (Ilinskaya 1968). The former is a component of mesophytic forest and is not found in wet habitats, the other grows in riparian forest (Barnes 1991).

Occurrence in the fossil floras of Poland. To date this species has not been reported from the Polish Neogene.

Dicotyledonae incertae sedis

Symplociphyllum Z. Kvaček & Bůžek

Symplociphyllum breddini (Weyland) Juchniewicz

Fig. 6: 12; Pl. 21, figs 4, 4a

1934 *Kadsura breddini* Weyland; Weyland, p. 68, Pl. 11, fig. 2.
1959 *Kadsura breddini* (Weyland) emend. Kräusel & Weyland; Kräusel & Weyland, p. 108–110, Fig. 8, Pl. 20, figs 16, 17, Pl. 21, figs 18–24.
1975 *Symplociphyllum breddini* (Weyland) Juchniewicz; Juchniewicz, p. 89–90, Pl. 16, figs 1–3.
1995 *Dicotylophyllum* sp. 1 Worobiec; Worobiec, p. 245.

Material. KRAM-P 214: 182.

Morphological description. A small leaf fragment, 2 × 1 cm in size, entire-margined, with brochidodromous venation. Only three pairs of secondary veins preserved, interconnected in loops, these form an angle of about 90° with the primary vein. Other features of leaf morphology not visible.

Anatomical description. Leaf hypostomatic. Upper epidermis composed of mostly elongate cells, 40–60 µm in size. Anticlinal cell walls mostly V-undulate (rarely U-undulate), strongly cutinized. Cuticle granulate. Papillae measuring about 15 µm in diameter and that narrow upward and have rounded apices may be found on the upper epidermis. Intercostally the lower epidermal cells (Pl. 21, fig. 4) are mostly of variable-shape, measuring 40–60 µm in size. Anticlinal cell walls distinctly V-undulate (rarely U-undulate), sometimes knobs are found on the tops of waves. Cuticle distinctly striated. On the lower epidermis, over the veins, cells are rectangular, rather elongate, 70–150 µm long, anticlinal cell walls straight, short walls oblique. The cuticle of these cells has no ornamentation. Stomata paracytic (Pl. 21, fig. 4a) rather variable, wide elliptic to rounded, 30–40 µm in diameter. Outer stomatal ledge aperture wide elliptic or rounded, 18–20 µm in diameter. Roundish, papillae-like protrusions may be found on the stomatal poles. Unicellular trichome bases, ca. 20 µm in diameter, surrounded by 6 cells may be found on the lower epidermis.

Remarks. The species was first erected as *Kadsura breddini* by Weyland (1934) the diagnosis subsequently being emended (Kräusel & Weyland 1959). Epidermal material from Turów that had been placed in this species was studied by Juchniewicz (1975) and compared with recent representatives of the genus *Kadsura* Kaempf. ex Juss. Differences between the two were apparent, the fossil material appearing similar to extant *Symplocos brandii* Elm. from the Philippines. *Kadsura breddini* was then recombined within genus *Symplociphyllum* Z. Kvaček & Bůžek as *Symplociphyllum breddini* (Weyland) Juchniewicz (Juchniewicz 1975). The genus also includes *Symplociphyllum hradkaense* Z. Kvaček & Bůžek (= *Gordonia hradekensis* (Z. Kvacek & Bůžek) Palamarev & Bozukov) from the Early Miocene of the Kristina mine in the Czech Republic (Kvaček & Bůžek 1966). However, both species differ morphologically. The leaf fragment from Bełchatów is assigned to *Symplociphyllum breddini* as it has an entire margin and its secondary veins diverge from the primary vein at an angle of approx. 90°. In *S. hradkaense* the leaves have serrate margins, their secondary veins do not form distinct loops between themselves, and the angle formed by the secondary veins and the primary vein varies between 25 and 55°. Epidermal differences also exist, *Symplociphyllum breddini* having paracytic stomata with no distinct polar T-shaped cuticular thickening unlike *S. hradkaense*.

This genus may belong to the Theaceae rather than the Symplocaceae (Knobloch & Kvaček 1976), though the leaves from Bełchatów share similarities of the epidermis with the Hamamelidaceae (Z. Kvaček, pers. comm.).

Occurrence in the fossil floras of Poland. Lower Miocene – Turów (Juchniewicz 1975), Bełchatów (Worobiec 1995, as *Dicotylophyllum* sp. 1).

“*Ficus*” *truncata* Heer sensu Bůžek

Fig. 7: 6; Pl. 21, figs 2, 2a

1859 *Ficus truncata* Heer; Heer, p. 183, Pl. 152, fig. 15.
? 1910 *Phyllites anamirtaceus* Menzel; Menzel, p. 184–187, Pl. 15, figs 1, 6.
1971 “*Ficus*“ *truncata* Heer; Bůžek, p. 92–94, Fig. 15, Pl. 46, figs 1–9, Pl. 47, figs 1–8, Pl. 48, figs 1–4.

Material. KRAM-P 217: 131.

Morphological description. Fragment of entire-margined leaf, most probably orbiculate, 7 × 5 cm in size. Venation actinodromous, primary vein divides into between 5 and 7 branches with an angle of about 30^o between them. Higher-order venation reticulate.

Anatomical description. Leaf hypostomatic. Upper epidermis (Pl. 21, fig. 2) composed of isodiametric or rectangular cells, 18–32 µm (mostly 24 µm) in size, over the veins cells are more elongate, up to 45 µm long. Anticlinal cell walls straight or rounded. Trichome base-like structures composed of 6–8 radially arranged cells are found on the upper epidermis and surround strongly cutinized apertures measuring about 14 µm in diameter. Whole structure is about 40 µm in size. Lower epidermis (Pl. 21, fig. 2a) consists of variable-shape cells, 36–40 µm across with undulate anticlinal cell walls. Over the veins cells strongly elongate, up to 70 µm long and 7–14 µm wide. Stomata (Pl. 21, fig. 2a) most probably anomocytic, elliptic, 20–23 µm in size. Outer stomatal ledge aperture elliptic, 9–12 µm long and 5–6 µm wide. Some of stomata surrounded by cuticular striations perpendicular to the stomatal pore. What are most probably glandular trichomes are found over the veins, their remains consist of a few cells (mostly four) measuring up to 45 µm long and about 18 µm wide.

Remarks. Morphologically, this material is most similar to “*Ficus*” *truncata* Heer from Oehningen (Heer 1859). This species has been found in the Miocene of the Czech Republic and has been placed in synonymy with *Ficus rüminiana* Heer, *F. titanum* Ettingshausen and the leaves of *Populus mutabilis* Ettingshausen not Heer (Bůžek 1971).

Phyllites anamirtaceus Menzel from Koronowo (Menzel 1910) shows a great morphological similarity to “*Ficus*” *truncata*, and may represent the same taxon. *Phyllites* sp. 1 from the Early Pliocene of Ruszów is reportedly very similar to the leaves of *Phyllites anamirtaceus* Menzel (Hummel 1983). However, its epidermal structure is unknown and its preservation is so poor that it will not be discussed further.

“*Ficus*“ *truncata* is morphologically similar to *Byttneriophyllum tiliaefolium* (Al. Braun) Knobloch & Z. Kvaček (Bůžek 1971), differing from it in its venation pattern, particularly that of the third order. These taxa also differ in their epidermal structure, though ”*Ficus*“ *truncata* from Bełchatów has similar glandular trichomes to *Byttneriophyllum tiliaefolium*. As earlier descriptions of ”*Ficus*“ *truncata* have not included data on the epidermal structure they cannot be compared to the material from Bełchatów.

Morphologically the leaf fragment from Bełchatów assigned to “*Ficus*” *truncata* resembles extant *Tilia* L., *Populus* L. and *Cercis* L., and some representatives of the genus *Cocculus* DC. from family Menispermaceae (Z. Kvaček, pers. comm.). The epidermal structure of Bełchatów material resembles that of the genus *Tilia*, having similar characteristic glandular trichomes. However, similar trichomes also occur in the Sterculiaceae (Knobloch & Kvaček 1965). The striation of the cuticle around the stomatal apparatus that is in places noticeable in the fossil leaf fragment from Bełchatów, can be observed in the leaves of both *Populus* and *Tilia*. However, it differs from *Populus* in the structure of stomata (in *Populus* they are paracytic). “*Ficus*” *truncata* differs slightly from the leaves of *Cercis* and *Cocculus* in its venation pattern and more markedly in its epidermal structure. Also the recent representatives of the genus *Ficus* of the family Moraceae are characterized by the different anatomy and usually the other morphology of the leaves.

Occurrence in the fossil floras of Poland. Middle Miocene – Bełchatów (Stuchlik et al. 1990).

Dicotylophyllum **sp. 1**

Fig. 7: 5; Pl. 22, fig. 2

1995 *Dicotylophyllum* sp. 1; Worobiec, p. 245.

Material. KRAM-P 214: 80.

Morphological description. Fragment of entire-margined leaf, 5.0 cm long and 2.0 cm wide, leaf base cuneate but near petiole rounded, fragmentary petiole 0.6 cm long and 0.2 cm wide. Venation brochidodromous. Primary vein straight and stout. About 3 to 4 secondary veins preserved, these depart the primary vein near the leaf base at intervals of 0.7 cm and form an angle of 40–45^o with it. Higher-order venation not visible.

Anatomical description. Lower epidermis (Pl. 22, fig. 2) in the intercostal areas composed of variably shaped cells that are sometimes elongate, measuring 36–50 µm in size. Anticlinal cell walls V-undulate, often with knobs. The cells over the veins differ others on the upper epidermis cells, they are mostly rectangular, rather elongate, 70–120 µm long and 10–25 µm wide, anticlinal cell walls of these cells straight, short walls of cells oblique. Stomata mostly paracytic, sometimes anomocytic, wide elliptic to rounded (shape is rather variable), 28–36 µm in diameter. Numerous irregularly distributed and irregularly shaped strongly cutinized structures, probably the result of animal attack, are found on the lower epidermis (Pl. 22, fig. 2). One unicellular trichome base about 24 µm in diameter was found on the lower epidermis.

Remarks. Although morphologically distinct, differing in the angle of departure of the secondary veins from the primary vein, the epidermis of *Dicotylophyllum* sp. 1 shows great similarity to *Symplociphyllum breddini* (Weyland) Juchniewicz. However, anatomically it differs in having mixed stomatal types (both anomocytic and paracytic) and in the undulation of the epidermal walls. This material from Bełchatów shows great similarity to *Dicotylophyllum* sp. 1 from Wackersdorf (Knobloch & Kvaček 1976) which has been related to the Theaceae, particularly the genus *Schima* Reinw. ex Blume. However, *Dicotylophyllum* sp. 1 from Bełchatów has no cuticular striation around the stomatal apparatus.

Occurrence in the fossil floras of Poland. Early Miocene – Bełchatów (Worobiec 1995).

***Dicotylophyllum* sp. 2**

Fig. 6: 11; Pl. 21, fig. 3

1995 *Dicotylophyllum* sp. 2; Worobiec, p. 245.

Material. KRAM-P 214: 120/II.

Morphological description. Small fragment of entire-margined leaf 3.2 × 2.1 cm in size, with brochidodromous venation. Primary vein slightly bent and of moderate thickness. Four pairs of secondary veins preserved, these run off the primary vein at intervals of about 0.9 cm and form angles of 50–55^o in the middle part of leaf and 40^o near the leaf base with it. Secondaries curve upward and interconnect in loops. Tertiary venation forms composite network with intersecondary veins. Higher-order venation random reticulate. Areoles imperfectly develop. Veinlets branched.

Anatomical description. The specimen macerated poorly. Orientation of the cuticle was not possible. Stomata measuring several microns in size were observed on the epidermis (Pl. 21, fig. 3) along with a few, most probably unicellular, rounded, very strongly cutinized sharp-edged trichome bases that measured 12–20 µm in size.

Remarks. The described leaf fragment has been preserved in poor state for determination. The venation pattern resembles slightly the venation in the fossil leaf described by Hably and Kvaček (1997) from Gérce as *Dicotylophyllum* sp. 2 and leaves from the genus *Hedera* L.

Occurrence in the fossil floras of Poland. Lower Miocene – Bełchatów (Worobiec 1995).

***Dicotylophyllum* sp. 3**

Fig. 7: 1; Pl. 22, fig. 3

Material. KRAM-P 217: 248.

Morphological description. Fragment of entire-margined leaf, 5.2 × 5.0 cm in size. Venation brochidodromous. Primary vein straight and of moderate thickness. Secondary veins arranged alternately, form an angle of 55–65^o with the primary vein. Secondaries curved upward, close to the leaf margin interconnected in loops. Tertiary venation percurrent, perpendicular or oblique to the secondary veins. The tertiaries form an angle of about 135^o with the primary vein. 3 to 6 tertiary veins occur per 1 cm of secondary vein length. Higher-order venation reticulate.

Anatomical description. The upper

epidermal cells (Pl. 22, fig. 3) are mostly tetragonal with straight anticlinal cell walls and measuring up to 40 µm in size. The structure of the lower epidermis is unknown. However, distinct striations are visible on the cuticle. Only a single stomata was clearly visible, it was elliptic and measured about 24 µm in size. The outer stomatal ledge aperture was distinctly bicipital and thick, wide spindle-shaped, measuring up to 28 µm long and 8–12 µm wide. Strongly cutinized star-like trichome bases measuring about 10–13 µm in diameter were found on the lower epidermis.

Remarks. Systematic position unknown.

Occurrence in the fossil floras of Poland. To date similar leaf remains have not been reported from the Tertiary of Poland.

Dicotylophyllum **sp. 4**

Fig. 7: 2; Pl. 22, fig. 1–1b

Material. KRAM-P 217: (190/II, 191 – twin specimens).

Morphological description. Leaf fragment, entire-margined, probably ovate, 6 cm long, presumed width about 4 cm, with cordate base. Venation actinodromous imperfect. Primary vein branches into 5, though only 3 branches are visible (Fig. 7:2), an angle of 35–40° separates them. Higher-order venation reticulate. Marginal ultimate venation most probably looped.

Anatomical description. Leaf hypostomatic. Cells of upper epidermis (Pl. 22, fig. 1) predominantly tetragonal, 20–42 µm in size, anticlinal cell walls slightly undulate or curved, rarely straight. Lower epidermis (Pl. 22, fig. 1a) composed of polygonal cells, 20–30 µm in size, with rounded or undulate anticlinal cell walls. Stomata (Pl. 22, fig. 1a) anomocytic, wide elliptic to rounded, 18–22 µm in diameter. Outer stomatal ledge aperture wide spindle-shaped or elliptic, 9–13 µm long and ca. 6–7 µm wide. Scattered unicellular trichome bases were found (Pl. 22, fig. 1b).

Remarks. Systematic position unknown.

Occurrence in the fossil floras of Poland. To date similar leaf remains have not been reported from the Tertiary of Poland.

Dicotylophyllum **sp. 5**

Fig. 7: 3; Pl. 22, fig. 5

Material. KRAM-P 217: 196/II.

Morphological description. Leaf fragment 6.0 × 4.0 cm in size, leaf base obtuse. Leaf margin serrate, teeth small, apical and basal sides of teeth straight, tooth apex acute. Venation semicraspedodromous. Primary vein straight and of moderate thickness. Only five pairs of secondary veins preserved, arranged more or less opposite and at intervals of 0.3–2.0 cm along the primary vein with which they form an angle of about 45°. Secondaries curve upward, forked and interconnected in loops. Teeth are supplied by veins arising from secondary vein loops close to the leaf margin. Tertiary venation percurrent, tertiaries simple or forked, mostly perpendicular, sometimes oblique to the secondary veins. About 4 tertiary veins occur per 1 cm of secondary vein length. Higher-order venation orthogonal reticulate. Areoles small, 0.10–0.25 mm in size. Veinlets rarely present, simple. Marginal ultimate venation looped.

Anatomical description. Leaf probably hypostomatic. Cuticle of both sides of epidermis striate. Stomata wide elliptic, 13–24 µm (mostly 20 µm) in diameter. Outer stomatal ledge aperture wide elliptic, 9–18 µm long and 5–11 µm wide. Other features of both sides of epidermis not visible.

Remarks. A somewhat similar venation pattern can be found in recent representatives of the genera *Euonymus* L., *Actinidia* Lindley and *Clethra* L.. A comparison of the structure of the epidermis in the fossil specimen with recent herbarium material has not resolved the systematic position of *Dicotylophyllum* sp. 5.

Occurrence in the fossil floras of Poland. To date similar leaf remains have not been reported from the Tertiary of Poland.

Dicotylophyllum **sp. 6**

Fig. 6: 14

Material. KRAM-P 211: 1.

Morphological description. Fragment of probably entire-margined leaf 3.8 × 2.8 cm in size. Venation brochidodromous. Primary vein slightly bent and of moderate thickness.

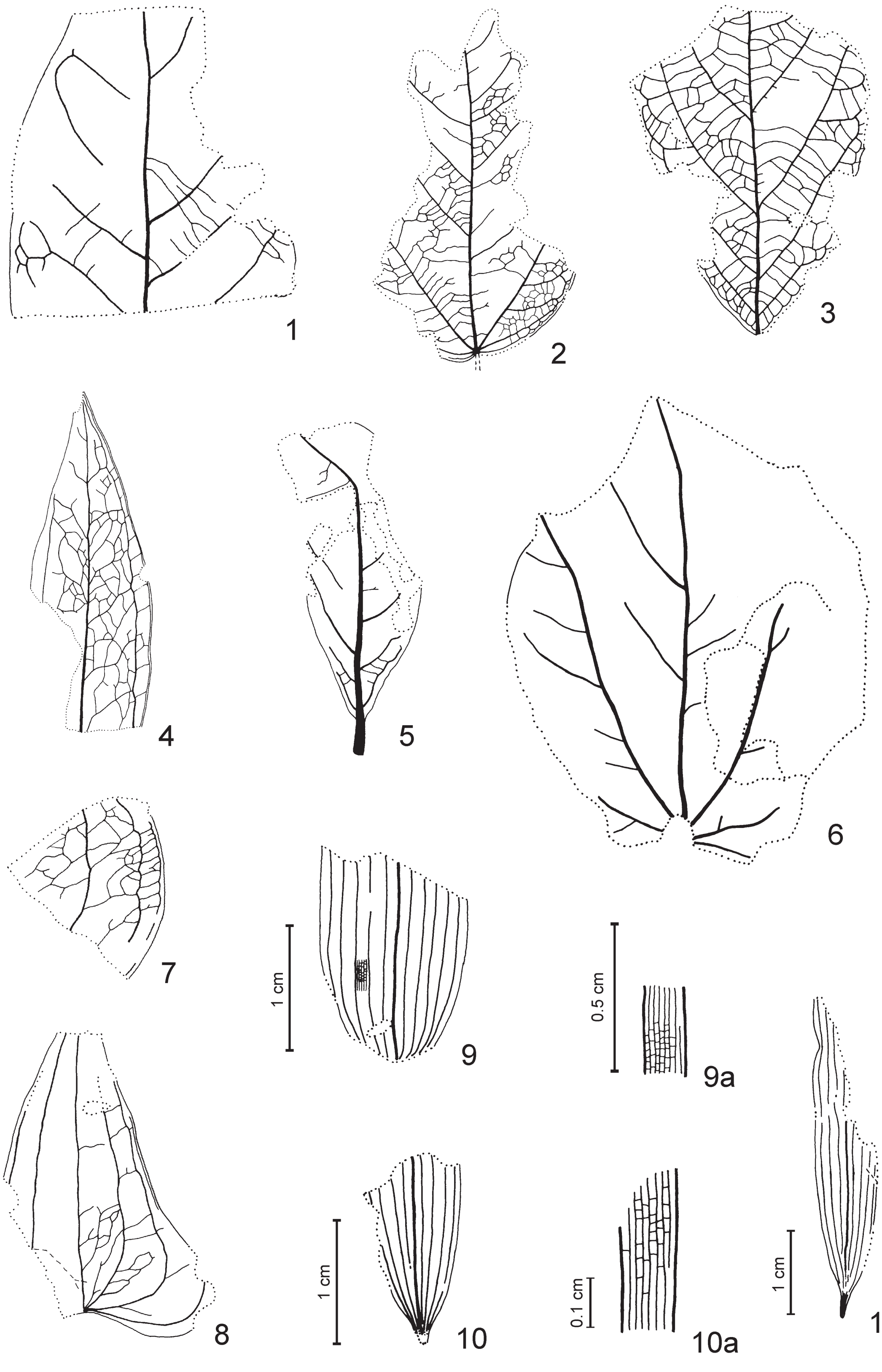

Fig. 7. 1 – *Dicotylophyllum* sp. 3 – specimen KRAM-P 217/248; **2 –** *Dicotylophyllum* sp. 4 – specimen KRAM-P 217/190/II; **3 –** *Dicotylophyllum* sp. 5 – specimen KRAM-P 217/196/II; **4 –** *Smilax* cf. *protolancaefolia* Kolakovsky – specimen KRAM-P 217/254; **5 –** *Dicotylophyllum* sp. 1 – specimen KRAM-P 214/80; **6** – *"Ficus" truncata* Heer sensu Bůžek – specimen KRAM-P 217/131; **7 –** *Smilax* cf. *weberi* Wessel in Wessel & Weber – specimen KRAM-P 217/142; **8 –** *Smilax sagittifera* Heer sensu Hantke – specimen KRAM-P 214/192a; **9–11 –** *Bambusa lugdunensis* Saporta: 9 – specimen KRAM-P 217/198, 9a – specimen KRAM-P 217/198, enlargement of leaf venation, 10 – specimen KRAM-P 217/225/II, 10a – specimen KRAM-P 217/225/II, enlargement of leaf venation, 11 – specimen KRAM-P 217/53/III. Specimens without scale were reduced 15% from natural size

Secondary veins arranged more or less opposite at intervals of 0.7 cm along the primary vein and form an angle of about 60° with it. Secondaries curve upward, forked and interconnected in loops. Intersecondary veins present. Tertiary venation reticulate, not regular.

Remarks. Systematic position unknown.

Occurrence in the fossil floras of Poland. To date similar leaf remains have not been reported from the Tertiary of Poland.

Liliopsida (= Monocotyledones)

Hydrocharitaceae

Stratiotes L.

Stratiotes kaltennordheimensis (Zenker) Keilhack

Pl. 24, fig. 3

1833 *Folliculites kaltennordheimensis* Zenker; Zenker, p. 177, Pl. 4, fig. A: 3–7.

1896 *Stratiotes kaltennordheimensis* (Zenker) Keilhack; Keilhack, p. 987.

Material. KRAM-P 211: 44, 45 (15 seeds on the two fragments of coaly clay).

Morphological description. Fifteen characteristically bent elongate seeds measuring up to 0.8–0.9 cm long by 0.3–0.4 cm wide. Testa thick (about 0.5 mm) and lignified. External surface of testa covered with rows of elongate tubercles. Internal surface of testa shiny and nearly smooth.

Remarks. These seed characters permit them to be assigned to *Stratiotes kaltennordheimensis* (Zenker) Keilhack, a water plant recorded from the Oligocene to the Upper Miocene of Europe (Zastawniak et al. 1996). Living *Stratiotes* L. is a monotypic genus (Holý & Bůžek 1966), being represented by *S. aloides* L., a water plant, often found growing in ox-bow lakes. It occurs in Europe and Western Siberia (Mai & Walther 1978).

Occurrence in the fossil floras of Poland. Lower Miocene – Bełchatów (Worobiec 1995); Middle Miocene – Dobrzyń on the Vistula (Kownas 1956), Konin (Raniecka-Bobrowska 1959), Nowy Sącz (Łańcucka-Środoniowa 1980), Rypin (Łańcucka-Środoniowa 1957), Bełchatów (Stuchlik et al. 1990).

Smilacaceae

Smilax L.

Smilax sagittifera Heer sensu Hantke

Fig. 7: 8; Pl. 22, fig. 4, Pl. 23, figs 1, 1a

1855 *Smilax sagittifera* Heer; Heer, p. 82, Pl. 30, figs 7a-b.

1954 *Smilax sagittifera* Heer; Hantke, p. 82–84, Pl. 14, fig. 13, Pl. 15, figs 1, 2.

1995 *Smilax hastata* (Brongn.) Saporta; Worobiec p. 245.

Material. KRAM-P 214: 192 a and b (two fragments of the same leaf).

Morphological description. Fragment of entire-margined leaf, 5.0 cm long. Leaf base hastate. Venation campylodromous. Primary vein branched into 7 arched branches interconnected by means of higher-order venation.

Anatomical description. Leaf hypostomatic. Upper epidermis (Pl. 22, fig. 4) composed of mostly isodiametric, sometimes elongate cells of variable size (36–60 µm). Anticlinal cell walls undulate, strongly cutinized and thick (2–3 µm). Cuticle of upper epidermis granulate. Lower epidermis (Pl. 23, fig. 1) composed of variably shaped cells, somewhat elongate, 30–60 µm in size. Anticlinal cell walls undulate, strongly cutinized and very thick (2–4 µm). Stomata (Pl. 22, fig. 1a) paracytic, elliptic to spindle-shaped, 18–22 µm in size. Outer stomatal ledge aperture spindle-shaped, 13–15 µm long. Irregularly shaped papillae can be found on the periclinal cell walls of the lower epidermis (Pl. 23, fig. 1).

Remarks. The specimen has been assigned to the genus *Smilax* because of its characteristic campylodromous venation. However, it does not belong to *Smilax hastata* (Brongn.) Saporta, as previously reported (Worobiec 1995). In fact, this leaf is most similar to *Smilax sagittifera* Heer sensu Hantke that is characterized by sagittate leaves. This species is also similar in its epidermal structure (the presence of papillae). According to Hantke (1954) the cuticle of the upper epidermis of *Smilax sagittifera* has a granular surface. Leaves of this species have been reported from the Lower Miocene of the western Czech Republic (Bůžek et al. 1996). The lower epidermis of these leaves is characterized by the presence of papillae. Papillae have not been observed on the surface of the lower epidermis in another fossil species – *Smilax weberi* Wessel in Wessel & Weber.

Smilax aspera L., an evergreen liana growing in the area extending from Canary Islands to India, in a warm Mediterranean climate, is considered a recent counterpart of *Smilax sagittifera*. It is a component of the Mediterranean vegetation found growing in a relatively humid climate (Podbielkowski 1991).

Occurrence in the fossil floras of Poland. Lower Miocene – Bełchatów (Worobiec 1995, as *Smilax hastata* (Brongn.) Saporta).

Smilax cf. ***weberi*** Wessel in Wessel & Weber

Fig. 7: 7, Pl. 23, figs 2, 2a

? 1856 *Smilax weberi* Wessel in Wessel & Weber; Wessel & Weber, p. 127, Pl. 21, fig. 1.

Material. KRAM-P 217: 142.

Morphological description. Leaf fragment, entire-margined, 3.0 × 2.5 cm in size. Venation probably campylodromous. Only 3 branches of primary vein preserved, curved. Branches of primary vein interconnected by means of secondary veins oblique to them. Higher-order venation reticulate.

Anatomical description. Leaf hypostomatic. Upper epidermis (Pl. 23, fig. 2) consists of elongate cells, 60–120 µm in size with undulate anticlinal cell walls. Lower epidermis (Pl. 23, fig. 2a) composed of polygonal cells, 30–60 µm in size, with undulate anticlinal cell walls. Over the veins cells of lower epidermis distinctly elongate, rectangular with striated cuticle. Stomata (Pl. 23, fig. 2a) paracytic and of rather regular elliptic shape, 28–30 µm long and 16–20 µm wide. Outer stomatal ledge aperture spindle-shaped, narrow, 20–22 µm long and about 5 µm wide.

Remarks. Based on its venation pattern and epidermal structure the leaf fragment has been assigned to *Smilax*, and has been compared with two fossil species: *Smilax sagittifera* Heer sensu Hantke and *Smilax weberi* Wessel in Wessel & Weber. The former has characteristic papillae on the surface of the lower epidermal cells, and the cells lying above the veins have no parallel striation. However, the specimen from Bełchatów has parallel striations on the cuticle of cells lying above the veins, as in *Smilax weberi*, reported from the Miocene of Fasterholt in Denmark (Christensen 1975).

Dispersed cuticle from Turów assigned to *Smilax tertiaria* Juchniewicz differs in having more undulate cell walls (Ω-like undulation) compared with those of the lower epidermis of *Smilax weberi*. The lower epidermis of *Smilax* sp. from Gozdnica is similar to that of *Smilax weberi* (Dyjor et al. 1992). Conversely, author of this paper believes that the two differ in that the whole cuticular surface of the epidermis in *Smilax* sp. is striate whereas in *Smilax weberi* striations only occur above the veins. This feature makes *Smilax sp.* from Gozdnica similar to recent *S. hispida* Muhl. (comp. Christensen 1975).

Smilax weberi has leaves of highly variable shape (Bůžek 1971); in older publications the morphological forms of this taxon were usually described as different species (e.g. *Smilax grandifolia* (Unger) Heer).

Smilax hispida Muhl. growing in the south-eastern states of the USA and *Smilax excelsa* L. from south-eastern Europe and Asia Minor are, according to Christensen (1975), most similar to fossil *Smilax weberi*, though neither is identical. Bůžek (1971) also considers *S. rotundifolia* L. from wet habitats in North America, a species showing great morphological variability of its leaves to be similar to *Smilax weberi*.

The fossil leaves of *Smilax weberi* are frequently found in Neogene floras from central and western Europe (Bůžek 1971, Christensen 1975, Knobloch & Kvaček 1976). This taxon was undoubtedly a liana, just as most recent species of this genus and grew in the undergrowth of wet forest.

Occurrence in the fossil floras of Poland. Lower Miocene – Rozewie (Heer 1869, as *Smilax grandifolia* (Unger) Heer); Middle Miocene – Swoszowice (Ilinskaya 1962, as *Smilax grandifolia*).

Smilax cf. ***protolancaefolia*** Kolakovsky

Fig. 7: 4; Pl. 23, figs 3, 3a

? 1976 *Smilax protolancaefolia* Kolakovsky; Kolakovsky & Shakryl, p. 105, Pl. 1, fig. 8.

Material. KRAM-P 217: 254.

Morphological description. Fragment of elongate, entire-margined leaf, 6.0 cm long and about 2.3 cm wide, with acute apex. Venation probably campylodromous. Primary vein branched into 5 (only 4 could be visible on Fig. 7: 4), these are bent and run more or less parallel to each other. Between branches of the primary vein run secondary veins that arise obliquely at angle of about 50° to it. Secondaries branched. Higher-order venation reticulate, meshes large.

Anatomical description. Leaf hypostomatic. Upper epidermis (Pl. 23, fig. 3) composed of large cells, 60–80 µm in size with undulate anticlinal cell walls. Cuticle of upper epidermis seems somewhat granulate. Structures measuring about 400 µm in size, with an aperture of about 160 µm in diameter can be found on the upper epidermis. These structures may represent the remains of spine-bases or leaf cork-warts (Stace 1965). Lower epidermis (Pl. 23, fig. 3a) composed of elongate cells, 50–60 µm in size with strongly Ω-like undulate anticlinal cell walls. Stomata (Pl. 23, fig. 3a) wide elliptic, 22–28 µm in diameter. Outer stomatal ledge aperture spindle-shaped, 22–26 µm long and 10–12 µm wide. Around the stomata striations directed radially towards the stomatal pore are visible.

Remarks. The specimen has been compared with leaves of *Majantemophyllum* Heer and *Smilax*, differing from the former in its venation pattern. In *Majantemophyllum* the branches of the primary vein occur at more or less equal intervals, while in the study material branching occurs more frequently nearer the leaf margin.

The specimen from Bełchatów shows a general similarity to leaves *Smilax protolancaefolia* Kolakovsky, *S. lingulata* Heer, *S. abscondita* Saporta, *S. philliberti* Saporta and *S. linearis* Saporta. Among them, *Smilax protolancaefolia* is most similar to the leaf under discussion but its epidermis has so far not been analysed. No fossil species of *Smilax* with an epidermis similar to *Smilax* cf. *protolancaefolia* from Bełchatów has been found in the literature. The leaves of *Smilax lingulata* from the Lower Miocene of Rozewie (Heer 1869) somewhat resemble *Smilax* cf. *protolancaefolia* from Bełchatów. According to Kolakovsky and Shakryl (1976) the extant species *Smilax lancaefolia* Roxb. growing in China and the Himalayas morphologically has the most similar leaves to fossil taxa.

Occurrence in the fossil floras of Poland. To date similar leaf remains have not been reported from the Neogene of Poland.

Poaceae

Bambusa Schreber

Bambusa lugdunensis Saporta

Fig. 7: 9–11; Pl. 24, figs 1, 2, 4(C)

1869 *Bambusa lugdunensis* Saporta; Saporta, p. 760.

Material. KRAM-P 217: 48/II, 53/III, 58, 66/III, 76, 79, 83, 84, 123/IV, 127/II, 134/II, 145/II, 198, 225/II, 239.

Morphological description. Fragments of elongate leaves, up to 6.0 cm long and 0.8–2.0 cm, most commonly 1.1 cm, wide. Leaf base obtuse and decurrent to petiole. Leaf margin serrate, teeth very small, acute, strongly upwardly curved and those almost parallel to the margin. Venation parallelodromous. Distinct primary mid-vein. On both sides of the primary vein lie 4 to 6, most commonly 4, less distinct veins (secondary veins) spaced 1.0–1.5 mm apart. In between these lie 5 to 9, most commonly 6 or 7, delicate, intersecondary veins, spaced 0.15–0.20 mm apart. All veins interconnected by means of short anastomoses.

Remarks. The leaves have rounded bases which pass into petioles (Fig. 7: 11, Pl. 24, figs 2, 4), the petiole being of the so-called *Bambusa* type found to occur in the Poaceae, above all in the subfamily Bambusoidae; in other grasses it is found only rarely (Dahlgreen & Clifford 1982). In the genus *Phragmites* Adanson, whose leaves are morphologically rather similar, the leaves are sessile and pass directly into a sheath. The remaining features, such as the venation pattern and the leaf margin with small teeth, are typical of grasses.

The leaf from Bełchatów is most similar to *Bambusa lugdunensis* Saporta described from the Pliocene of Meximieux by Saporta (1869), and illustrated by Saporta and Marion (1876). They are of a similar size and with a similar number of secondary veins. *Bambusa lugdunensis* has been reported from the Pliocene of the Transcarpathians (Ilinskaya 1968) and the Miocene of the Massif du Coiron in France (Grangeon 1958), this material being similar to that from Bełchatów.

The leaves from Bełchatów clearly differ from *Bambusa ilinskiae* described from the Miocene of the Precarpatians (Shvareva 1970), which has more secondary veins (8–10 pairs at each side of the primary vein, between which are 6–10 intersecondary veins) and broader leaves, up to 5.5 cm. The other fossil bamboo, *Sasa kodorica* Kolakovsky described from the Pliocene of Kodor in Abkhazia (Kolakovsky 1964) differs markedly from *Bambusa lugdunensis*. It is over twice as broad (to 3.5 cm), a feature considered by Kolakovsky (op. cit.) characteristic of *Sasa* Mak. & Shibata and *Pseudosasa* Mak. For this reason a new combination *Sasa lugdunensis* (Saporta) Givulescu created by Givulescu (1984) for the relatively narrow leaves of *Bambusa lugdunensis* seems incorrect. The leaves from Bełchatów when compared with those of *Bambusium* sp. B. from the Late Miocene flora of Tatsumigote (Honsiu, Japan) appear to have a similar size and venation pattern (Ozaki 1980).

The leaves of *Bambusa lugdunensis* are known mainly from the Pliocene of southern France (Saporta 1869, Saporta & Marion 1876, Boulay 1892, Laurent 1904–05, Grangeon 1958), the Middle Miocene of Austria (Berger & Zaubusch 1953) and the Neogene of the Transcarpathians (Ilinskaya 1968).

Poacites mengeanus Heer, that morphologically somewhat resembles *Bambusa lugdunensis*, has been reported by Heer (1869) from the Lower Miocene of Rozewie and compared with the extant genera *Uniola* L., *Panicum* L., *Bambusa* Schreber and *Arundinaria* Michx.

According to Laurent (1904–05) *Bambusa lugdunensis* is closely related to extant species from the genera *Phyllostachys* Sieb. & Zucc. and *Arundinaria* Michx., and particularly to the species *Arundinaria japonica* Sieb. Likewise, *Bambusa lugdunensis* has been related the genera *Bambusa* and *Arundinaria* by Grangeon (1958). The author of this publication also considers the genus *Arundinaria* to be closely related to *Bambusa lugdunensis*. It should be noticed that two North American species of the genus *Arundinaria*: *A. gigantea* (Walter) Muhlenberg (= *A. macrosperma* Michx.) and *A. tecta* (Walter) Muhlenberg grow in wet habitats. *Arundinaria gigantea* is a component of the swamp vegetation in the south-eastern USA, while *A. tecta* is a component of wet forest communities, frequently growing on river banks in the same area (Kearney 1901). In swampy areas *A. gigantea* may become a dominant species forming stands that resemble reed-beds (Kearney op. cit.).

Occurrence in the fossil floras of Poland. To date similar leaf remains have not been reported from the Neogene of Poland.

GENERAL CHARACTERISTICS OF THE MATERIAL

The KRAM-P 211/214, and KRAM-P 217 fossil floras comprise mostly leaf remains. Altogether 503 specimens, fragments of rock with 1 or more fossil plants and preparations of isolated leaves, have been analysed.

The KRAM-P 211/214 flora comprises 241 specimens with 252 remains of taxa (Table 2). Among them, there are 4 specimens representing the family Osmundaceae (subclass Pterophytina), 13 specimens of the families Pinaceae, Taxodiaceae and Cupressaceae (subclass Pinophytina), 236 specimens assigned to the subclass Magnoliophytina (= Angiosperms), of which most specimens belong to the class Magnoliopsida (= Dicotyledones). Monocotyledones (class Liliopsida) are represented by 16 specimens belonging to the families Smilacaceae and Hydrocharitaceae.

In the KRAM-P 211/214 flora representatives of the Aceraceae, Betulaceae, Fagaceae, Juglandaceae, Lauraceae, Myricaceae, Nyssaceae and Ulmaceae have been identified. Some of the poorly preserved or incomplete remains have only been determined to genus (*Acer*, *Liquidambar*, *Populus*, *Quercus* and *Ulmus*). Several specimens of Dicotyledonous leaves whose systematic position is unclear (*Symplociphyllum* and *Dicotylophyllum*) have been classified in *Dicotyledonae incertae sedis*. Monocotyledones are represented by the leaves of *Smilax sagittifera* Heer sensu Hantke and the fruits of *Stratiotes kaltennordheimensis* (Zenker) Keilhack. The KRAM-P 211/214 flora are taxonomically relatively poorly differentiated being dominated by leaf remains of the Fagaceae (over 49% of all the specimens). Among them the leaves of "*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček are most numerous; they are frequently accompanied by the families Aceraceae and Lauraceae, and coniferous plants.

The KRAM-P 217 flora numbers 262 specimens with 353 taxa remains (Table 3). 66 spe-

Table 2. Taxonomic list of the flora KRAM-P 211/214

Taxon	Number of specimens
Osmunda parschlugiana (Unger) Andreánszky	4
Glyptostrobus europeus (Brongniart) Unger	4
Pinus hampeana (Unger) Heer	2
Pinus sp. div.	5
Taxodium dubium (Sternberg) Heer	1
Tetraclinis salicornioides (Unger) Z. Kvaček	1
"*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček	118
Acer integrilobum O.Weber	20
cf. *Acer integrilobum* O.Weber	6
Acer tricuspidatum Bronn sensu Procházka & Bůžek	1
Acer sp. div.	1
Alnus julianiformis (Sternberg) Z. Kvaček & Holý	11
cf. *Carya serrifolia* (Goeppert) Kräusel	2
Daphnogene polymorpha (Al.Braun) Ettingshausen	18
Laurophyllum pseudoprinceps Weyland & Kilpper	1
Liquidambar sp.	1
Myrica lignitum (Unger) Saporta	7
Nyssa ornithobroma Unger	1
Populus sp.	1
Quercus rhenana (Kräusel & Weyland) Knobloch & Z. Kvaček	4
Quercus sp. sect. *Cerris* Oersted vel sect. *Dentata* C.K. Schneid.	3
Ulmus sp.	1
Dicotylophyllum sp. 1	1
Dicotylophyllum sp. 2	1
Dicotylophyllum sp. 6	1
Symplociphyllum breddini (Weyland) Juchniewicz	1
Smilax sagittifera Heer sensu Hantke	1
Stratiotes kaltennordheimensis (Zenker) Keilhack	15
Indeterminate vel Incertae sedis	19
Total	252

cimens have been assigned to the families Pinaceae and Taxodiaceae (subclass Pinophytina). 285 specimens represent the subclass Magnoliophytina (= Angiosperms). Most of the angiospermous remains belong to the Dicotyledones (class Magnoliopsida, 268 specimens) and only 17 specimens to the Monocotyledones (class Liliopsida). The KRAM-P 217 flora as above, is poorly taxonomically differentiated, comprising 20 species and 18 genera. Among the coniferous plants (Coniferopsida) two genera (*Pinus* and *Sequoia*) have been identified, while the Dicotyledones are represented by the Aceraceae, Betulaceae, Cyrillaceae, Ebenaceae, Ericaceae, Fagaceae, Hippocastanaceae, Juglandaceae, Loranthaceae, Myricaceae and Malvaceae sensu lato. The Monocotyledonous plants are represented by the Smilacaceae (*Smilax*) and the Poaceae (*Bambusa*). Dicotyledonous leaves whose systematical position is unclear have been described as *Dicotylophyllum*. Only scarce carpological macroremains were washed out from the clay sample

Table 3. Taxonomic list of the flora KRAM-P 217

Taxon	Number of specimens
Pinus cf. *spinosa* Herbst	7
Pinus sp. div.	3
Sequoia abietina (Brongniart) Knobloch	56
Acer sp. div.	1
Aesculus cf. *hippocastanoides* Ilinskaya	1
Alnus gaudinii (Heer) Knobloch & Z. Kvaček	34
cf. *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček	4
Alnus menzelii Raniecka-Bobrowska	125
cf. *Alnus menzelii* Raniecka-Bobrowska	7
Alnus sp.	3
Byttneriophyllum tiliaefolium (Al. Braun) Knobloch & Z. Kvaček	6
Carpinus sp.	1
Cyrilla thomsonii Kräusel & Weyland	8
Diospyros anceps Heer	43
cf. *Diospyros anceps* Heer	3
Fagus silesiaca Walther & Zastawniak	3
Kalmia cf. *saxonica* Litke	1
Myrica lignitum (Unger) Saporta sensu lato	20
cf. *Myrica lignitum* (Unger) Saporta sensu lato	2
Pterocarya paradisiaca (Unger) Ilinskaya	1
Viscophyllum pliocenicum (Engelhardt) Mädler	1
"*Ficus*" *truncata* Heer sensu Bůžek	1
Dicotylophyllum sp. 3	1
Dicotylophyllum sp. 4	1
Dicotylophyllum sp. 5	1
Bambusa lugdunensis Saporta	15
Smilax cf. *protolancaefolia* Kolakovsky	1
Smilax cf. *weberi* Wessel in Wessel & Weber	1
Indeterminate vel Incertae sedis	2
Total	353

Table 4. Taxa of fruits and seeds of fossil flora KRAM-P 217 (det. M. Lesiak)

Taxon
Abies/Keteleeria
Pinus sp.
Sequoia sp.
Thuja sp.
Actinidia sp.
Alnus sp.
Betula sp.
Cephalantus sp.
cf. *Fagus* sp.
Menyanthes trifoliata L. foss.
Myrica sp.
Rubus sp.
Carex sp.

collected at KRAM-P 217. Among them 4 genera of coniferous plants and 9 angiosperms have been identified (Table 4).

The KRAM-P 217 flora is dominated by leaf remains from the Betulaceae (174 specimens) of which *Alnus menzelii* Raniecka-Bobrowska was the most common. *Sequoia abietina* (Brongniart) Knobloch was next most abundant, followed by *Diospyros anceps* Heer, *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček, *Myrica lignitum* (Unger) Saporta sensu lato and *Bambusa lugdunensis* Saporta. All other remains are represented by less than 10 specimens and many of them only by single specimens (e.g. *Aesculus*, *Pterocarya*, *Smilax*).

Eight new taxa to the Polish Tertiary were reported. These taxa are *Acer integrilobum* O. Weber, *Aesculus* cf. *hippocastanoides* Ilinskaya, *Bambusa lugdunensis* Saporta, "*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček, *Cyrilla thomsonii* Kräusel & Weyland, *Kalmia* cf. *saxonica* Litke, *Smilax* cf. *protolancaefolia* Kolakovsky, and *Smilax sagittifera* Heer sensu Hantke. Additionally, the epidermis of the leaflets of *Osmunda parschlugiana* (Unger) Andreánszky has been described and illustrated from the Polish Tertiary for the first time.

Several new taxa for the Tertiary of Bełchatów were reported: *Acer integrilobum* O. Weber, *Acer tricuspidatum* Bronn sensu Procházka & Bůžek, *Aesculus* cf. *hippocastanoides* Ilinskaya, *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček, *Alnus julianiformis* (Sternberg) Z. Kvaček & Holý, *Bambusa lugdunensis* Saporta, "*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček, *Daphnogene polymorpha* (Al. Braun) Ettingshausen, *Diospyros anceps* Heer, *Laurophyllum pseudoprinceps* Weyland & Kilpper, *Quercus rhenana* (Kräusel & Weyland) Knobloch & Z. Kvaček, *Smilax* cf. *protolancaefolia* Kolakovsky, *Smilax sagittifera* Heer sensu Hantke, *Symplociphyllum breddini* (Weyland) Juchniewicz, *Smilax* cf. *weberi* Wessel in Wessel & Weber and *Viscophyllum pliocenicum* (Engelhardt) Mädler.

CHARACTERISTICS OF PLANT COMMUNITIES IN ORICTOCENOSES KRAM-P 211/214 AND KRAM-P 217

The presence of two types of vegetation has been found in the KRAM-P 211/214 fossil flora. The first group comprises azonal vegetation represented by swamp and riparian forest which surrounded a water reservoir, probably a large lake with swampy shores. Zonal vegetation is represented by taxa characteristic of mesophytic forest which probably overgrew the nearby elevations.

The swamp forest stand was composed of coniferous *Glyptostrobus europeus* (Brongniart) Unger and *Taxodium dubium* (Sternberg) Heer, and deciduous *Acer tricuspidatum* Bronn sensu Procházka & Bůžek, *Nyssa ornithobroma* Unger and *Quercus rhenana* (Kräusel & Weyland) Knobloch & Z. Kvaček. The undergrowth was composed of evergreen shrubs (*Daphnogene polymorpha* (Al.Braun) Ettingshausen, *Myrica lignitum* (Unger) Saporta), and ferns (*Osmunda parschlugiana* (Unger) Andreánszky). Lianas were also recorded (*Smilax sagittifera* Heer sensu Hantke). This swamp forest was inundated for most of the year and the presence of *Myrica lignitum* (Unger) Saporta indicates that locally it could be classed as bog forest. The accumulation of wood, which later on formed lignite seams, may have occurred in these bog forest regions. Pine (*Pinus*), as indicated by the presence of its needles and cones, may also have grown in this swamp forest. Clumps of *Stratiotes kaltennordheimensis* (Zenker) Keilhack floated on the lake surface.

Slightly drier areas on mineral soils that were inundated only periodically, were overgrown with riparian forest formed of *Acer* *integrilobum* O. Weber, *Alnus julianiformis* (Sternberg) Z. Kvaček & Holý, *Carya serrifolia* (Goeppert) Kräusel, also trees of *Liquidambar*, *Populus*, and *Ulmus*.

"*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček, a species dominating the fossil flora under discussion in terms of the number of specimens, may have grown in the riparian forest or may have been a component of the mesophytic forest vegetation. This species has been reported from Pliocene fossil floras of Hungary (Pula and Gerce) where it formed part of a forest vegetation surrounding a lake in the crater of an extinct volcano (Hably & Kvaček 1997). This vegetation has a mesophytic character, perhaps providing an indicator of its character at Bełchatów. *Laurophyllum pseudoprinceps* Weyland & Kilpper and *Tetraclinis salicornioides* (Unger) Z. Kvaček may also be components of mesophytic forest.

Palynological analyses of the KRAM-P 211/214 flora can be used to complete the reconstruction of the local vegetation. Palynological profile IXc samples 135–140 (Stuchlik et al. 1990) corresponds to the flora recorded from the clay layer, the so-called *Pinus*-*Quercetum mixtum* phase. The pollen spectrum is characterized by maxima of *Pinus* t. *sylvestris* (54%), *Pinus* t. *haploxylon* (24%) and coniferous trees from the bisaccate group (*Picea*, *Abies*, altogether 13%). Some angiosperms such as *Betula*, *Ulmus*, *Carya*, *Pasania* and *Quercus* also reach their maxima in this phase. According to Stuchlik (op. cit.) the period was characterized by a predominance of coniferous forest with an admixture of deciduous and mixed oak-pine forest containing a considerable proportion of *Betula*, *Carya* and *Ulmus*; the undergrowth was dominated by Caprifoliaceae and *Ilex*. Small swampy areas were occupied by poor swamp forest containing *Taxodium* and an admixture of *Nyssa* and *Alnus*. The presence of *Liquidambar* and *Pterocarya* pollen in the palynological profile indicate the occurrence of small areas of riparian forest.

The KRAM-P 217 flora has a slightly different character, swamp forest passing in places into bush swamp and riparian forest having been distinguished. Very small numbers of leaves characteristic of mesophytic taxa and representing the zonal vegetation have been found (Table 3). These include *Fagus silesiaca* Walther & Zastawniak and *Aesculus* cf. *hippocastanoides* Ilinskaya and may have been transported to the site from remote places.

The swamp forest stand was dominated by *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček, *Alnus menzelii* Raniecka-Bobrowska, *Byttneriophyllum tiliaefolium* (Al. Braun) Knobloch & Z. Kvaček and *Sequoia abietina* (Brongniart) Knobloch, with some pines (*Pinus*). Near the shore of the reservoir the undergrowth comprised *Cyrilla thomsonii* Kräusel & Weyland, *Kalmia* cf. *saxonica* Litke and *Myrica lignitum* (Unger) Saporta sensu lato. Lianas belonging to *Smilax* grew among the trees and shrubs, while mistletoe (*Viscophyllum*) parasitized tree branches. The presence of *Cyrilla* and *Kalmia* is characteristic of bush swamps (Teichmüller 1958) and indicates that in places soils were rather acidic and swamp forest was replaced by bog. Analysis of compressed remains in the leaf litter layer reveals the dominance of four tree species: *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček, *Alnus menzelii* Raniecka-Bobrowska, *Byttneriophyllum tiliaefolium* (Al. Braun) Knobloch & Z. Kvaček and twigs of *Sequoia abietina* (Brongniart) Knobloch. The rich accumulation of these remains (the layer of litter is approx. 30 cm thick and comprises thousands of leaves) testifies to their autochtonous origin.

Sites on neutral soils, which were periodically inundated, were overgrown by riparian forest, as indicated by the presence of such species as *Diospyros anceps* Heer and *Pterocarya paradisiaca* (Unger) Ilinskaya. The shore of the water reservoir was covered by rushes dominated by the bamboo (*Bambusa lugdunensis* Saporta).

The KRAM-P 217 flora also comprised a few carpological remains (Table 4). The occurrence of the genera *Alnus*, *Cephalanthus*, *Menyanthes*, *Myrica* and *Sequoia* confirm the presence of swampy vegetation, while *Actinidia*, *Betula*, and *Rubus* the presence of riparian forest. Fossil remains of the genera *Abies* vel *Keteleeria* and *Thuja* may have originated from mesophytic forest; as may a seed that most probably belongs to the genus *Fagus*.

These macrofossil studies of the mesophytic forest are complemented by a palynological analysis (Table 5). The palynological spectrum is dominated by pollen and spores of swamp plant taxa (*Alnus*, Polypodiaceae sensu lato, *Sequoia*, Taxodiaceae/Cupressaceae, together 40%). However, mesophytic vegetation (*Abies*,

Table 5. Results of palynological analysis of clay sample from fossil flora KRAM-P 217 (det. E. Worobiec)

Taxon	Number of sporomorphs	macroremains
Polypodiaceae sensu lato	27	
Osmunda	6	
Abies	21	+
cf. *Podocarpus*	2	
Keteleeria	1	+
Picea	8	
Pinus type *haploxylon*	22	+
Pinus type *sylvestris*	107	+
Sciadopitys	4	
Sequoia	31	+
Taxodiaceae/Cupressaceae	141	
Tsuga type *canadensis*	6	
Tsuga type *diversifolia*	6	
Acer	2	+
Alnus	53	+
Araliaceoipollenites edmundi (Araliaceae)	5	
Arceuthobium	1	
Betula	14	+
Caprifoliaceae	1	
Carpinus	2	+
Carya	10	
Castanea/Castanopsis	3	
cf. *Cercidiphyllum*	1	
cf. *Itea*	1	
cf. Labiatae	1	
cf. *Parrotia*	1	
Cornaceae/Araliaceae	11	
Cyrillaceae/Clethraceae	6	+
Diervilla (Caprifoliaceae)	1	
Diospyros ?	3	+
Engelhardtia	4	
Ericaceae (small forms)	4	+
Fagus	10	+
Ilex (Ilexpollenites iliacus)	6	
Ilex (Ilexpollenites margaritatus)	2	
Intratriporopollenites instructus (Tiliaceae)	14	
Juglans	1	
Liquidambar	1	
Lythraceae	1	+
Myrica	9	+
Nympheaceae	1	
Nyssa	4	
Oleaceae	2	
Parthenocissus	2	
Pterocarya	6	+
Quercoidites henrici	3	
Quercus	15	
Rosaceae	5	+
Rubiaceae ?	1	+
Schizeaceae ?	2	
Symplocos	1	
Tricolporopollenites fallax (Leguminosae)	5	
Tricolporopollenites pseudocingulum	6	
Ulmus/Zelkova	9	
Vitis ?	4	
Butomus ?	1	
cf. Palmae	1	
Cyperaceae	4	+
Poaceae	1	+
Varia	12	
Microthyriaceae	5	
Plankton	3	

Carpinus, Cornaceae/Araliaceae, *Fagus*, Oleaceae, *Picea*, *Quercus*, *Tsuga* and *Ulmus/Zelkova*) was also an important component. Taxa characteristic of riparian forest (*Carya*, *Juglans*, *Liquidambar*, and *Pterocarya*) were poorly represented, *Carya* being the most commonly occurring (1.5%).

The palynological analysis confirmed the presence of a well-developed shrub layer in the forest communities. This layer was composed of representatives of the Aquifoliaceae, Araliaceae, Caprifoliaceae, Cyrillaceae/Clethraceae, Ericaceae, Leguminosae and Rosaceae. The pollen analysis also showed the presence of water plants (Nympheaceae) and indicated the occurrence of ?*Butomus* and Cyperaceae in the rush vegetation overgrowing the shores of the reservoir.

COMPARISON OF THE DESCRIBED PLANT COMMUNITIES WITH THOSE OF MAI (1995)

The wet habitat azonal vegetation from KRAM-P 211/214, and 217 can be classified either as swamp forest, riparian forest or bush swamp vegetation. According to Mai (1995) swamp forests were dominated by trees such as *Taxodium* and *Glyptostrobus* with *Alnus* and/or *Nyssa* (more than 40%) and were accompanied by subsidiary quantities of *Acer*, *Betula*, *Byttneriophyllum*, *Cephalanthus*, *Cornus*, *Cyrilla*, *Fraxinus*, *Ilex*, *Myrica*, *Quercus*, *Populus*, *Magnolia*, *Salix* and *Sassafras*. Lianas (e.g. *Smilax*) were common, while herbaceous plants were dominated by pteridophytes (*Osmunda*, *Pronephrium*, *Pteridium*, *Woodwardia*), amphibious species of Lythraceae, Onagraceae and Urticaceae, and monocotyledons (Alismataceae, Cyperaceae, Poaceae and Zingiberaceae). Laurophyllous vegetation (e.g. *Daphnogene*) was also present during warmer periods. Forests of this type grew in Europe from the Palaeocene to the Pliocene.

Riparian forests were less diversified and were represented by *Acer*, *Alnus*, *Celtis*, *Cyclocarya*, *Fraxinus*, *Juglans*, *Liquidambar*, *Platanus*, *Populus*, *Pterocarya*, *Quercus*, *Salix*, *Sassafras*, *Ulmus*, *Glyptostrobus*, and *Taxodium*. The shrub layer was composed of *Cephalanthus*, *Forestiera*, *Itea*, *Nerium*, *Paliurus*, *Rubus*, *Sambucus*, *Staphylea* and *Swida*. Lianas (*Actinidia*, *Berchemia*, *Menispermum*, *Parthenocissus*, *Smilax*, *Toddalia* and *Vitis*) occurred abundantly. The herbaceous plants were represented by Cyperaceae and Zingiberaceae, horsetails and ferns (*Osmunda*). The composition of riparian forests changed depending on their location on the floodplain of a river. In Europe this type of forest occurred from the Middle Palaeocene to the Lowest Pleistocene.

Bush swamp community occurred primarily in coal-forming peat bogs and on sandy river banks and comprised moderate diversity stands of shrubs belonging to the genera *Clethra*, *Cyrilla*, *Ilex*, *Illicium*, *Eurya*, *Leitneria*, *Magnolia*, *Myrica*, *Quercus* and *Symplocos*, lianas of the genera *Calamus*, *Dioscorea* and *Smilax*, and ferns of the genera *Abacopteris*, *Lygodium* and *Osmunda*. This type of vegetation has been recorded in Europe from the Eocene to the Pliocene.

The remains of the zonal vegetation belong to Mixed Mesophytic Forest communities. The mesophytic forests from Bełchatów correspond to the two types of forest in Mai's classification (1995). The Mixed Mesophytic Forest from the Early Miocene (KRAM-P 211/214 flora) was of the "Warmgemäßigte Regenwälder" type and was characterized by very diversified stands, composed of numerous genera of deciduous (e.g. *Engelhardia*, *Ficus*, *Magnolia*, *Meliosma*, *Quercus* and *Symplocos*) and coniferous trees (e.g. *Cathaya*, *Keteleeria* and *Tetraclinis*). The proportion of evergreen species (e.g. Lauraceae) was large. Forests of this type occurred in Europe from the Palaeocene to the Late Miocene.

The Late Miocene (KRAM-P 217 flora) Mixed Mesophytic Forest vegetation was of the *Fagus*-*Quercus*-*Carpinus* type ("Eichen-Hainbuchen-Kastanien Mischwälder"). This community was of low diversity and mainly comprised *Acer*, *Betula*, *Carpinus*, *Carya*, *Fagus*, *Parrotia*, *Quercus*, *Ulmus*, and coniferous *Abies*, *Keteleeria*, *Picea*, and *Tsuga*. The undergrowth contained also some evergreen shrubs (e.g. *Daphne*, *Buxus*, *Eurya*, *Ilex*, *Laurocerasus* and *Rhododendron*), and lianas (Actinidiaceae, Rhamnaceae and Vitaceae). These forest grew in Europe from the Late Oligocene to the Earliest Pleistocene, and they were frequently found in the Pliocene.

PHYTOGEOGRAPHIC ANALYSIS OF THE KRAM-P 211/214 AND KRAM-P 217 FOSSIL FLORAS

The KRAM-P 211/214 and KRAM-P 217 fossil floras comprise plants characteristic of modern northern hemisphere ecosystems growing in warm temperate or subtropical climates (Table 6). *Acer*, *Alnus*, *Carya*, *Castanea*, *Glyptostrobus*, *Liquidambar*, *Myrica*, *Nyssa*, *Osmunda*, *Pinus*, *Populus*, *Quercus*, *Stratiotes*, *Taxodium*, and *Ulmus* the dominant components of the KRAM-P 211/214 flora belong to the Arctotertiary geoflora and represent the warm temperate element. *Acer*, *Aesculus*, *Alnus*, *Betula*, *Fagus*, *Kalmia*, *Myrica*, *Pinus*, *Pterocarya*, *Sequoia*, and *Viscophyllum* represent this element in the KRAM-P 217 flora. Both floras comprise more thermophilous genera, components of the palaeotropical geoflora. Recent counterparts of the fossil taxa of this group are connected with areas characterized by a warm and humid climate; these are often evergreen plants. In the KRAM-P 211/214 flora the palaeotropical element is represented by the Lauraceae (*Daphnogene*, *Laurophyllum*) and *Smilax*, *Symplociphyllum* and *Tetraclinis*, while in the KRAM-P 217 flora it is represented by the genera *Bambusa*, *Cyrilla*, *Diospyros* and *Smilax*.

Analysis of the recent geographical distribution of the genera representative of the Bełchatów fossil flora (*Acer*, *Betula*, *Pinus*, *Populus* and *Ulmus*) reveals a panholarctic range. The genera *Diospyros*, *Smilax* and *Viscum* have extensive ranges including areas with a warmer climate. In modern ecosystems the genus *Myrica* has a wide range and can be found on all continents, except Australia. A disjunctive range is characteristic of the genera *Carya*, *Nyssa* (East Asia, North America), *Liquidambar* (East Asia, Asia Minor, North America), *Aesculus*, *Castanea*, *Fagus* (East Asia, Asia Minor, Europe, North America) and *Pterocarya* (East Asia, Asia Minor). The genera *Kalmia*, *Taxodium* and *Sequoia* now occur in North America, while *Tetraclinis* grows only in the western part of the Mediterranean basin. Recent *Glyptostrobus* has a relic range limited to a small area in south-eastern China and Vietnam.

RECENT PLANT COMMUNITIES CORRESPONDING TO PALAEOPHYTOCOENOSES OF THE KRAM-P 211/214, AND KRAM-P 217 FOSSIL FLORAS

Recent plant communities corresponding to the floral associations recorded from the two floras investigated in Bełchatów have been previously reported from East Asia, Transcaucasia, eastern and north-eastern North America and southern Europe (Table 6).

Communities of swamp and riparian character, similar to those described from the Neogene of Bełchatów, occur at the present time in the south-eastern part of North America, in the Mississippi River delta, on the south-eastern coast of Atlantic and also in the Gulf of Mexico. In these locations riparian forest occur in river valleys that are within the range of episodic flooding, and are characterized by a great floristic diversity. These are composed of trees and shrubs of *Acer*, *Aesculus*, *Carya*, *Celtis*, *Cephalanthus*, *Diospyros*, *Fraxinus*, *Gleditsia*, *Juglans*, *Liquidambar*, *Nyssa*, *Platanus*, *Populus*, *Quercus*, *Rhus*, *Salix*, and *Ulmus*. There are numerous lianas including the genera *Cocculus*, *Parthenocissus*, *Passiflora*, *Schizandra* and *Vitis*. In these association the shoots of *Tillandsia usneoides* L., belonging to the family Bromeliaceae, hang over many tree branches (Knapp 1965). *Diospyros virginiana* L. grows in these forest and resembles the fossil species *Diospyros anceps* Heer. The climates of this areas are characterized by rather high precipitation (1200–1500 mm) falling mainly on summer period. The mean annual temperature varies between +16 and +19.8°C, and the temperature of the mean coolest month is between +5 and +15°C. The mean temperature for the warmest month reaches approximately +26°C, while the absolute minimum temperature varies between -12 and -17°C (Knapp 1965, Barnes 1991).

In these areas places that are permanently or for the most part of the year inundated by water are overgrown by swamp forest. The level of stagnant water reaches up to 1 m (Knapp 1965). A typical cypress dominated swamp forest stand, occurring in permanently inundated places, is composed of only a few species, and these are often dominated by *Taxodium distichum* (L.) Rich., *Nyssa aquatica* L. and an admixture of *Planera*. *Tillandsia usneoides* L. hangs abundantly over tree branches (Knapp 1965, Kac 1975). Shrubs are scarce in forest of this kind. In sites with lower water levels, forest associations have a greater number of taxa; in addition to the species mentioned above there are trees representing the genera *Acer*, *Carya*, *Fraxinus*, *Liquidambar*, *Magnolia*, *Persea*, *Pinus*, *Quercus*, and *Ulmus*. In addition there are numerous shrubs including the *Cephalanthus*, *Cyrilla*, *Gordonia*, *Ilex*, *Swida*, and lianas including *Vitis* and *Smilax*. Also *Acer rubrum* var. *drummondii* (Hook & Arnott) Sarg. that compares favourably to the fossil species *Acer tricuspidatum* Bronn sensu Procházka & Bůžek grows in this environment. In many places the bamboo *Arundinaria gigantea* (Walter) Muhlenberg (= *A. macrosperma* Michx.), considered to be a close relative of the fossil species *Bambusa lugdunensis* Saporta, builds a community structure that is an analogue of the reed (Kearney 1901). In addition to swamp forest, in the south-eastern part of North America there are bush swamps, the so-called pocosin. Pocosin are sporadically inundated over the year, and are overgrown by acidophilous shrubs with xeromorphic leaves, among which there are many representatives of the family *Ericaceae*. Also trees, shrubs and shrublets of *Andromeda*, *Chamaecyparis*, *Clethra*, *Cliftonia*, *Cyrilla*, *Ilex*, *Magnolia*, *Myrica*, *Pieris*,

Table 6. Comparison of fossil taxa from Bełchatów with their recent counterparts

Fossil taxon	Recent counterparts		
	taxon	community	geographical distribution
Acer integrilobum O.Weber	*Acer longiceps* Rheder *A. cappadocicum* Gleditsch	mesophytic forest	eastern Asia (China)
Acer tricuspidatum Bronn sensu Procházka & Bůžek	*Acer rubrum* var. *drummondii* (Hook & Arnott) Sarg.	swamp forest	North America
Acer sp. div.	–	–	–
Aesculus cf. *hippocastanoides* Ilinskaya	*Aesculus glabra* Willd. *A. octandra* Marsch.	mesophytic and riparian forest	eastern North America
Alnus gaudinii (Heer) Knobloch & Z. Kvaček	*Alnus nitida* (Spach) Endlicher	mesophytic forest	India, Himalaya
Alnus julianiformis (Sternberg) Z. Kvaček & Holý	*Alnus japonica* Sieb. & Zucc. *A. trabeculosa* Hand.-Mazz.	mesophytic forest	Japan, China, Korea, eastern Russia, south-eastern China
Alnus menzelii Raniecka-Bobrowska	*Alnus serrulata* (Ait.) Willd *A. subcordata* C.A. Mey.	mesophytic forest, riparian forest Hyrcanian forest, seaside alder carrs	eastern North America Caucasus, Iran
Bambusa lugdunensis Saporta	*Arundinaria gigantea* (Walter) Chapm. *A. tecta* (Walter) Muhlenberg	swamps, river banks, wetland forest	eastern and south-eastern North America
Byttneriophyllum tiliaefolium (Al. Braun) Knobloch & Z. Kvaček	members of the families Tiliaceae or Sterculiaceae	–	–
cf. *Carya serrifolia* (Goeppert) Kräusel	*C. cordiformis* (Wangh.) K. Koch *Carya pecan* (Marsh.) Engl. & Graebn. *C. tomentosa* Nutt.	swamp and riparian forest	eastern North America North America eastern North America
"*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček	species of the genus *Castanea* Mill., oaks of the sect. *Cerris* Oersted (e.g. *Quercus libani* Oliv.)	various types of forest communities	eastern Asia, North America
"*Ficus*" *truncata* Heer sensu Bůžek	–	–	–
Carpinus sp.	–	–	–
Cyrilla thomsonii Kräusel & Weyland	*Cyrilla racemiflora* L.	swamps, swamp forest	eastern and south-eastern North America and West India
Daphnogene polymorpha (Al.Braun) Ettingshausen	various species from genera *Cryptocarya, Litsea* Lam., *Lindera* Thunb., *Neolitsea (Benth.)* Merrill	–	–
Dicotylophyllum sp. 1	–	–	–
Dicotylophyllum sp. 2	–	–	–
Dicotylophyllum sp. 3	–	–	–
Dicotylophyllum sp. 4	–	–	–
Dicotylophyllum sp. 5	–	–	–
Dicotylophyllum sp. 6	–	–	–
Diospyros anceps Heer	*Diospyros kaki* L. *D. lotus* L. *D. virginiana* L.	mesophytic and riparian forest mesophytic and riparian forest, rarely swamp forest	eastern Asia eastern North America
Fagus silesiaca Walther & Zastawniak	*Fagus hayatae* Palibin ex Hayata	mesophytic forest	south-eastern China
Glyptostrobus europeus (Brongniart) Unger	*Glyptostrobus pensilis* (Staunton) K. Koch	on the river banks	south-eastern China, Vietnam
Kalmia cf. *saxonica* Litke	*Kalmia angustifolia* L. *K. latifolia* L.	bogs, swamp forest, acid forest	eastern North America

Table 6. Continued.

Fossil taxon	Recent counterparts		
	taxon	community	geographical distribution
Laurophyllum pseudoprinceps Weyland & Kilpper	various members of the family Lauraceae	–	–
Liquidambar sp.	species of the genus *Liquidambar* L.	mesophytic and riparian forest	south-eastern Asia, Asia Minor, eastern North America
Microthyriaceae gen. & sp. indet.	–	–	–
Myrica lignitum (Unger) Saporta sensu lato	species of the genus *Myrica* L. *Myrica rubra* Sieb. & Zucc.	mostly bogs and acid, sandy soils mesophytic forest	all continents besides Australia China, Japan
Nyssa ornithobroma Unger	*Nyssa sinensis* Oliv. *N. ogeche* Marsch.	mesophytic forest swamp forest	south-eastern Asia south-eastern North America
Osmunda parschlugiana (Unger) Andreánszky	*Osmunda regalis* L.	mostly humid forest (swamp and riparian)	diffused
Pinus hampeana (Unger) Heer	*Pinus massoniana* Sieb. & Zucc.	mesophytic forest	Japan
Pinus cf. *spinosa* Herbst	*Pinus* sect. *Pinaster* Loudon	–	–
Pinus sp. div.	–	–	–
Populus sp.	–	–	–
Pterocarya paradisiaca (Unger) Ilinskaya	*Pterocarya pterocarpa* (Michaux) Kunth	riparian and mesophytic forest	Transcaucasus, Iran, Turkey
Quercus rhenana (Kräusel & Weyland) Knobloch & Z. Kvaček	*Quercus flagelifera* Trel. *Q. imbricaria* Michx. *Q. laurifolia* Michx. *Q. virginiana* Mill.	swamp, riparian and mesophytic forest	North America
Quercus sp. sect. *Cerris* Oersted vel sect. *Dentata* C.K. Schneid.	*Quercus* sp. sect. *Cerris* Oersted vel sect. *Dentata* C.K. Schneid.	dry, mesophytic forest	–
Sequoia abietina (Brongniart) Knobloch	*Sequoia sempervirens* (D. Don.) Endl.	humid forest on the western slopes of Sierra Nevada Mts.	western North America
Smilax cf. *weberi* Wessel in Wessel & Weber	*Smilax hispida* Muhlenb. *S. rotundifolia* L. *S. excelsa* L.	humid forest and woods, mesophytic forest	south-eastern North America Balkan Peninsula, Transcaucasus, Asia Minor
Smilax sagittifera Heer sensu Hantke	*Smilax aspera* L.	Mediterranean vegetation	Mediterranean areas, Middle Asia
Smilax cf. *protolancaefolia* Kolakovsky	*Smilax lancaefolia* Roxb.	mesophytic forest	China, Himalaya Mts.
Stratiotes kaltennordheimensis (Zenker) Keilhack	*Stratiotes aloides* L.	lakes, oxbow lakes	Europe, western Siberia
Symplociphyllum breddini (Weyland) Juchniewicz	Theaceae (?)	–	–
Taxodium dubium (Sternberg) Heer	*Taxodium distichum* (L.) Rich. *T. mucronatum* Tenore	swamp and riparian forest mountain riparian forest	eastern North America Mexico
Tetraclinis salicornioides (Unger) Z. Kvaček	*Tetraclinis articulata* (Vahl.) Mast.	dry Mediterranean vegetation	north Africa, Malta, south-eastern Spain
Ulmus sp.	–	–	–
Viscophyllum pliocenicum (Engelhardt) Mädler	various species from genus *Viscum*	–	–

Pinus, *Rhamnus*, and *Vaccinium* as well as lianas (*Smilax*, *Dioscorea*) grow in this setting.

In the eastern part of North America, along river banks and lake shores one can find birch-alder dominated riparian forest and bush ecosystems, that contains, among others, *Alnus serrulata* (Ait.) Willd. that is comparable to the fossil species *Alnus menzelii* Raniecka-Bobrowska. In addition to the alder, these communities are composed of species belonging to the genera *Betula*, *Carpinus*, *Cephalanthus*, *Cornus*, and *Salix* (Knapp 1965). *Taxodium mucronatum* Tenore, a close representative of the fossil species *Taxodium dubium* (Sternberg) Heer, grows in mountainous riparian forest in Mexico; it is associated with *Alnus*, *Fraxinus*, *Juglans*, *Platanus*, *Populus*, *Salix*, and *Ulmus* (Knapp 1965, Röhrig 1991).

In the available literature are no detailed descriptions of the composition of the riparian forest from East Asia. The relictual species *Glyptostrobus pensilis* Koch, a descendant of the widely distributed Tertiary species *Glyptostrobus europeus* (Brongniart) Unger appears to grow in the communities of that type on river banks in south-eastern China, and Vietnam (Krüssmann 1972, Hiêp & Vidal 1996).

Riparian forests, resembling the Neogene plant communities from Bełchatów, are also found on river banks in the Talysh Lowlands and Colchis in Transcaucasia. Riparian forest with *Acer velutinum* Boiss., *Alnus subcordata* C. A. Mey, similar to *Alnus menzelii* Raniecka-Bobrowska, *Gleditsia caspia* Desf., *Pterocarya pterocarpa* (Michaux) Kunth, comparable to the fossil species *Pterocarya paradisiaca* (Unger) Ilinskaya and *Zelkova carpinifolia* (Pall.) Dipp. grow in the Talysh Lowland (Tutayuk 1975).

The Neogene mesophytic forest from Bełchatów correspond to recent, floristically rich mesophytic deciduous forest from the eastern part of North America. Their species and generic composition change depending on their geographical situation, elevation above sea level and specific habitat conditions (including humidity of substratum and soil type). Among many genera of angiosperms trees occurring in this forest there are, *Acer*, *Aesculus*, *Betula*, *Castanea*, *Carya*, *Celtis*, *Fagus*, *Fraxinus*, *Juglans*, *Liquidambar*, *Liriodendron*, *Magnolia*, *Nyssa*, *Platanus*, *Quercus*, *Sassafras*, *Tilia*, *Ulmus*, and others. Coniferous trees are represented by the genera *Pinus* and *Tsuga* (Braun 1964, Barnes 1991, Knapp 1965). Areas where this forest grow are characterized by mean annual temperatures ranging from +6.3 to +11.9°C and with annual precipitation in the range of 700 to 1000 mm.

The other area with similar plant occurrences in mesophytic forest is East Asia, where many plant genera have survived as relicts since the Tertiary. Mixed Mesophytic forest occurring in central China, mainly in the drainage basin of the Jangcy River, have most genera in common with Tertiary mesophytic forest (Wang 1961). In this forest one can find trees, shrubs and lianas representing the genera *Acer*, *Alnus*, *Betula*, *Carpinus*, *Carya*, *Celtis*, *Cercidiphyllum*, *Fagus*, *Fraxinus*, *Kalopanax*, *Liquidambar*, *Magnolia*, *Nyssa*, *Ostrya*, *Phellodendron*, *Populus*, *Pterocarya*, *Quercus*, *Tilia*, and *Ulmus*. Also evergreen trees and shrubs of the genera *Castanopsis*, *Michelia* and *Pasania*, representatives of the family *Lauraceae*, and lianas (e.g. *Smilax*) are numerous. There are also many genera of coniferous trees, often of relictual character including *Cephalotaxus*, *Cryptomeria*, and *Cunninghamia*. In addition, *Alnus japonica* Sieb. & Zucc., closely comparable to the fossils species *Alnus julianiformis* (Sternberg) Z. Kvaček & Holý and *Alnus nitida* (Spach) Endlicher, closely related to the Tertiary species *Alnus gaudinii* (Heer) Knobloch & Z. Kvaček grow in Mixed Mesophytic Forest. The east-Asiatic beech species *Fagus hayatae* Palibin is closely related to the fossil species *Fagus silesiaca* Walther & Zastawniak. Among numerous representatives of the family Lauraceae occurring in Mixed Mesophytic Forest in China there are genera (e.g. *Litsea*, *Lindera*, *Neolitsea*, *Cryptocarya*) resembling fossil *Daphnogene polymorpha* (Al.Braun) Ettingshausen and *Laurophyllum pseudoprinceps* Weyland & Kilpper. Areas occupied by this forest are characterized by a rather mild monsoon climate with mean annual temperatures ranging from +11 to +16°C, and comparatively high annual precipitation levels (1000–1500 mm) that falls predominantly over the summer months (Wang 1961).

The last area with recent mesophytic forest comprising relic genera in common with the Tertiary forest vegetation from Bełchatów, is the Transcaucasia region that includes the Talysh Lowlands and Colchis in adjacent areas of Iran and Turkey. Mesophytic forest growing in lowlands and at lower mountains is composed of trees representing the genera *Acer*, *Alnus*, *Carpinus*, *Fraxinus*, *Populus*, *Quercus Ulmus*, and genera which have the character of Tertiary relics, such as *Diospyros*, *Gleditsia*, *Parrotia* and *Zelkova* (Walter 1974, Tutayuk 1975, Röhring 1991). The climate of the Talysh Lowlands is mild; mean annual temperatures oscillate around +14ºC and the mean temperature of the coolest month is +3ºC. Considerable annual precipitation (1250 mm) falls mainly during the autumn months and in contrast, the summer is a relatively dry period. Frosts occur rarely in this environmental setting and those frosts that do occur are typically of short duration.

Sequoia abietina (Brongniart) Knobloch and *Tetraclinis salicornioides* (Unger) Z. Kvaček have their recent counterparts among the vegetation of the other type. *Sequoia sempervirens* Endl., considered an analogue of fossil *Sequoia abietina* (Brongniart) Knobloch, grows at the present time on the western slopes of the Sierra Nevada in California. In this setting *Sequoia sempervirens* Endl. is associated with trees and shrubs of the genera *Acer*, *Cornus*, *Corylus*, *Lithocarpus*, *Rhododendron* and *Rhus*, and grow under mild and humid climate conditions. Here the mean temperature of the coolest months may reach +8.1ºC, and annual precipitation can range from 800 to 2500 mm (Knapp 1965; Podbielkowski 1987). The other species, *Tetraclinis salicornioides* (Unger) Z. Kvaček is related to recent *Tetraclinis articulata* (Vachl.) Mast., that occurs in the western part of the Mediterranean Sea basin. The typical vegetation of this area is maquis (Podbielkowski 1987). This area is characterized by a Mediterranean climate with dry summers and rainy and almost frost-free winters (Podbielkowski op. cit.)

PALAEOCLIMATE

Prevailing climate conditions during the time of the KRAM-P 211/214 and KRAM-P 217 floras have been determined on the basis of a comparison with a climate of areas in which the recent counterparts of the fossil taxa occur. This palaeoclimate reconstruction was based on the principle underlying the so-called “coexistence approach” method, as established by Mosbrugger and Utescher (1997) for the reconstruction of Tertiary palaeoclimates. The parameters of the palaeoclimate have been established on the basis of requirements of the recent plant genera, closely related to the fossil ones and characterized by rather limited ranges. This approach allows one to determine relatively precisely meteorological parameters, e.g. mean annual temperature. However, in case of the floras from Bełchatów the use of the “coexistence approach” method has certain limitations and actually I have performed a “palaeoclimate analysis of the nearest living relatives of selected taxa”.

To determine climatic conditions in which the fossil flora KRAM-P 211/214 existed, two species: *Taxodium distichum* (L.) Rich. – equivalent of fossil *Taxodium dubium* (Sternberg) Heer, and *Glyptostrobus pensilis* Koch – equivalent of fossil *Glyptostrobus europaeus* (Brongniart) Unger have been selected. Mean annual temperatures in the area of the occurrence of *Taxodium distichum* (L.) Rich. are usually in the region of +15 to +18ºC (the lowest +13.3ºC), while means for the coolest month vary between +4.9 and +9.9ºC (Mai 1995). The duration of the frost-free period is minimum 240 days and mean annual precipitation exceeds 1000 mm (Barnes 1991). In the area of the natural distribution of the species *Glyptostrobus pensilis* Koch. mean annual temperature is in the region of +17.7ºC, mean annual precipitation is in excess of 1400 mm, mean temperature for the coolest month is approximately +6ºC, and mean temperature for the warmest month reaches approximately +30ºC (Mai 1995).

On the basis of a comparison between the climatic requirements of these two taxa, the basic parameters of the palaeoclimate of the flora KRAM-P 211/214 have been determined as follows: mean temperature for the coolest month may have been in the region of +5 to +9ºC, mean annual temperature was likely to have been in the region of +15 to +18ºC, and annual precipitation was likely to have been in the region of 1000 to 1500 mm.

To reconstruct the climate for the flora KRAM-P 217, the author has selected recent counterparts of fossil *Sequoia abietina* (Brongniart) Knobloch (*Sequoia sempervirens* Endl.), *Cyrilla thomsonii* Kräusel & Weyland (*Cyrilla racemiflora* L.) and *Pterocarya paradisiaca* (Unger) Ilinskaya (*Pterocarya pterocarpa* (Michaux) Kunth).

Recent forest with *Sequoia sempervirens* Endl. occur in areas with mean annual temperatures reaching +11 to +15ºC, mean temperature for the coolest month approximately +8 to +11ºC, mean annual temperature for the warmest month between +13.5 to +19.5ºC, and with annual precipitation varying between 800 and 2500 mm (Knapp 1965, Podbielkowski

1987, Mai 1995). The areas of the occurrence of *Pterocarya pterocarpa* (Michaux) Kunth are characterized by a mean annual temperature of approximately +14°C, a mean temperature for the coolest month of approximately +3°C, mean temperature for the warmest month of +24°C and total annual precipitation approximately 1200 mm. In North America, *Cyrilla racemiflora* L. occurs in the area approximating the range of *Taxodium distichum* (L.) Rich.

The parameters of the palaeoclimate for the flora KRAM-P 217 were as follows: a mean annual temperature of approximately +14°C and a mean temperature for the coolest month between +4 and +8°C. Annual precipitation was likely to have been higher than or equal to 1000 mm, as indicated by the presence of epiphyllous fungi from the family *Microthyriaceae* (Elsik 1978).

Comparing the obtained climatic data for the two fossil floras from Bełchatów, one can see that the flora KRAM-P 217 occurred under the conditions of a slightly cooler climate than the flora KRAM-P 211/214, whereas annual precipitation was similar in both cases.

According to Köppen's classification (Köppen 1918, 1931), the palaeoclimates of both fossil floras correspond to recent type Cfa. It is a moderately warm and humid climate, without a dry period and with hot summers.

For comparison, meteorological data for Piotrków Trybunalski (51°24' N, 19°41' E) are given. They characterize the contemporary climatic conditions prevailing in the area where the Bełchatów Lignite Mine is situated. The town is situated at 207 m a.s.l. and has a mean annual temperature of +7.6°C, a mean temperature for the warmest month of +17.9°C, a mean temperature of the coolest month of –2.5°C, and mean annual precipitation in the region of 576 mm (Kondracki 1988).

AGE OF THE FOSSIL FLORAS KRAM-P 211/214 AND KRAM-P 217

The determination of the age of the two described fossil floras from Bełchatów on the basis of parameters including their location in the profile and dating the sediments will be discussed separately. Dating based exclusively on radiometric data was possible only in the case of the flora KRAM-P 211/214, which was found in clays overlying the paratonstein horizon TS-3 (vel TS-4). On the basis of dating zircons from this paratonstein, using a fission track (FT) method, it was found that it originated 18.1 ± 1.7 Ma BP (Burchart 1985) or 17.25 ± 0.4 Ma BP (Burhart et al. 1988). These absolute ages corresponds to the upper part of the Early Miocene (Ottnangian or Karpatian in the scheme of Paratethys, Steininger et al. 1988). As clays with the flora lie directly over the paratonstein and no traces of the possible hiatus have been observed, it can be inferred that the layer with the flora is practically of the same age as the paratonstein. Stuchlik (Stuchlik et al. 1990), on the basis of palynological studies, established that the upper part of the profile IXc (from which clays with the flora KRAM-P 211/214 originate) is of an age corresponding to the end of the Ottnangian. It should be added that in lacustrine limestone underlying the paratonstein TS-3 (vel TS-4), at its contact with coal intercalations, there were numerous vertebrate remains that have been dated as Late Ottnangian – Karpatian, (mammal zone MN4, Kowalski 1993, 1994).

For the other examined flora (KRAM-P 217), which lies in the floor of the clayey-sandy unit in the erosion hole at the contact with the clayey-coal unit, there are no radiometric data available. The age of sediments of this part of the geological profile of the Bełchatów Lignite Mine has been estimated by different scientists as belonging to the younger Neogene. Stuchlik et al. (1990), Stuchlik and Szynkiewicz (1998) and Szynkiewicz (1999), on the basis of an analysis of plant macro-remains dated the lower part of the clayey-sandy unit as the Late Miocene (Pannonian). On the basis of lithology, Wilczyński (1992) correlated the lower members of the clayey-sandy unit (members A and B) with the deposits of the Poznań series of the Poznań-Wrocław basin. Baraniecka et al. (1997), using the results of palynological studies on the fossil soil section found within the unit under discussion, established its age as Late Miocene/ Early Pliocene. Gotowała and Hałuszczak (1999) are of the opinion that the third stage of the structural development of the Kleszczów graben, with which the accumulation of the young Tertiary sediments over the limit (GTPN) between the clayey-coal unit and clayey-sandy unit is connected, began in the Middle Pannonian (10 Ma BP).

Krzyszkowski and Szuchnik (1995) dated the uppermost part of the clayey-sandy unit as the Late Pliocene (Reuverian C).

Therefore, there is little doubt that the diachronous sediments of the clayey sandy unit were deposited in the Late Miocene to Pliocene (comp. Baraniecka et al. 1997). On this basis the same age interval can be accepted for the flora KRAM-P 217.

To determine the stratigraphic position of the flora KRAM-P 217 more precisely, Gregor's method (1982) was used. This method is based on a physionomical-taxonomical analysis of the fossil leaf remains. For the purposes of the method Gregor (op. cit.) divided fossil leaf forms into 23 morphotypes, based on such morphological characters of leaves as their venation pattern, a type of leaf margin, a size (surface) of leaves and their probable thickness. To these types he assigned corresponding letter symbols that are used for the schematic description of fossil floras; the most numerous forms are considered characteristic. To assess the frequency of occurrence Gregor used a four-grade scale. The commonest components of a given fossil flora (more than 100 specimens) were given grade 1, frequent elements (11–100 specimens) grade 2, not numerous forms (1–11 specimens) grade 3, while sporadic components grade 4.

In the flora KRAM-P 217 12 leaf morphotypes have been found: b – lauroid (*Cyrilla*, *Kalmia*), c – diospyroid (*Diospyros*, *Dicotylophyllum* sp. 3), d – coniferoid (*Sequoia*), e – myricoid (*Myrica*), f – juglandoid (*Aesculus*, *Dicotylophyllum* sp. 5, *Pterocarya*), i – quercoid (*Fagus*), k – tilioid (*Byttneriophyllum*, "*Ficus*"), m – carpinoid (*Alnus*, *Carpinus*), r – typhoid (*Bambusa*), s – smilacoid (*Smilax*), v – viscoid (*Viscophyllum*), w – pinoid (*Pinus*). The most numerous are morphotypes m (174 specimens), d (56), c (48), e (22) and r (15). On the scale of the frequency of occurrence they correspond to grades 1 (m) and 2 (d, c, e, r). Types w, b, k, i, f and s have frequency 3 and type v 4.

On the basis of an analysis of the frequency of particular morphotypes, the flora KRAM-P 217 can be coded as "m d c e f". This flora is closest to the floras of the "d e f g m" type within the larger group of floras "d e f g i k m" (Gregor 1982), which are characterized by the considerable floral richness of plant communities composed principally of deciduous trees and shrubs, with a large share of coniferous plants and presence of thermophilous elements.

Gregor (op. cit.) introduced to the characteristics of fossil floras the coefficient E_g, which is the ratio of all morphotypes representing evergreen taxa to the total number of morphotypes represented in a given flora. For floras "d e f g m" value E_g reaches 26, while for the flora from the locality KRAM-P 217 E_g is 33, which suggests a large share of evergreen elements in the flora KRAM-P 217. This should not be, however, an effect of particularly favourable climatic conditions. Taxa representing this element are mostly coniferous plants (types d, w – *Sequoia*, *Pinus*) and the shrubby vegetation of acid and poor bog habitats with xeromorphic and evergreen leaves (*Cyrilla*, *Kalmia*), typical of oligotrophic habitats. The presence of this group of plants was linked above all to edaphic conditions.

Floras of the "d e f g m" type occurred during the Late Miocene. They may be correlated with a climate of the Cfa type according to Köppen's classification, in its cooler form (Gregor 1982). In the opinion of Gregor (op. cit.), the fossil floras from Achldorf (d e f g i k m), Massenhausen (d e f g m), Moravská Nová Ves (d e f g m), Burghausen (d e f g m) and Chiuzbaia (d e f g m) are of this type. The flora from Achldorf, which shares with the flora KRAM-P 217 such characteristic leaf taxa as *Diospyros* or "*Ficus*" *truncata* Heer sensu Bůžek, is considered the Middle Miocene (Sarmatian) or the Late Miocene (Pannonian, Knobloch 1986).

The results of an analysis of the flora KRAM-P 217 based on Gregor's method (1982) allows one, in the opinion of the author of this publication, to date it more precisely as the Late Miocene (Pannonian-Pontian).

THE DESCRIBED LEAF FLORAS IN THE LIGHT OF THE PREVIOUSLY EXAMINED MACROFLORAS FROM THE BEŁCHATÓW LIGNITE MINE

The described fossil floras contributed to the knowledge of the Neogene macrofloras from the Bełchatów Lignite Mine. The flora KRAM-P 211/214 is the first leaf flora described from the Lower Miocene of Bełchatów. Clays with this flora can be correlated with the floor part of palaeobotanical section IX and the roof part of section IXc, which were described in the paper by Stuchlik et al. (1990). The macroflora of sections IX and IXc is represented exclusively by carpological remains and twigs of coniferous trees. With the floor part of section IX (samples 31–38), the flora KRAM-P 211/214 has two taxa in common: *Glyptostrobus europaeus* (Brongniart) Unger and *Stratiotes kaltennordheimensis* (Zenker) Keilhack.

In the whole section IXc Stuchlik et al. (op. cit.) identified approx. 20 taxa of plant macroremains but they did not mention which of them originated from the top part of the section. The bottom of section IX and section IXc, similarly as flora KRAM-P 211/214, are dominated by plant remains from wetlands (mostly swamp forest and riparian forest), whereas the share of taxa representing mesophytic vegetation is scarce. The detailed dating of the flora KRAM-P 211/214 allowed one to determine the age of the bottom part of palaeobotanical section IX and that of the top of section IXc as the Early Miocene.

The KRAM-P 217 flora originated from the clayey-sandy unit, which has yielded so far numerous macro-floras from sections III, VI, X, Xa, XII, XIII and XIIIa (Stuchlik et al. 1990 Szynkiewicz 2000), abundant in fossil fruits, seeds and leaves. The flora KRAM-P 217 and the leaf floras of sections VI, Xa and XII have two taxa in common: *Alnus menzelii* Raniecka-Bobrowska and *Fagus silesiaca* Walther & Zastawniak (as *Fagus attenuata* Goeppert). The leaf floras of sections VI, Xa and XII are dominated by the components of rich deciduous and mixed forest, which in the younger Neogene covered the area of central Europe. Also the share of azonal vegetation, both swamp and riparian, which dominates the flora KRAM-P 217, is well-marked. A precise correlation of the flora KRAM-P 217 with the macrofloras of sections VI, Xa and XII on the basis of data from the papers by Stuchlik et al. (1990) and Szynkiewicz (2000) is impossible. Sections VI and Xa have the closest stratigraphic position, whereas section XII lies much higher within the clayey-sandy unit (comp. Szynkiewicz 2000). The composition of the floras mentioned does not allow one to date precisely the deposits, as the identified taxa in these floras are known from the Neogene till the Late Pliocene in central Europe. Only the presence of oak leaves of the section *Cerris* Oersted (e.g. *Qurecus pseudocastanea* Goeppert emend. Walther & Zastawniak) suggests that the flora of section XII originates from the younger part of Neogene (Middle/ Late Miocene-Pliocene, Stuchlik et al. 1990).

COMPARISON WITH NEOGENE LEAF FLORAS FROM POLAND AND CENTRAL EUROPE

KRAM-P 211/214

Comparing the taxonomic composition of the flora KRAM-P 211/214 from Bełchatów with other Neogene leaf floras from Poland (Table 7), one can find that such taxa as *Laurophyllum pseudoprinceps* Weyland & Kilpper, *Quercus rhenana* (Kräusel & Weyland) Knobloch & Z. Kvaček and *Symplociphyllum breddini* (Weyland) Juchniewicz also occur in the floras from Osieczów (Raniecka-Bobrowska 1962b) and Turów (Juchniewicz 1975, Czeczott & Skirgiełło 1980). *Daphnogene polymorpha* (Al. Braun) Ettingshausen, common in the Lower Miocene, in the Middle Miocene was found in Poland only in Swoszowice (Unger 1849, Ilinskaya 1962) and Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997). The flora KRAM-P 211/214 has five taxa in common with the flora from Osieczów and Turów, and four taxa with the flora from Rozewie.

The fossil taxa *Laurophyllum pseudoprinceps* and *Daphnogene polymorpha* are present in the fossil floras of central Europe (Table 8) a little longer than in Poland, and reach even the Upper Miocene (Belz & Mosbrugger 1994, Kovar-Eder et al. 1995). *Quercus rhenana*, which in central Europe is reported mainly from the Lower Miocene and disappears in the Middle Miocene, is characterized by a narrower stratigraphic range (Walther 1994). An example of fossil floras approximating the flora KRAM-P 211/214, from beyond the area of Poland are the Early Miocene floras from Bílina (Bůžek et al. 1992), Western Bohemia (Cheb and Sokolov Basin, Bůžek et al. 1996), Wackersdorf (Knobloch & Kvaček 1976), southern Bohemia (Mydlovary Formation, Knobloch & Kvaček 1996) and northern Bohemia (Čermníky, Bůžek 1971). The Early Miocene flora of Bełchatów has 12 species in common with the floras from Cheb Basin and Mydlovary, and 9–10 species with the floras from Wackersdorf and Bílina (Table 8). All the compared floras comprise *Daphnogene poly-*

Table. 7. The occurrence of fossil taxa of the flora KRAM-P 211/214 in selected floras of the Neogene of Poland; (+) – taxon given under another name

Taxon	Lower Miocene			Middle Miocene										Upper Miocene				Mio-Pliocene		Pliocene		
	Osieczów (Raniecka-Bobrowska 1962b)	Rozewie (Heer 1869)	Turów (Czeczott & Skirgiełło 1959, Czeczott & Skirgiełło 1961, Czeczott 1967, Czeczott & Skirgiełło 1975, Czeczott & Skirgiełło 1980, Juchniewicz 1975)	Bełchatów (Stuchlik et al. 1990)	Dobrzyń on the Vistula (Kownas 1956)	Kokoszyce (Kräusel 1920)	Konin (Raniecka-Bobrowska 1954)	Koronowo (Menzel 1910)	Mirostowice (Zastawniak 1978)	Młyny (Zastawniak 1980)	Stare Gliwice (Szafer 1961)	Swoszowice (Ilinskaya 1962)	Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997)	Bełchatów (Stuchlik et al. 1990)	Gozdnica (Dyjor et al. 1992)	Sośnica (Goeppert 1855, Kräusel 1920, 1921, Meyer 1919, Łańcucka-Środoniowa et al. 1981, Reimann 1919, Zastawniak & Walther 1991, Zastawniak & Walther 1998)	Stare Bystre (Worobiec 1994)	Bełchatów Stawek 1A (Worobiec & Lesiak 1998)	Gnojna (Krajewska 1998)	Bełchatów (Wójcicki & Zastawniak 1998)	Domański Wierch (Zastawniak 1972)	Ruszów (Hummel 1983)
Acer integrilobum O. Weber																						
Acer tricuspidatum Bronn sensu Procházka & Bůžek	(+)				(+)	(+)				+	(+)					(+)						+
Alnus julianiformis (Sternberg) Z. Kvaček & Holý										+						+						+
“*Castanea*” *kubinyii* Kovats ex Ettingshausen sensu Knobloch & Z. Kvaček																						
cf. *Carya serrifolia* (Goeppert) Kräusel					+					+				+		+						+
Daphnogene polymorpha (Al.Braun) Ettingshausen	(+)	(+)	(+)									(+)	(+)									
Glyptostrobus europeus (Brongniart) Unger		+	+	+	+		+		+				+	+								+
Laurophyllum pseudoprinceps Weyland & Kilpper	(+)																					
Myrica lignitum (Unger) Saporta sensu lato					(+)							+		+						+		+
Nyssa ornithobroma Unger																						
Osmunda parschlugiana (Unger) Andreánszky																						
Pinus hampeana (Unger) Heer		+											+	+								
Quercus rhenana (Kräusel & Weyland) Knobloch & Z. Kvaček	(+)		(+)																			
Quercus sp. sect. *Cerris* vel sect. *Dentata*																					(+)	(+)
Smilax sagittifera Heer sensu Hantke																						
Stratiotes kaltennordheimensis (Zenker) Keilhack				+	+		+															
Symplociphyllum breddini (Weyland) Juchniewicz			+																			
Taxodium dubium (Sternberg) Heer		(+)	+	+	(+)			(+)	+			+	+	+	+	(+)		+	+	+		+
Tetraclinis salicornioides (Unger) Z. Kvaček	(+)					(+)				(+)	(+)		+	(+)	+	(+)						

Table. 8. The occurrence of fossil taxa of the flora KRAM-P 211/214 in selected floras of the Neogene of Central Europe; (+) – taxon given under another name

Taxon	Lower Miocene								Middle Miocene					Upper Miocene				Pliocene		
	Bílina (Bůžek et al. 1992)	Cheb Basin (Bůžek et al. 1996)	Čermníky (Bůžek 1971)	Mydlovary (Knobloch & Kvaček 1996)	North Bohemian Baked Rocks (Kvaček & Hurník 2000)	Oberdorf (Meller et al. 1999)	Sokolov Basin (Bůžek et al. 1996)	Wackersdorf (Knobloch & Kvaček 1976)	Achldorf (Knobloch 1986)	Kreuzau (Ferguson 1971)	Precarpathians (Shvareva 1983)	Schrotzburg (Oehningen) (Hantke 1954)	Wischgrund (Striegler 1985, 1990)	Molassezone of Austria (Kovar-Eder 1988)	Moravská Nová Ves (Knobloch 1969)	Neuhaus/Klausenbach (Kovar-Eder et al. 1995)	Paldau (Krenn 1998)	Berga (Mai & Walther 1988)	Willershausen (Wilde et al. 1992)	Transcarpathians (Ilinskaya 1968)
Acer integrilobum O. Weber		+		+		+			+	?				+	+					
Acer tricuspidatum Bronn sensu Procházka & Bůžek	+	+	+	+	+	+	+	+	+		(+)	(+)	+	+	+	+	+	+		(+)
Alnus julianiformis (Sternberg) Z. Kvaček & Holý	+	+		+	+			+					+							
"*Castanea*" *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček		+		+				+	?		?		+	?	?	?				?
cf. *Carya serrifolia* (Goeppert) Kräusel			+		+			?	+	?	(+)		+		+					(+)
Daphnogene polymorpha (Al.Braun) Ettingshausen	+	+	(+)	+	+	+	+	+	(+)	(+)	(+)	(+)			(+)	(+)				
Glyptostrobus europeus (Brongniart) Unger	+	+		+	+		+	+			+	+		+	+	+	+		+	+
Laurophyllum pseudoprinceps Weyland & Kilpper	+	+	+	+		+	+	+		+							+			
Myrica lignitum (Unger) Saporta sensu lato	+	+		+	+			+	+	+	+	?	+	+		+	+			
Nyssa ornithobroma Unger		+		+		+														
Osmunda parschlugiana (Unger) Andreánszky			+	+	+						(+)									(+)
Pinus hampeana (Unger) Heer																				
Quercus rhenana (Kräusel & Weyland) Knobloch & Z. Kvaček	+	+	(+)		+			+												
Quercus sp. sect. *Cerris* vel sect. *Dentata*																				
Smilax sagittifera Heer sensu Hantke		+		+								+								
Stratiotes kaltennordheimensis (Zenker) Keilhack	+																			
Symplociphyllum breddini (Weyland) Juchniewicz																				
Taxodium dubium (Sternberg) Heer	+		+		+				+	(+)			+					+		+
Tetraclinis salicornioides (Unger) Z. Kvaček	+	+		+			+	(+)		(+)	(+)		+		?	+				

morpha; *Laurophyllum pseudoprinceps* is absent only in one of them (Kvaček & Hurník 2000). In most of the localities mentioned there are *Acer integrilobum*, *Acer tricuspidatum*, *Alnus julianiformis*, *Glyptostrobus europeus*, *Nyssa ornithobroma*, *Quercus rhenana* and *Tetraclinis salicornioides*. A characteristic feature is the presence of *"Castanea" kubinyii*, occurring abundantly in Bełchatów and reported from the floras of Cheb Basin, Wackersdorf and Mydlovary (Table 8). In central Europe this taxon appears in the upper part of the Lower Miocene, but its peak development occurs in the younger Neogene (Knobloch & Kvaček 1996).

With the fossil floras from the Middle and Late Miocene of central Europe, the flora KRAM-P 211/214 has less taxa in common (up to 6). It has the least common taxa with the Pliocene floras from Berga (Mai & Walther 1988) and Willershausen (Wilde et al. 1992) and slightly more (5) with the Pliocene floras from Transcarpatians (Ilinskaya 1968).

KRAM-P 217

The composition of the fossil flora KRAM-P 217 from Bełchatów differs much from the Neogene floras hitherto known from Poland (Table 9). The flora KRAM-P 217 has most common species (4) with the Late Miocene flora from Sośnica: *Alnus gaudinii*, *Alnus menzelii*, *Fagus silesiaca* and *Pterocarya paradisiaca*. However, the flora from Sośnica differs from the flora from Bełchatów in that it has much larger proportion of mesophytic taxa, e.g. *Carpinus grandis* Unger, *Parrotia pristina* (Ettingshausen) Stur, *Qurecus gigas* and *Q. pseudocastanea* (Goeppert 1855, Meyer 1919, Kräusel 1921, Łancucka-Środoniowa et al. 1981, Walther & Zastawniak 1991, Zastawniak & Walther 1998).

A comparison of the flora KRAM-P 217 and the Late Miocene flora from Gozdnica is rather interesting (Dyjor et al. 1992). They have not only certain common species, such as *Fagus silesiaca*, *Pinus* cf. *spinosa* and *Sequoia abietina* but also the representatives of such families as Cyrillaceae, Ericaceae, Myricaceae and Smilacaceae.

The flora KRAM-P 217 from Bełchatów resembles also the central European Middle and Late Miocene fossil floras from beyond Poland (Table 10). Among the Middle Miocene floras, the greatest similarity (8 common species) is shown by the flora from Precarpathians (Shvareva 1983), and the flora from Achldorf (Knobloch 1986, 5 common species). *Myrica lignitum* and leaves of the genera *Diospyros* and *Smilax* are common for the floras mentioned. In addition, the leaves of *Alnus menzelii* and *"Ficus" truncata* found in Achldorf occur also in the flora KRAM-P 217. The flora from Achldorf differs in that it has a larger proportion of the mesophytic elements (e.g. *Carpinus* cf. *grandis*, *Parrotia pristina*, *Quercus pseudocastanea*).

With the Transcarpathian Pliocene flora (Ilinskaya 1968) the flora KRAM-P 217 has 7 common species (e.g. *Bambusa lugdunensis*, *Byttneriophyllum tiliaefolium*, *Pterocarya paradisiaca* and *Smilax weberi*).

The flora KRAM-P 217 from Bełchatów has least common species (1–2) with the Pliocene floras from Berga (Mai & Walther 1988) and Willershausen (Wilde et al. 1992).

A comparison between the flora KRAM-P 217 from Bełchatów and the Neogene fossil floras from Poland and other countries in central Europe is the last question in the discussion on dating the lower part of the clayey-sandy unit. It confirms the results of dating the age of the flora KRAM-P 217 as the Late Miocene (Pannonian/Pontian), based on Gregor's method. Indicative to this is the presence of both characteristic species of the younger stages of Neogene (*Aesculus* cf. *hippocastanoides*, *Bambusa lugdunensis*, *Fagus silesiaca*) and taxa only sporadically found in the deposits younger than Late Miocene, e.g. *Alnus gaudinii*, *Cyrilla thomsonii*, *Diospyros anceps* and *Smilax* cf. *weberi* (Table 11). Characteristic taxa of the Pliocene fossil floras, closely related to or identical with recent species, for example *Quercus castaneifolia* C.A. Mey. foss. and *Ulmus carpinifolia* Gled. foss. in Willershausen (Wilde et al. 1992), have not been found in Bełchatów. Then, a considerable share of evergreen plants in the flora KRAM-P 217 is characteristic of the Miocene floras from central Europe. The presence of this element makes the flora from Bełchatów similar to the Late Miocene floras from Neuhaus/Klausenbach (Kovar-Eder et al. 1995) and Moravská Nová Ves (Knobloch 1969), from which the leaves of evergreen plants were described. In the Early Pliocene floras a share of evergreen taxa is very small or they are absent. The com-

Table. 9. The occurrence of fossil taxa of the flora KRAM-P 217 in selected floras of the Neogene of Poland; (+) – taxon given under another name

Taxon	Lower Miocene			Middle Miocene										Upper Miocene				Mio-Pliocene		Pliocene		
	Osieczów (Raniecka-Bobrowska 1962b)	Rozewie (Heer 1869)	Turów (Czeczott & Skirgiełło 1959, Czeczott & Skirgiełło 1961, Czeczott 1967, Czeczott & Skirgiełło 1975, Czeczott & Skirgiełło 1980, Juchniewicz 1975)	Bełchatów (Stuchlik et al. 1990)	Dobrzyń on the Vistula (Kownas 1956)	Kokoszyce (Kräusel 1920)	Konin (Raniecka-Bobrowska 1954)	Koronowo (Menzel 1910)	Mirostowice (Zastawniak 1978)	Młyny (Zastawniak 1980)	Stare Gliwice (Szafer 1961)	Swoszowice (Ilinskaya 1962)	Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997)	Bełchatów (Stuchlik et al. 1990)	Gozdnica (Dyjor et al. 1992)	Sośnica (Goeppert 1855, Kräusel 1920, 1921, Meyer 1919, Łańcucka-Środoniowa et al. 1981, Reimann 1919, Walther & Zastawniak 1991, Zastawniak & Walther 1998)	Stare Bystre (Worobiec 1994)	Bełchatów Stawek 1A (Worobiec & Lesiak 1998)	Gnojna (Krajewska 1998)	Bełchatów (Wójcicki & Zastawniak 1998)	Domański Wierch (Zastawniak 1972)	Ruszów (Hummel 1983)
“*Ficus*” *truncata* Heer sensu Bůžek								?														
Aesculus cf. *hippocastanoides* Ilinskaya																						
Alnus gaudinii (Heer) Knobloch & Z. Kvaček		(+)				(+)	(+)									+						
Alnus menzelii Raniecka-Bobrowska							+	(+)								+		+	+			+
Bambusa lugdunensis Saporta																						
Byttneriophyllum tiliaefolium (Al. Braun) Knobloch & Z. Kvaček			(+)	+				(+)														
Cyrilla thomsonii Kräusel & Weyland			?																			
Diospyros anceps Heer	(+)	+										(+)										
Fagus silesiaca Walther & Zastawniak						(+)								(+)	+	+	(+)	+		+	(+)	(+)
Kalmia cf. *saxonica* Litke																						
Myrica lignitum (Unger) Saporta sensu lato					(+)							+		+						+		+
Pinus cf. *spinosa* Herbst				+							+		+		+							
Pterocarya paradisiaca (Unger) Ilinskaya			(+)								+		+	+		(+)	+			+	+	
Sequoia abietina (Brongniart) Knobloch	(+)		(+)	?									+		+							
Smilax cf. *protolancaefolia* Kolakovsky																						
Smilax cf. weberi Wessel in Wessel & Weber		(+)										(+)										
Viscophyllum pliocenicum (Engelhardt) Mädler											+											

Table 10. The occurrence of fossil taxa of the flora KRAM-P 217 in selected floras of the Neogene of Central Europe; (+) – taxon given under another name

Taxon	Lower Miocene								Middle Miocene					Upper Miocene				Pliocene		
	Bílina (Bůžek et al. 1992)	Cheb Basin (Bůžek et al. 1996)	Čermníky (Bůžek 1971)	Mydlovary (Knobloch & Kvaček 1996)	North Bohemian Baked Rocks (Kvaček & Hurník 2000)	Oberdorf (Meller et al. 1999)	Sokolov Basin (Bůžek et al. 1996)	Wackersdorf (Knobloch & Kvaček 1976)	Achldorf (Knobloch 1986)	Kreuzau (Ferguson 1971)	Precarpathians (Shvareva 1983)	Schrotzburg (Oehningen) (Hantke 1954)	Wischgrund (Striegler 1985, 1990)	Molassezone of Austria (Kovar-Eder 1988)	Moravská Nová Ves (Knobloch 1969)	Neuhaus/Klausenbach (Kovar-Eder et al. 1995)	Paldau (Krenn 1998)	Berga (Mai & Walther 1988)	Willershausen (Wilde et al. 1992)	Transcarpathians (Ilinskaya 1968)
“*Ficus*” *truncata* Heer sensu Bůžek	+		+		+				+	?										
Aesculus cf. *hippocastanoides* Ilinskaya											+									+
Alnus gaudinii (Heer) Knobloch & Z. Kvaček	+	+			+		+	+												
Alnus menzelii Raniecka-Bobrowska	?				+				+		?					+	+			?
Bambusa lugdunensis Saporta																				+
Byttneriophyllum tiliaefolium (Al. Braun) Knobloch & Z. Kvaček											(+)			+						(+)
Cyrilla thomsonii Kräusel & Weyland																				
Diospyros anceps Heer			(+)						(+)		(+)	(+)								
Fagus silesiaca Walther & Zastawniak											(+)	(+)	(+)	(+)	(+)	(+)		?	?	
Kalmia cf. *saxonica* Litke			+																	
Myrica lignitum (Unger) Saporta sensu lato	+	+		+	+			+	+	+	+	?	+	+		+	+			
Pinus cf. *spinosa* Herbst																				
Pterocarya paradisiaca (Unger) Ilinskaya								+		?	+		?	+	+		+			+
Sequoia abietina (Brongniart) Knobloch	?												?	+	+				(+)	(+)
Smilax cf. *protolancaefolia* Kolakovsky																				
Smilax cf. weberi Wessel in Wessel & Weber	+		+		+			+	?	?	(+)									(+)
Viscophyllum pliocenicum (Engelhardt) Mädler																				

Table 11. Stratigraphical range of species found in fossil floras KRAM-P 211/214 and KRAM-P 217 in the Neogene of Poland

Taxon	KRAM-P 211/214	KRAM-P 217	Stratigraphical range
Laurophyllum pseudoprinceps Weyland & Kilpper	+		Lower Miocene
"*Castanea*" *kubinyii* Kovats ex Ettingshausen sensu Knobloch & Z. Kvaček	+		Lower Miocene
Acer integrilobum O.Weber	+		Lower Miocene
Osmunda parschlugiana (Unger) Andreánszky	+		Lower Miocene
Quercus rhenana (Kräusel & Weyland) Knobloch & Z. Kvaček	+		Lower Miocene
Smilax sagittifera Heer sensu Hantke	+		Lower Miocene
Symplociphyllum breddini (Weyland) Juchniewicz	+		Lower Miocene
Daphnogene polymorpha (Al.Braun) Ettingshausen	+		Lower Miocene – Middle Miocene
Stratiotes kaltennordheimensis (Zenker) Keilhack	+		Lower Miocene – Middle Miocene
Pinus hampeana (Unger) Heer	+		Lower Miocene – Upper Miocene
Tetraclinis salicornioides (Unger) Z. Kvaček	+		Lower Miocene – Upper Miocene
Acer tricuspidatum Bronn sensu Procházka & Bůžek	+		Lower Miocene – Lower Pliocenee
Alnus julianiformis (Sternberg) Z. Kvaček & Holý	+		Lower Miocene – Lower Pliocenee
Glyptostrobus europeus (Brongniart) Unger	+		Lower Miocene – Lower Pliocenee
Quercus sp. sect. *Cerris* vel sect. *Dentata*	+		Lower Miocene – Pliocene
Taxodium dubium (Sternberg) Heer	+		Lower Miocene – Pliocene
cf. *Carya serrifolia* (Goeppert) Kräusel	+		Middle Miocene – Lower Pliocenee
Nyssa ornithobroma Unger	+		Miocene
Myrica lignitum (Unger) Saporta sensu lato	+	+	Lower Miocene – Pliocene
Diospyros anceps Heer		+	Lower Miocene – Middle Miocene
Smilax cf. *weberi* Wessel in Wessel & Weber		+	Lower Miocene – Middle Miocene
Alnus gaudinii (Heer) Knobloch & Z. Kvaček		+	Lower Miocene – Upper Miocene
Sequoia abietina (Brongniart) Knobloch		+	Lower Miocene – Upper Miocene
Byttneriophyllum tiliaefolium (Al. Braun) Knobloch & Z. Kvaček		+	Lower Miocene – Upper Miocene
Pterocarya paradisiaca (Unger) Ilinskaya		+	Lower Miocene – Pliocene
Viscophyllum pliocenicum (Engelhardt) Mädler		+	Middle Miocene
Pinus cf. *spinosa* Herbst		+	Middle Miocene – Upper Miocene
Alnus menzelii Raniecka-Bobrowska		+	Middle Miocene – Lower Pliocenee
Fagus silesiaca Walther & Zastawniak		+	Middle Miocene – Pliocene
"*Ficus*" *truncata* Heer sensu Bůžek		+	Upper Miocene
Aesculus cf. *hippocastanoides* Ilinskaya		+	Upper Miocene
Bambusa lugdunensis Saporta		+	Upper Miocene
Cyrilla thomsonii Kräusel & Weyland		+	Upper Miocene
Kalmia cf. *saxonica* Litke		+	Upper Miocene
Smilax cf. *protolancaefolia* Kolakovsky		+	Upper Miocene

position of the flora KRAM-P 217 does not allow its dating as Pliocene.

CONCLUSIONS

The two investigated fossil floras from the Bełchatów Lignite Mine (KRAM-P 211/214, and KRAM-P 217) are characterized by a relatively small floristic diversity (Tables 2 and 3). The flora KRAM-P 211/214 distinguishes itself by a large proportion of thermophilous evergreen taxa, including the representatives of the family Lauraceae (*Daphnogene*, *Laurophyllum*). Also in the flora KRAM-P 217 the percentage of evergreen taxa is significant, however their presence is connected rather with edaphic conditions than climatic ones.

Both flora KRAM-P 211/214, and flora KRAM-P 217 are dominated by the element characteristic of the Arctotertiary geoflora. The palaeotropical element has a small share and its typical representatives occur above all in flora KRAM-P 211/214.

In the examined fossil floras the remains of azonal vegetation prevail. According to Mai's classification (1995) the communities of fossil plants from Bełchatów can be assigned to swamp forest and riparian forest; in flora KRAM-P 217 also the occurrence of bush swampy vegetation has been found. Swamp forest grew on peaty soils, in places inundated by water for the most part of the year. The habitat of riparian forest was formed by mineral soils in areas that were situated within the reach of annual river floods. The plant communities mentioned occurred in the vicinity of water reservoirs, such as lakes (KRAM-P 211/214) or ox-bow lakes (KRAM-P 217). In the fossil floras described there were also remains of water and rush plants found. Part of the taxa discovered in the fossil floras indicate the presence of communities representing zonal vegetation: Mixed Mesophytic Forests in the flora KRAM-P 211/214 and mixed forest *Fagus-Quercus-Carpinus* in flora KRAM-P 217. The plant communities mentioned were common in the European Tertiary, and some of them were found still in the oldest Pleistocene.

Recent counterparts of the fossil plant taxa occur above all in south-eastern North America, East Asia, Transcaucasia, and southern Europe (Table 6). Swamp vegetation corresponding to the fossil communities from Bełchatów grows in lowlands of the south-eastern part of North America. Riparian forest occurring in these areas, and, Talysh and Colchis lowlands in Transcaucasia are rather similar to the Neogene riparian communities from Bełchatów. Recent analogues of the taxa representing mesophytic forest vegetation, found in the flora KRAM-P 211/214 as well as KRAM-P 217, are existing in both mesophytic forest in North America and in Mixed Mesophytic Forests in China.

Palaeoclimatic conditions have been reconstructed following the principle underlying the "coexistence approach" method (Mosbrugger & Utescher 1997). The period of the flora KRAM-P 211/214 origin was characterized by a moderately warm and humid climate (mean temperature of the coolest month was +5 to +9°C, mean annual temperature +15 to +18°C, and total annual precipitation reached 1000–1500 mm). The palaeoclimate corresponding to flora KRAM-P 217 was, as it seems, equally humid (annual precipitation was greater or equal to 1000 mm) but thermal conditions were less favourable (mean annual temperature approx. +14°C, mean temperature of the coolest month +4 to +8°C). The palaeoclimates corresponding to both fossil floras have been included into the Cfa type in Köppen's classification (1918, 1931).

The age of this part the geological profile of the Neogene of the Bełchatów Lignite Mine, where the fossil flora KRAM-P 211/214 was found, determined earlier (on the basis of absolute radiometric dating of the paratonstein TS-3 (vel TS-4) using the fission track method (Burchart 1985, Burchart et al. 1988) and the results of the palynological analysis (Stuchlik et al. 1990), as the Early Miocene (Ottnangian-Karpatian), has been confirmed by the results of an analysis of the stratigraphic range of the taxa.

A precise dating of fossil flora KRAM-P 217 from the floor part of the clayey-sandy unit on the basis of plant macroremains is rather difficult. The results obtained using Gregor's method (1982) show only that this flora coded as "m d c e f" corresponds to fossil floras of the "d e f g m" type which are typical of the younger Neogene (Late Miocene). A comparison with other fossil floras from the area of Poland and central Europe shows that the Pliocene age of flora KRAM-P 217 is unlikely. Analysing the stratigraphic ranges of some leaf taxa, the author has found that part of them is characteristic of the floras from Late Miocene to the Pliocene (*Fagus silesiaca*, *Aesculus hippocastanoides*), while others (e.g. *Cyrilla thomsonii*) have not been reported from younger periods than the Late Miocene. On the basis of the above findings, it has been accepted that flora KRAM-P 217 is of the Late Miocene age and corresponds to the Pannonian or Pontian stage in the scheme of Paratethys. The above conclusion is in agreement with the determination of the age of the lower part of the clayey-sandy unit, resulting from the previous palaeobotanical (Stuchlik et al. 1990, Baraniecka et al. 1997, Stuchlik & Szynkiewicz 1998, Szynkiewicz 1999) and geological studies (Wilczyński 1992, Gotowała & Hałuszczak 1999).

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PLATES

Plate 1

Pinus hampeana (Unger) Heer

1. Specimen KRAM-P 214/158, × 1.5

Pinus cf. *spinosa* Herbst

2. Specimen KRAM-P 217/15, × 1
8. Specimen KRAM-P 217/20, × 1.5
8a. Epidermis with stomata, specimen KRAM-P 217/20, × ca. 180

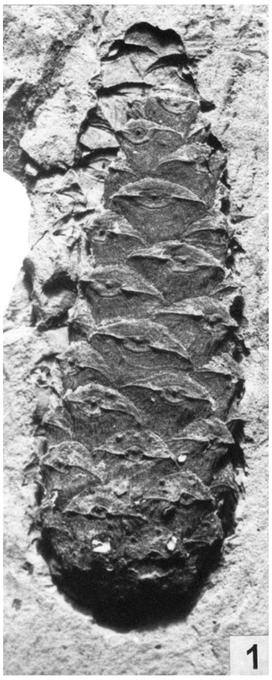
Pinus sp. div.

3. Specimen KRAM-P 217/49, × 3
5. Specimen KRAM-P 214/90, × 1
6. Specimen KRAM-P 214/16, × 5
7. Specimen KRAM-P 214/161, × ca. 5

Osmunda parschlugiana (Unger) Andreánszky

4. Specimen KRAM-P 214/36, × 5
4a. Stomatal apparatus, specimen KRAM-P 214/36, × 720

1–4, 5–8 phot. A Pachoński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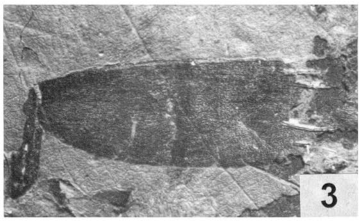
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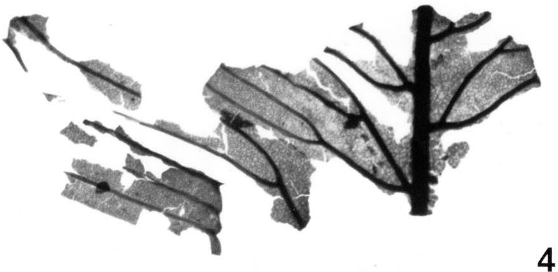
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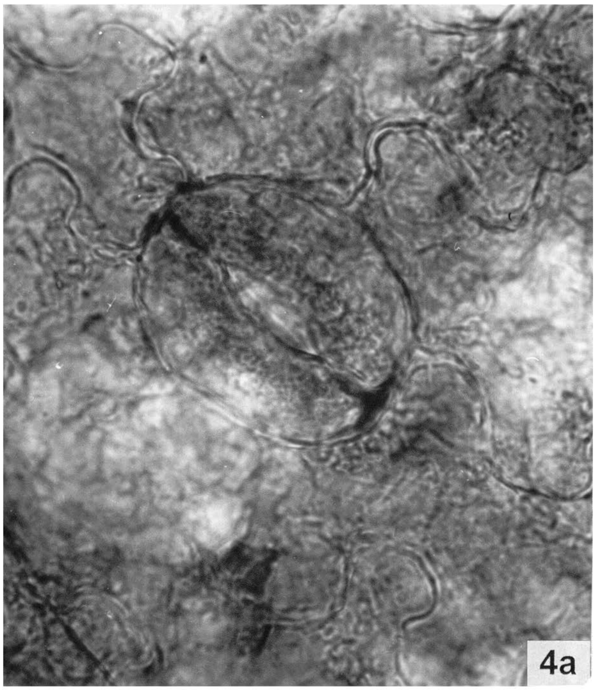
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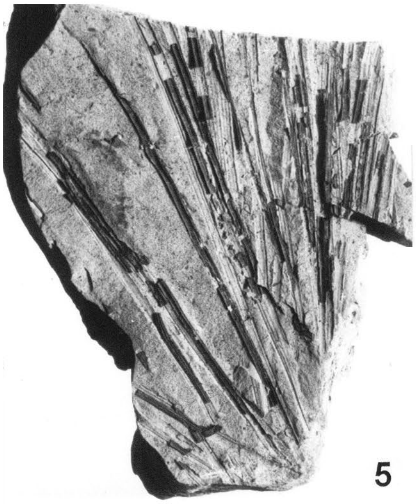
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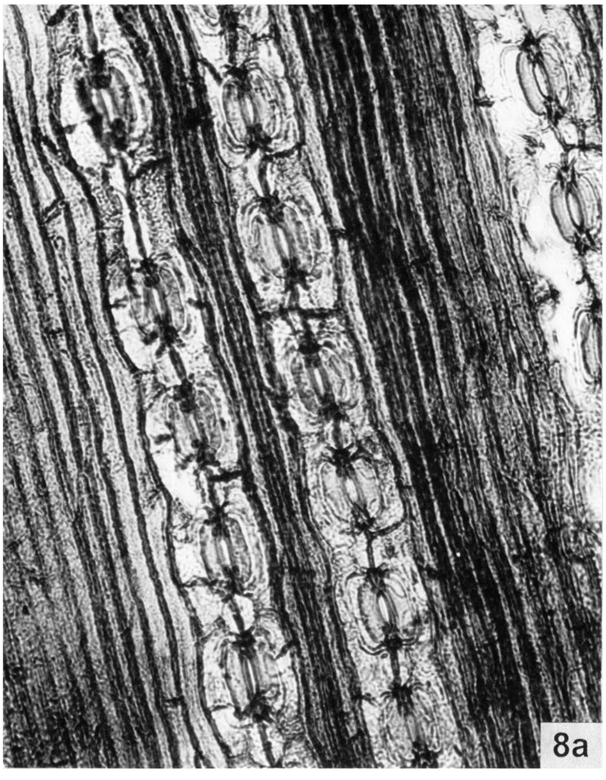
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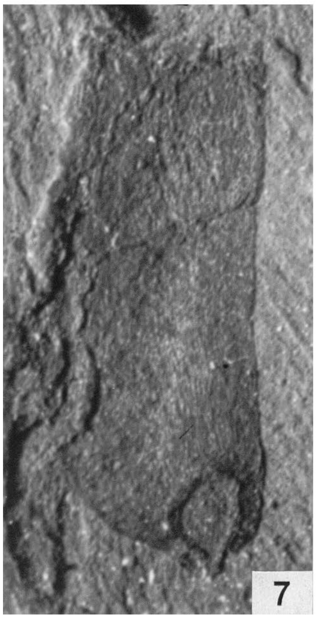
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Plate 2

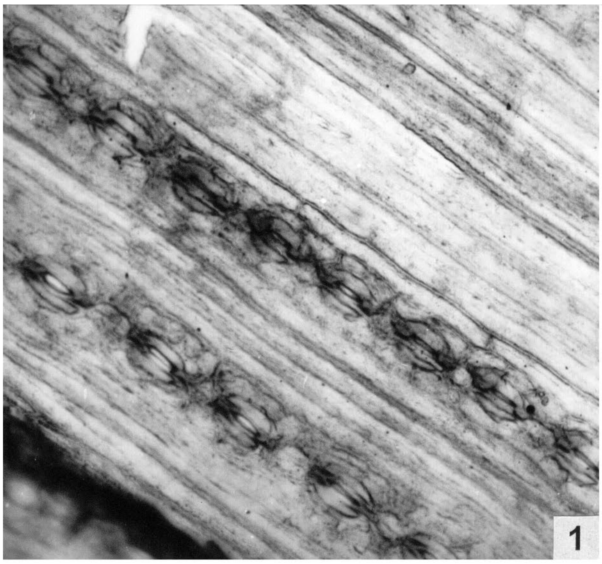
Pinus sp.

1. Epidermis with stomata, specimen KRAM-P 214/16, × ca. 180
1a. Stomatal apparatus, specimen KRAM-P 214/16, × ca. 720

Sequoia abietina (Brongniart) Knobloch

2. Cupressoid shoot, specimen KRAM-P 217/21, × 1
3. Taxodioid shoot, specimen KRAM-P 217/7, × 1
4. Taxodioid shoot, specimen KRAM-P 217/33/I, × 1
5. Cryptomerioid shoot, specimen KRAM-P 217/34, × 2
6. Specimen KRAM-P 217/223, × 1.5
7. Cupressoid shoot, specimen KRAM-P 217/31, × 1
8. Specimen KRAM-P 217/73, × 2

2–8 phot. A Pachoński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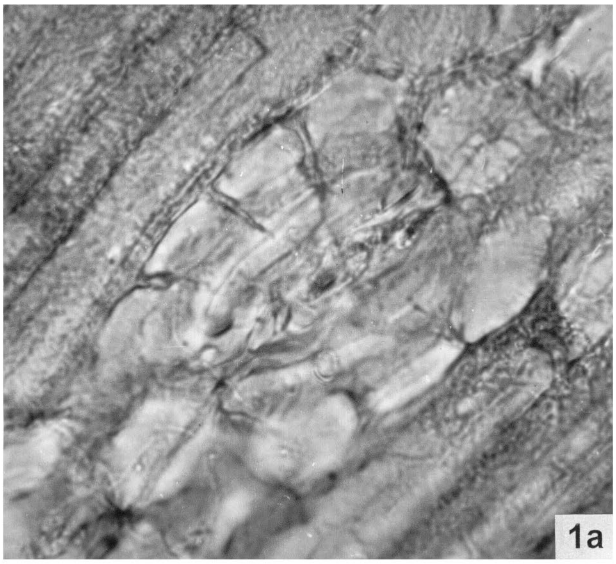
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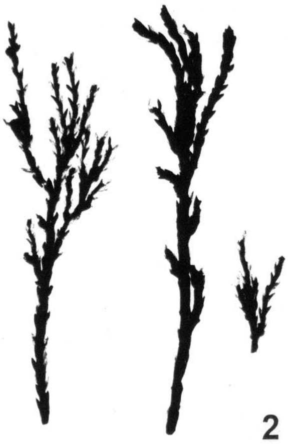
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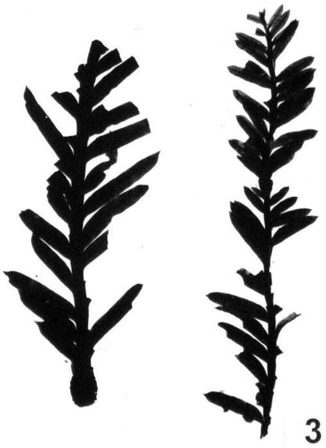
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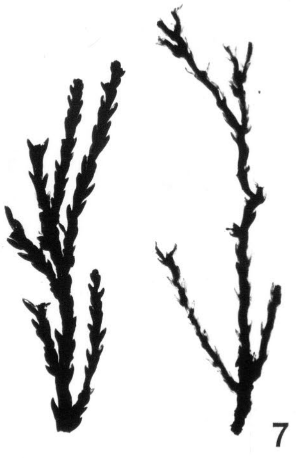
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Plate 3

Sequoia abietina (Brongniart) Knobloch

1. Cryptomerioid twig, epidermis with stomata, specimen KRAM-P 217/22, × ca. 180
2. Taxodioid twig, epidermis with stomata, specimen KRAM-P 217/218, × ca. 180

Taxodium dubium (Sternberg) Heer

3. Epidermis with stomata, specimen KRAM-P 211/27, × ca. 180

Tetraclinis salicornioides (Unger) Z. Kvaček

4. Specimen KRAM-P 214/20, × 5

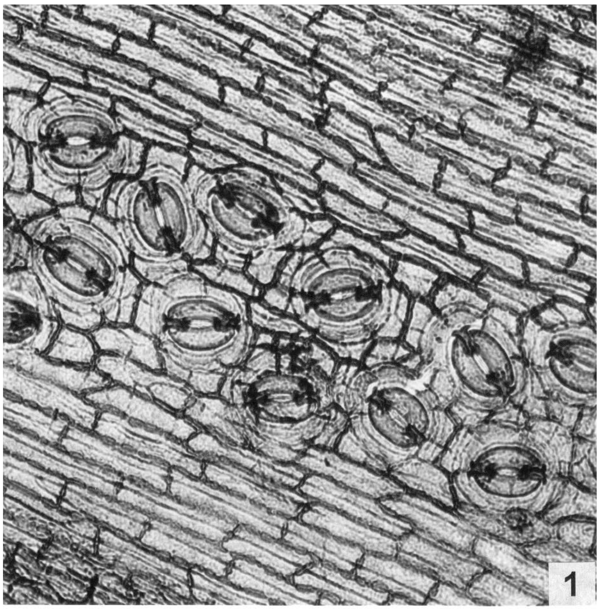
4a. Epidermis with stomata, specimen KRAM-P 214/20, × ca. 180

4b. Stomatal apparatus, specimen KRAM-P 214/20, × 720

Glyptostrobus europeus (Brongniart) Unger

5. Epidermis with stomata, specimen KRAM-P 214/136, × ca. 180

4 – phot. A Pachoński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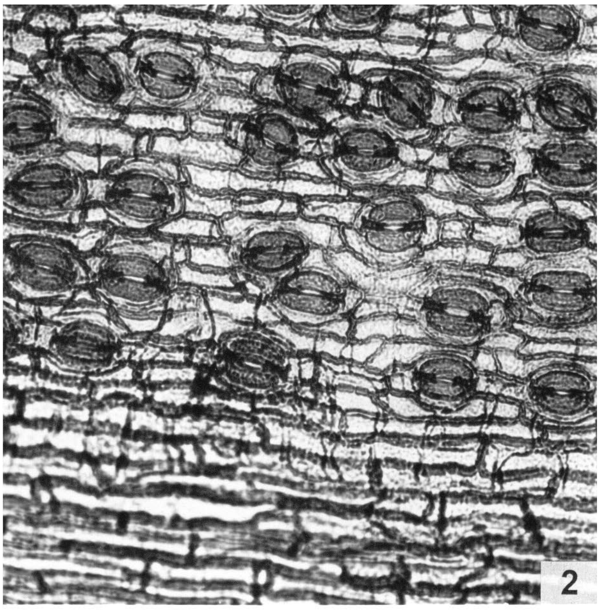
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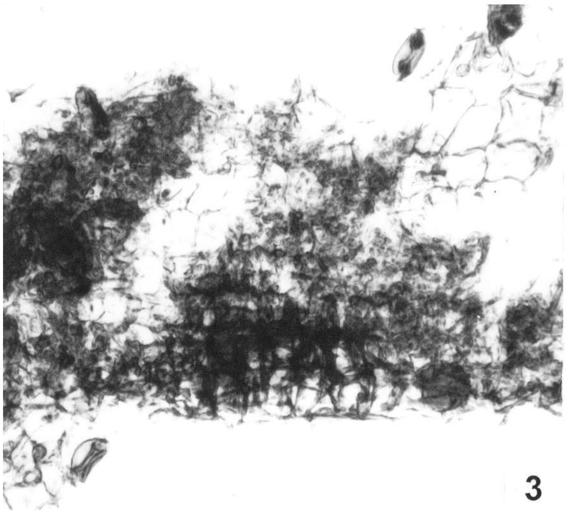
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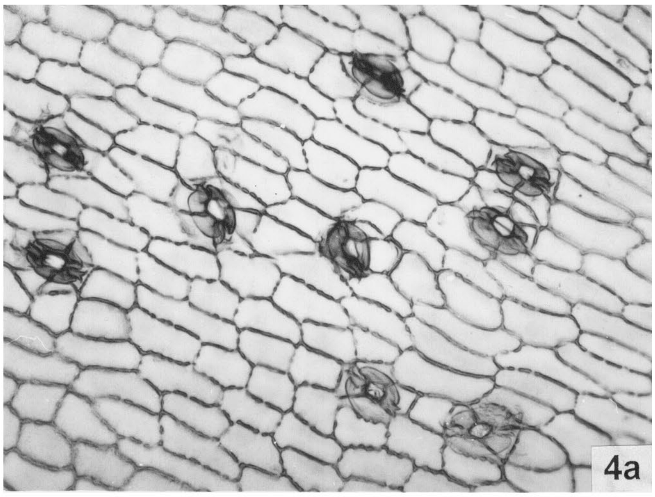
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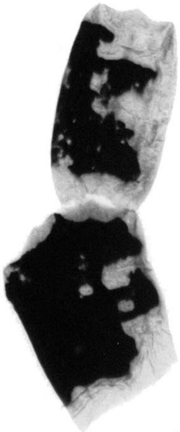
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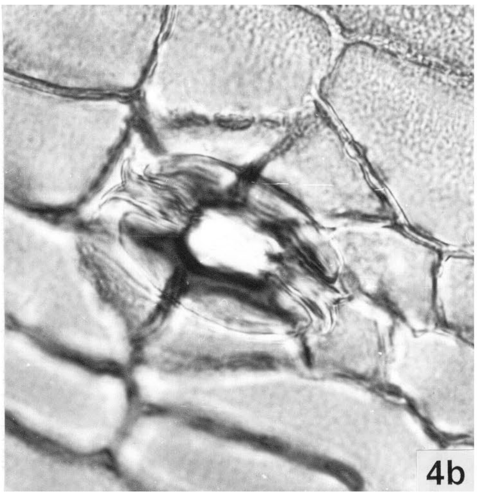
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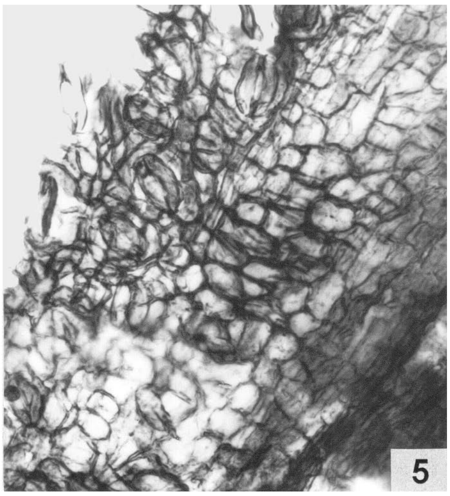
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Plate 4

Laurophyllum pseudoprinceps Weyland & Kilpper

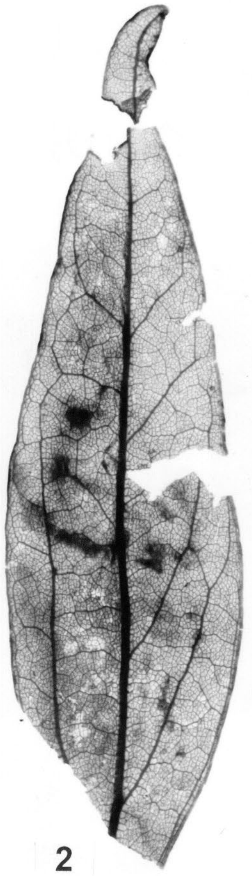
1. Specimen KRAM-P 214/40, × 3

Daphnogene polymorpha (Al.Braun) Ettingshausen

2. Specimen KRAM-P 214/39, × 3
3. Specimen KRAM-P 214/9, × 3
4. Upper epidermis with thyriotecia of Microthyriaceae, specimen KRAM-P 214/5, × ca. 180
5. Specimen KRAM-P 214/25, × 3
6. Specimen KRAM-P 214/13, × 3
7. Specimen KRAM-P 214/174, × 2

1–3, 5–7 phot. A Pachoński


1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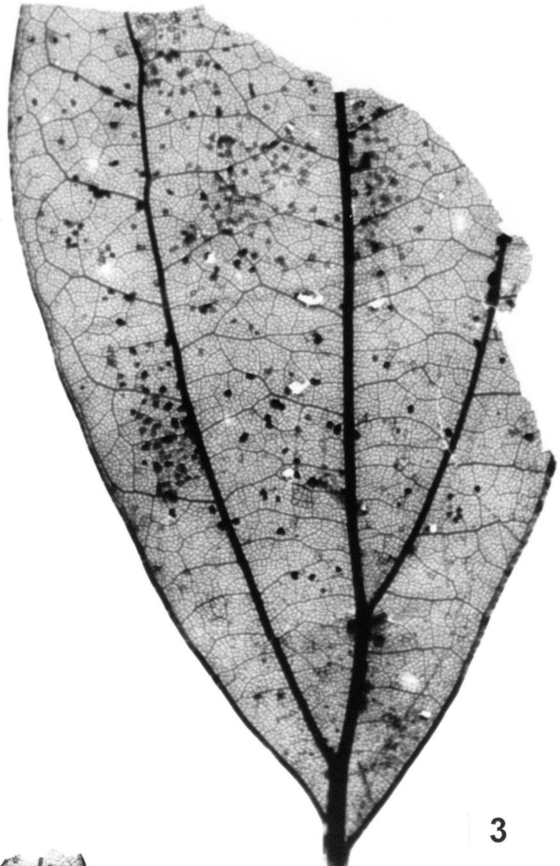
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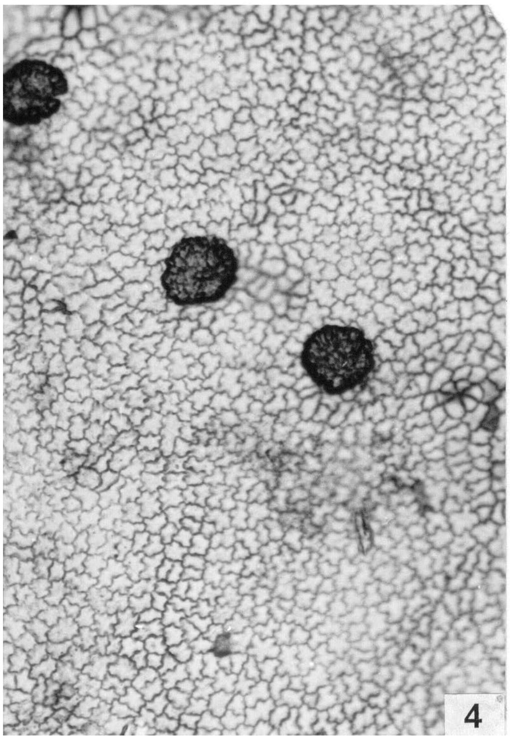
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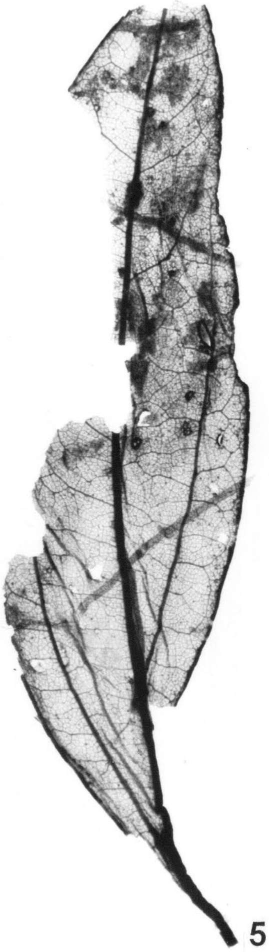
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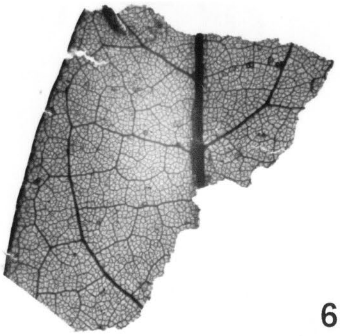
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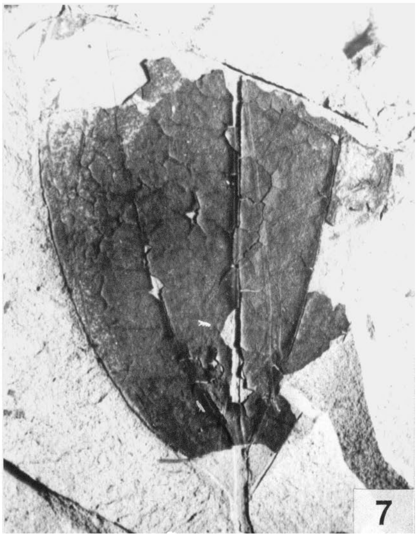
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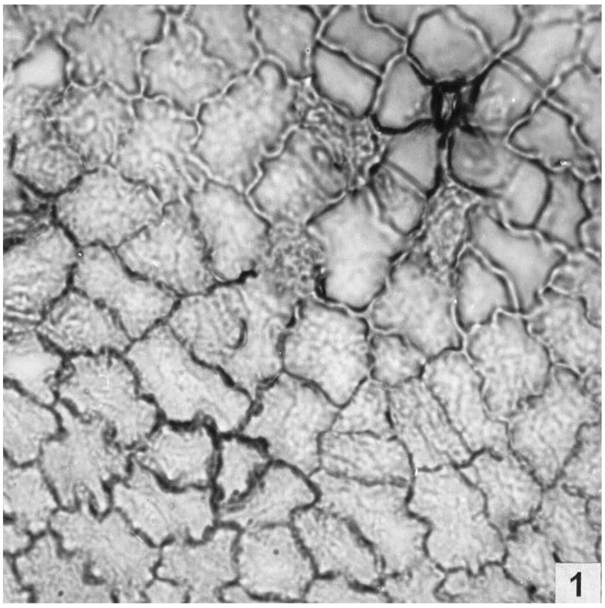
Plate 5

Daphnogene polymorpha (Al.Braun) Ettingshausen

1. Upper epidermis with trichome bases, specimen KRAM-P 214/5/I, × ca. 720
1a. Lower epidermis with numerous trichome bases, specimen KRAM-P 214/5/I, × ca. 180
1b. Lower epidermis with trichome bases, specimen KRAM-P 214/5/I, × ca. 720

Laurophyllum pseudoprinceps Weyland & Kilpper

2. Upper epidermis, specimen KRAM-P 214/40, × ca. 720
2a. Lower epidermis with stomata, specimen KRAM-P 214/40, × ca. 180
2b. Lower epidermis with stomata, specimen KRAM-P 214/40, × ca. 720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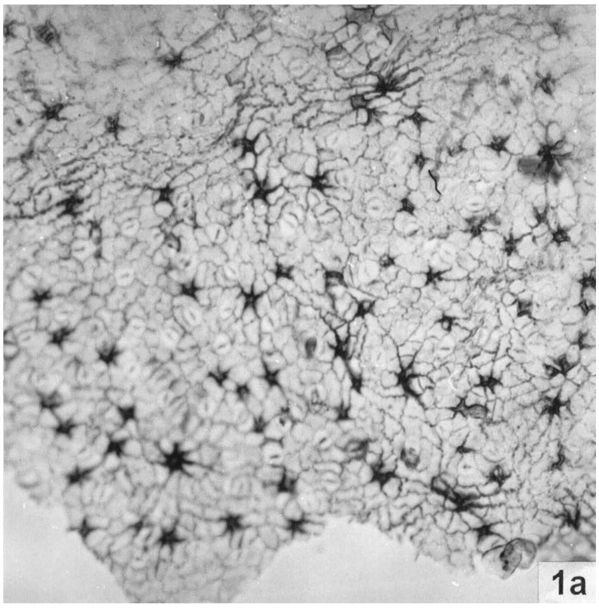
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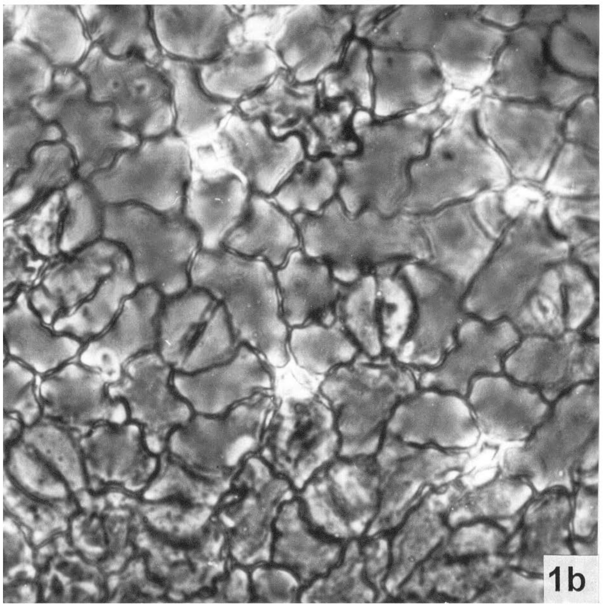
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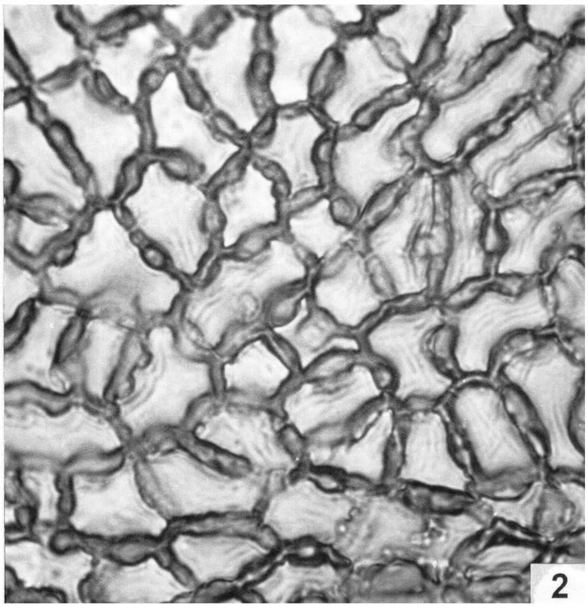
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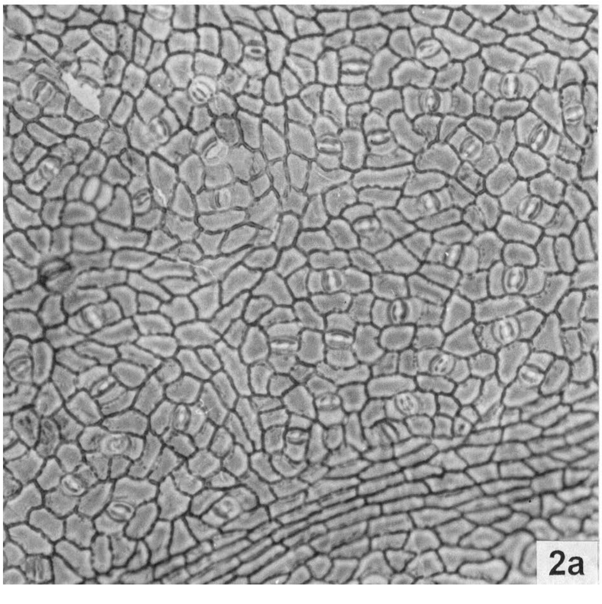
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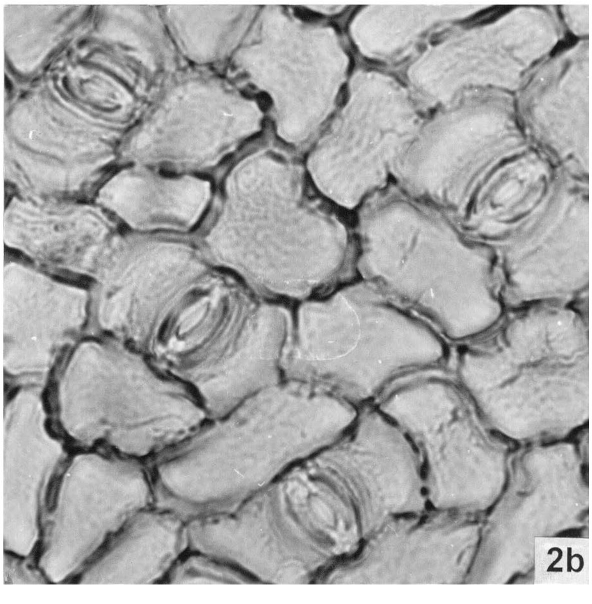
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Plate 6

Daphnogene polymorpha (Al.Braun) Ettingshausen

1. Specimen KRAM-P 214/21, × 4

Populus sp.

2. Specimen KRAM-P 214/130, × 5

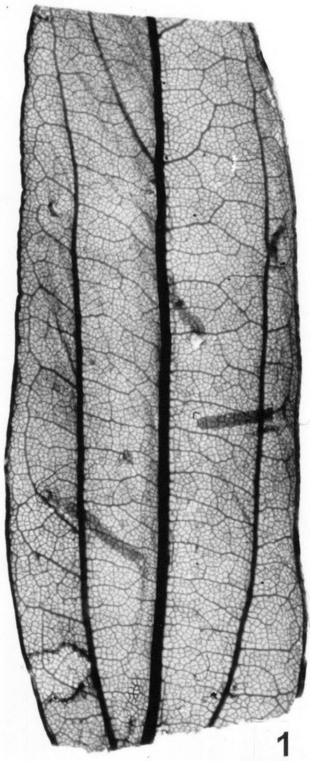
Myrica lignitum (Unger) Saporta sensu lato

3. Specimen KRAM-P 214/44, × 3
5. Shield of peltate trichome with preserved remains of resin, specimen KRAM-P 217/217, × ca. 180
6. Upper epidermis with hypodermis, specimen KRAM-P 214/26, × ca. 720
7. Epidermis with stomata and with two-celled trichome base, specimen KRAM-P 214/31, × ca. 720

Liquidambar sp.

4. Specimen KRAM-P 214/60, × 2

1–4 phot. A Pachoński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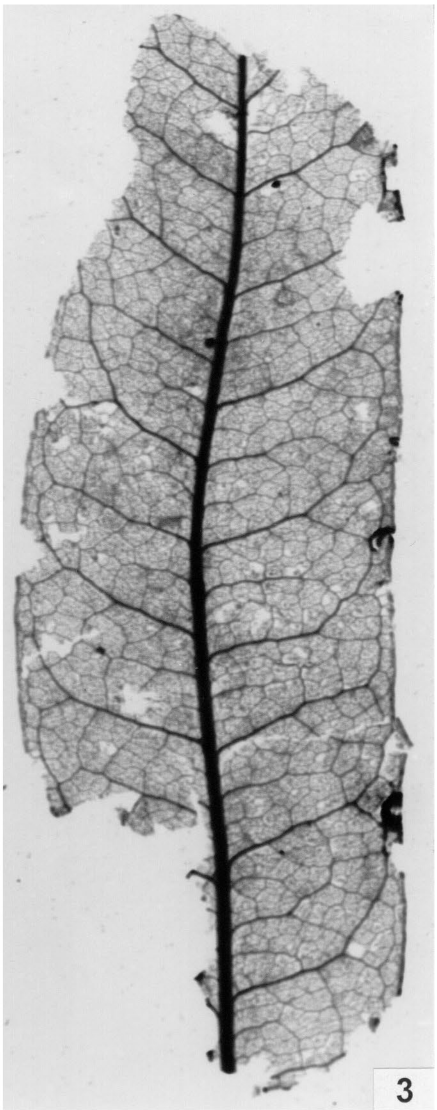
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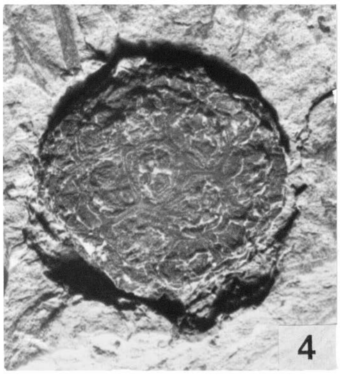
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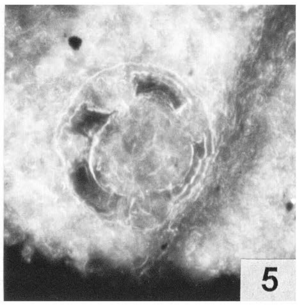
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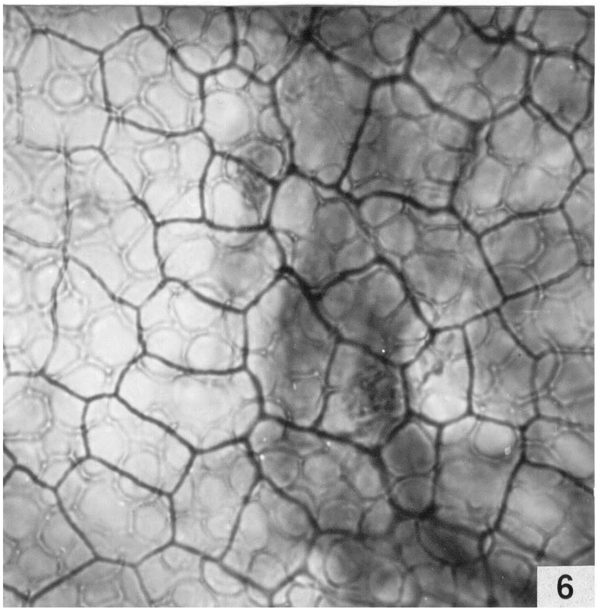
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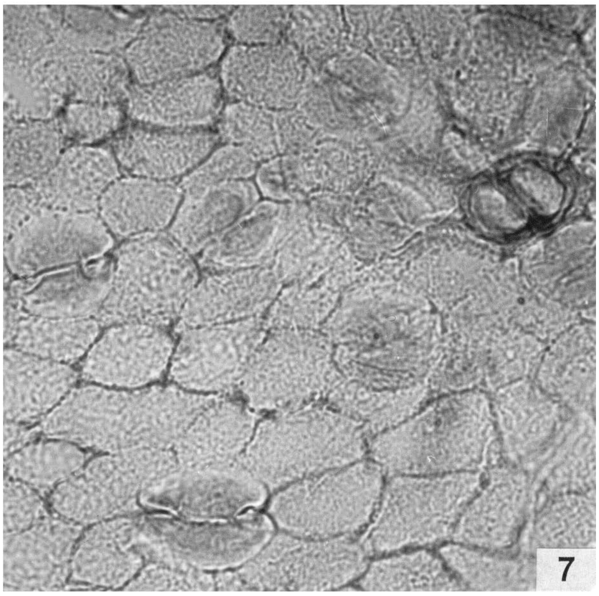
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Plate 7

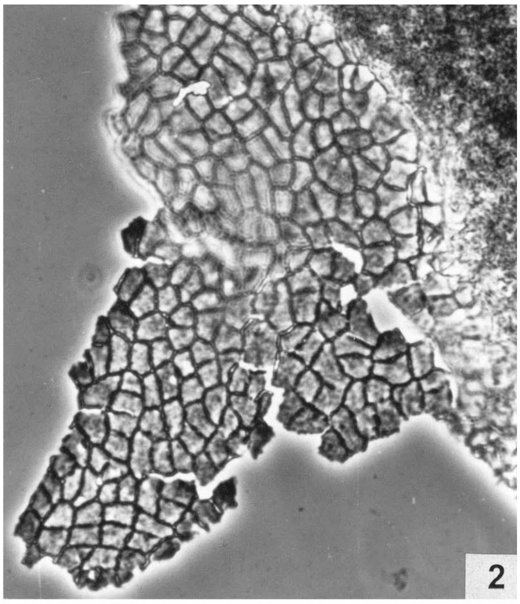
Myrica lignitum (Unger) Saporta sensu lato

1. Specimen KRAM-P 214/19, × 3
2. Upper epidermis, specimen KRAM-P 217/217, × ca. 180

2a. Upper epidermis, specimen KRAM-P 217/217, × ca. 720
2b. peltate trichome, specimen KRAM-P 217/217, × ca. 720
3. Lower epidermis with stomata, specimen KRAM-P 217/190/I, × ca. 180
3a. Lower epidermis with stomata, specimen KRAM-P 217/190/I, × ca. 720

1 – phot. A Pachoński

1



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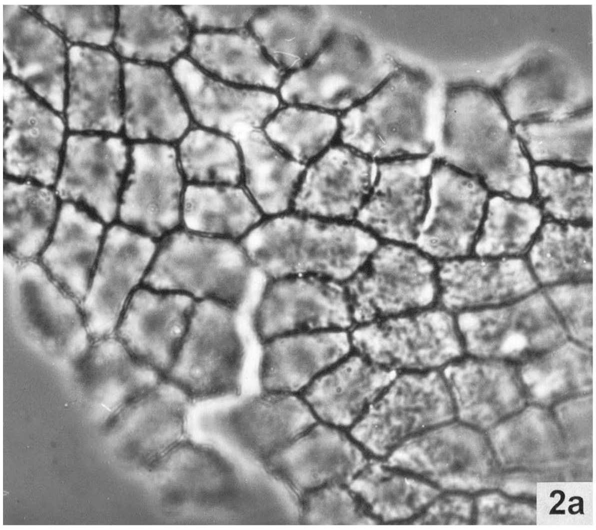

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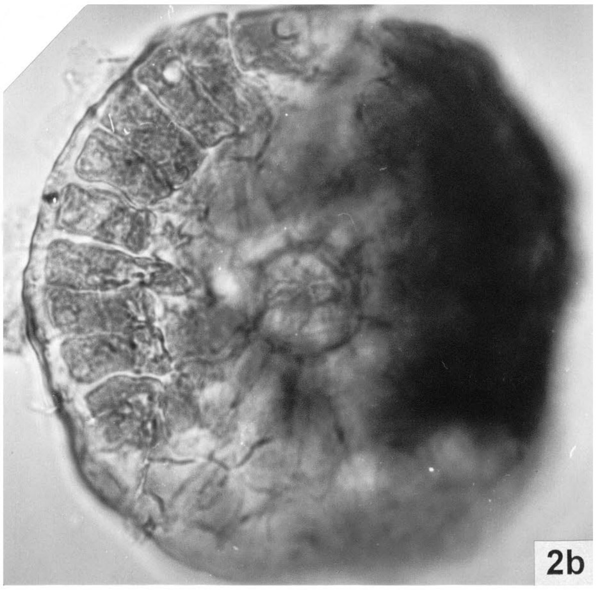

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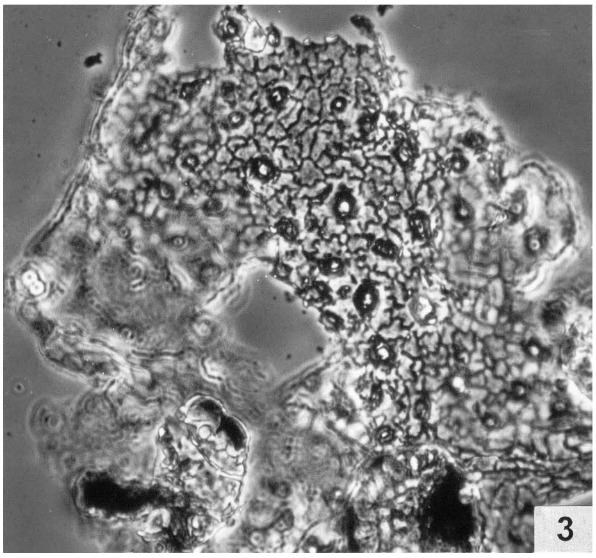

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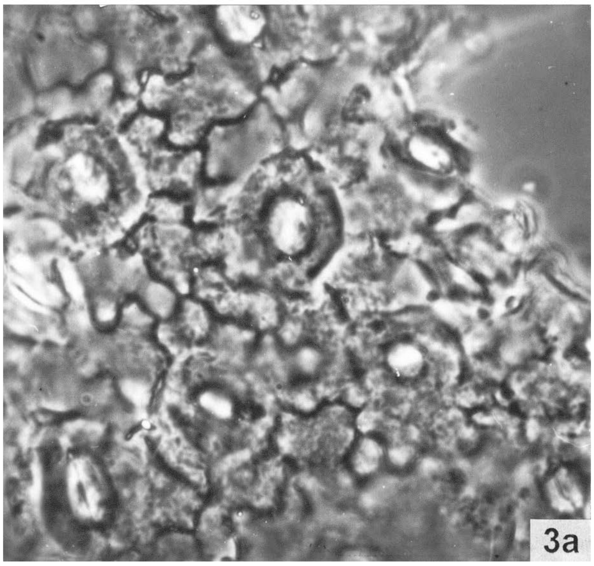


3a

Plate 8

Alnus gaudinii (Heer) Knobloch & Z. Kvaček

1. Specimen KRAM-P 217/176, × 1
2. Specimen KRAM-P 217/243/II, × 1
3. Specimen KRAM-P 217/6, × 1

3a. Specimen KRAM-P 217/6, × 3

4. Specimen KRAM-P 217/5, × 1

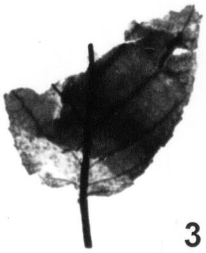
4a. Specimen KRAM-P 217/5, × 4

5. Specimen KRAM-P 217/97, × 2
6. Upper epidermis, specimen KRAM-P 217/130, × ca. 720
7. Specimen KRAM-P 217/201/II, × 2

1–5, 7 phot. A Pachoński


1


2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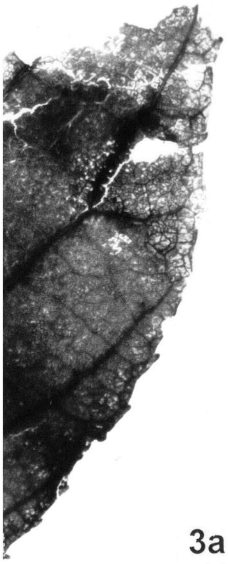
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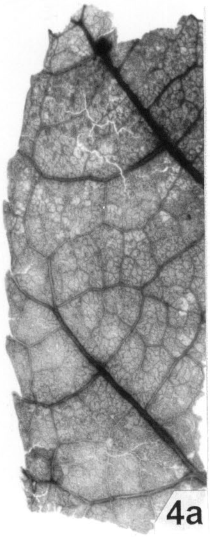
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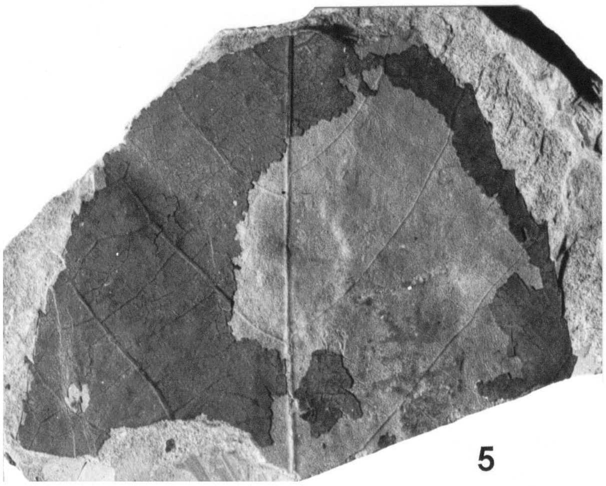
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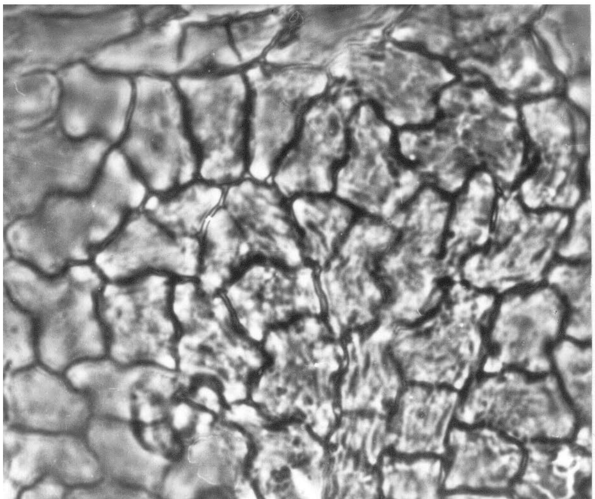
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7

Plate 9

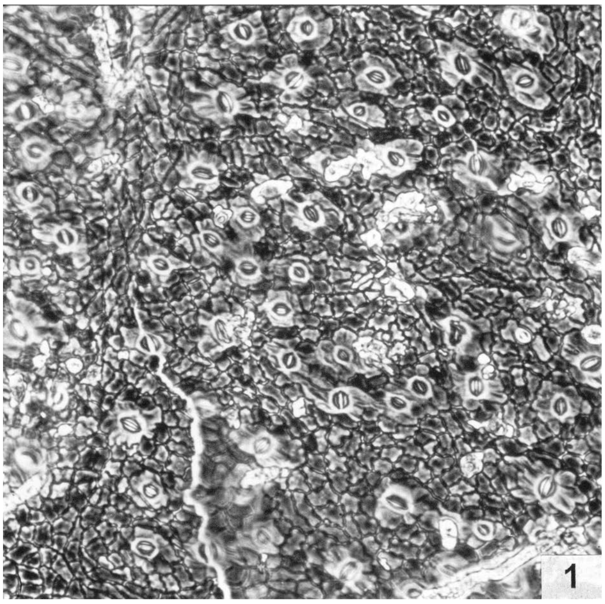
Alnus gaudinii (Heer) Knobloch & Z. Kvaček

1. Lower epidermis with stomata, specimen KRAM-P 217/243/II, × ca. 180
1a. Four-celled trichome base, specimen KRAM-P 217/243/II, × ca. 720
2. Lower epidermis with stomata, specimen KRAM-P 217/130, × ca. 720

Alnus julianiformis (Sternberg) Z. Kvaček & Holý

3. Specimen KRAM-P 214/28, × 1
3a. Lower epidermis, specimen KRAM-P 214/28, × ca. 720
3b. Four-celled trichome base, specimen KRAM-P 214/28, × ca. 720
3c. Four-celled trichome base, specimen KRAM-P 214/28, × ca. 720
4. Specimen KRAM-P 214/52, × 3

3, 4 phot. A Pachoński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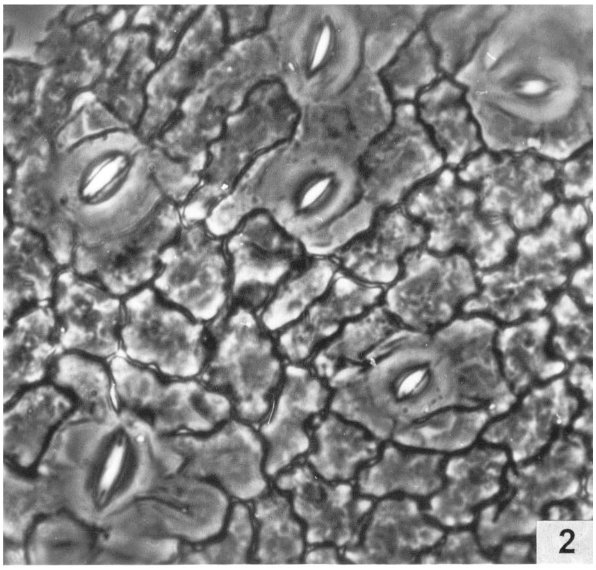
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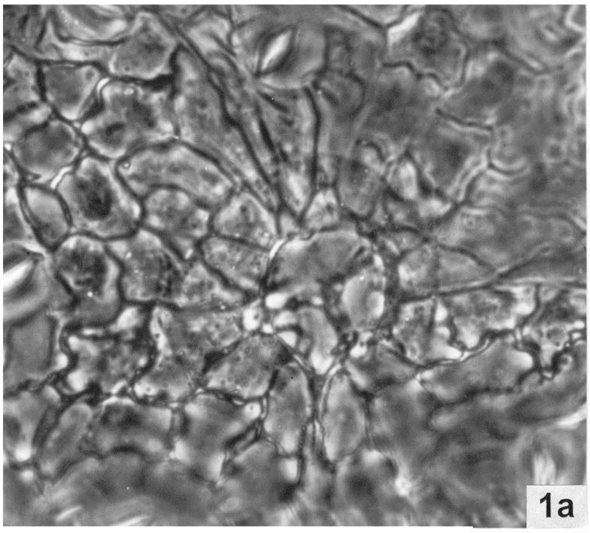
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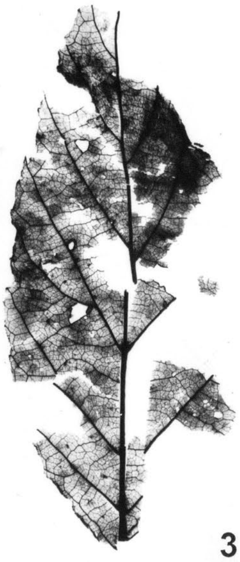
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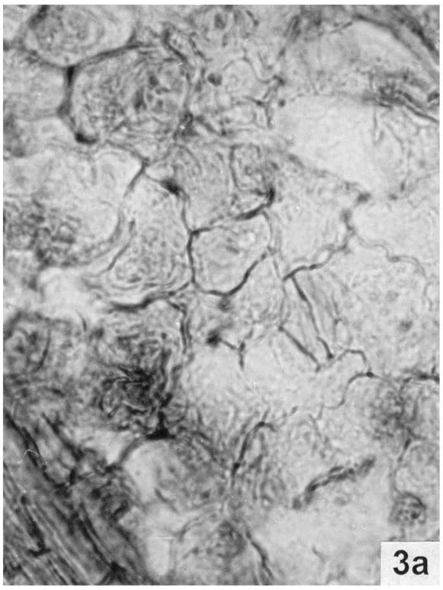
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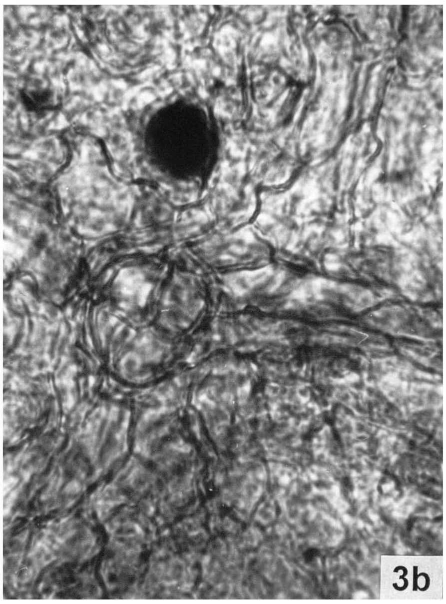
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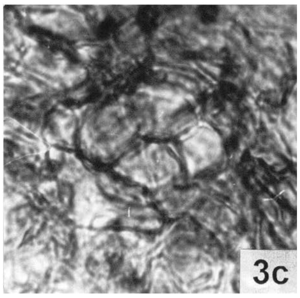
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Plate 10

Alnus menzelii Raniecka-Bobrowska

1. Specimen KRAM-P 217/2, × 3
2. Specimen KRAM-P 217/12, × 1
3. Specimen KRAM-P 217/13, × 1

3a. Specimen KRAM-P 217/13, × 4

4. Specimen KRAM-P 217/8/I, × 1.5

4a. Specimen KRAM-P 217/8/I, × 4

5. Specimen KRAM-P 217/25, × 1

5a. Specimen KRAM-P 217/25, × 4

6. Specimen KRAM-P 217/11, × 1
7. Specimen KRAM-P 217/35, × 1
8. Specimen KRAM-P 217/14, × 1
9. Specimen KRAM-P 217/171/I, × 1
10. Specimen KRAM-P 217/100, × 1.5

1–10 phot. A Pachoński


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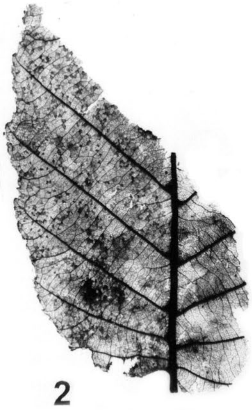
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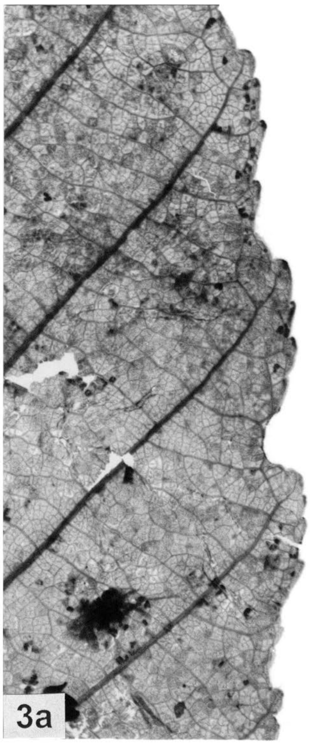
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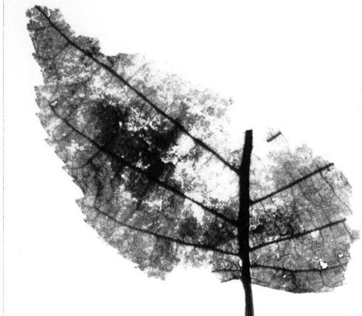
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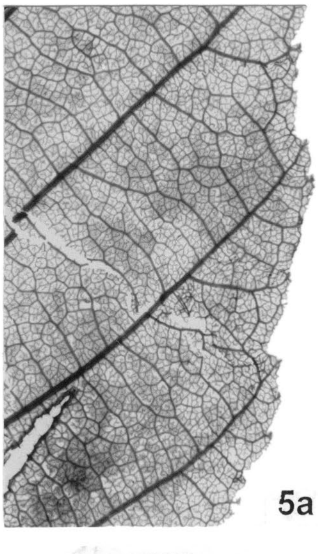
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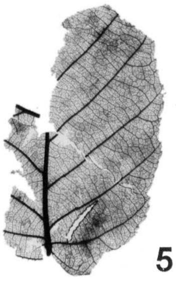
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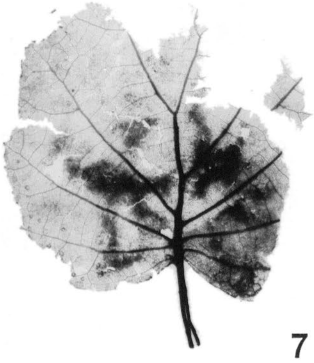
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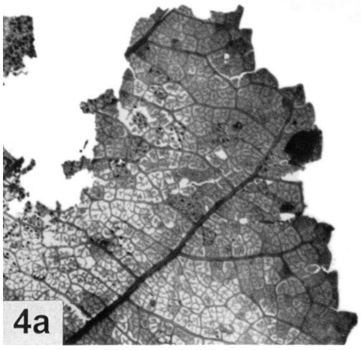
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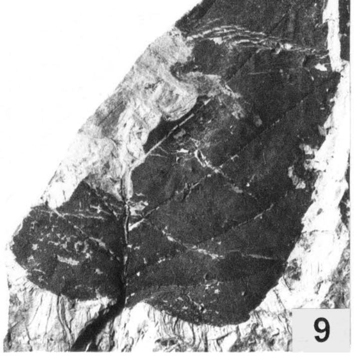
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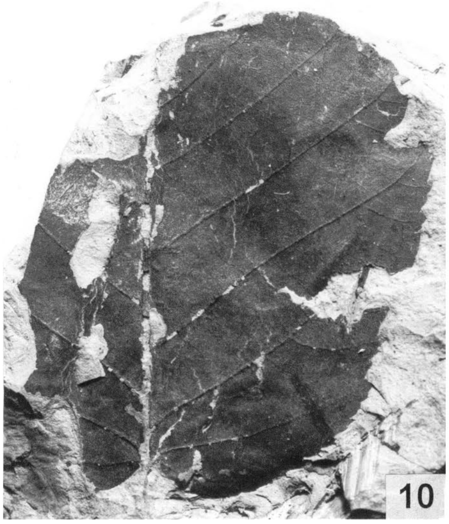
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Plate 11

Alnus menzelii Raniecka-Bobrowska

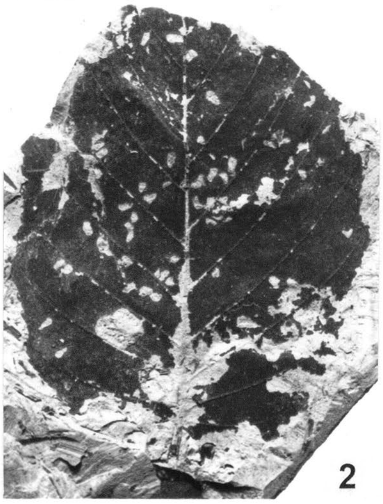
1. Specimen KRAM-P 217/233, × 1
2. Specimen KRAM-P 217/158, × 1
3. Specimen KRAM-P 217/74, × 1
4. Upper epidermis, specimen KRAM-P 217/112/I, × ca. 180

4a. Lower epidermis with stomata, specimen KRAM-P 217/112/I, × ca. 720

5. Cuticular striations on upper epidermis, specimen KRAM-P 217/157, × ca. 720
6. Stomatal apparatus, specimen KRAM-P 217/66/I, × ca. 720

1–3 phot. A Pachoński


1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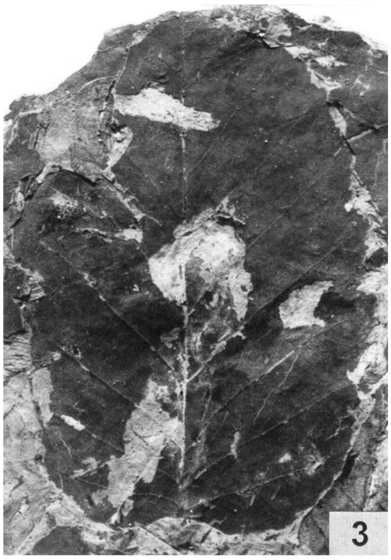
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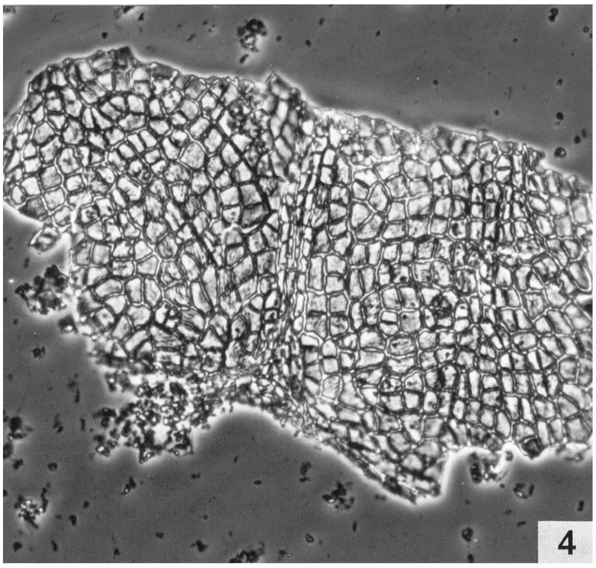
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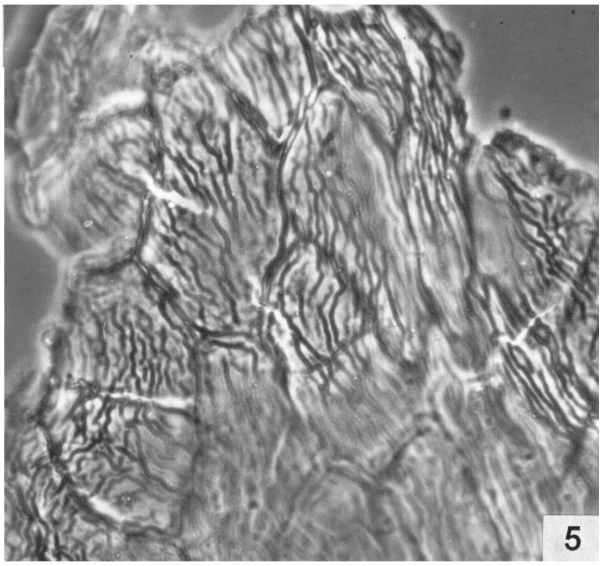
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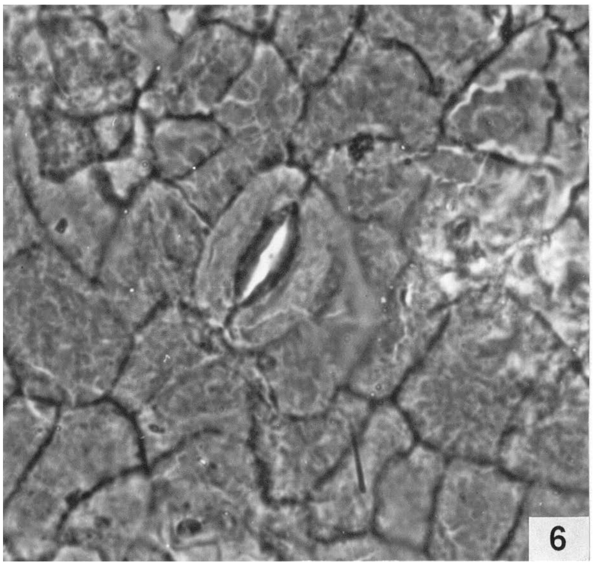
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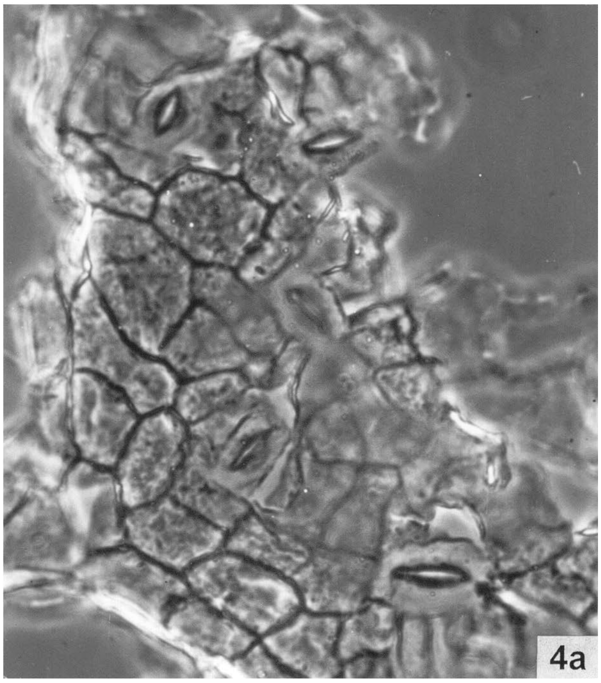

4a

Plate 12

Carpinus sp.

1. Upper epidermis, specimen KRAM-P 217/68/II, × ca. 360

1a. Lower epidermis with stomata, specimen KRAM-P 217/68/II, × ca. 360

Alnus menzelii Raniecka-Bobrowska

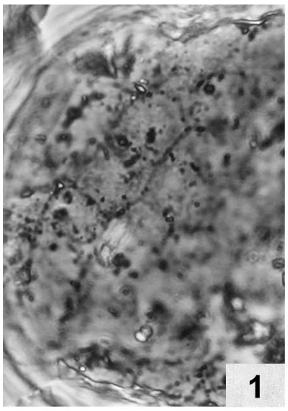
2. Lower epidermis with stomata and with peltate trichome, specimen KRAM-P 217/112/I, × ca. 720
3. Lower epidermis with four-celled base of peltate trichome, specimen KRAM-P 217/66/I, × ca. 720

Fagus silesiaca Walther & Zastawniak

4. Upper epidermis, specimen KRAM-P 217/249/II, × ca. 180

4a. Lower epidermis with stomata, specimen KRAM-P 217/249/II, × ca. 180

4b. Lower epidermis with stomata, specimen KRAM-P 217/249/II, × ca. 720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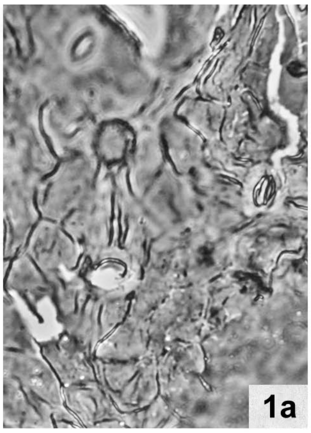
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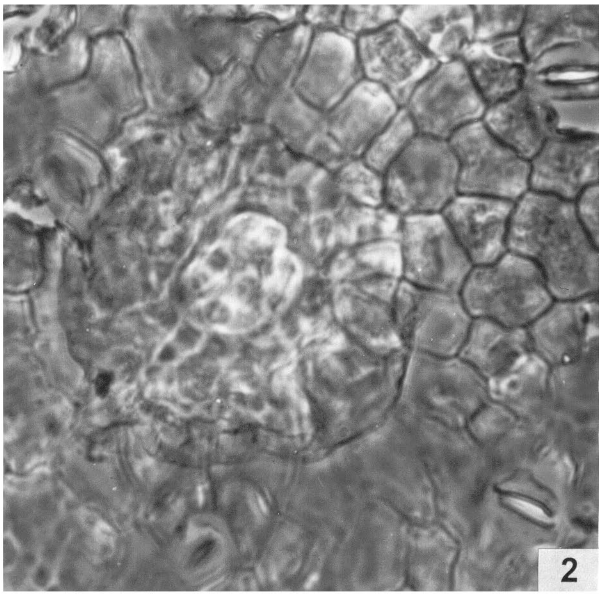
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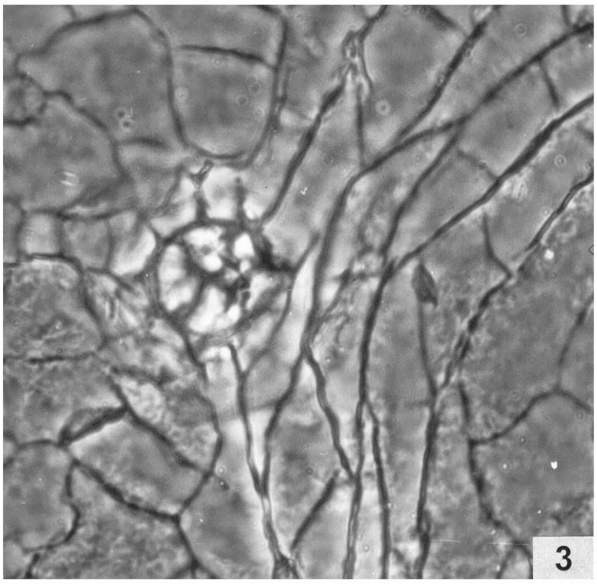
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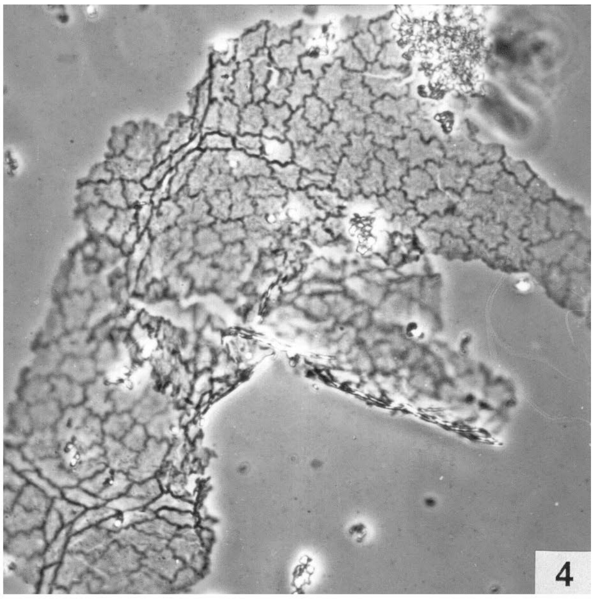
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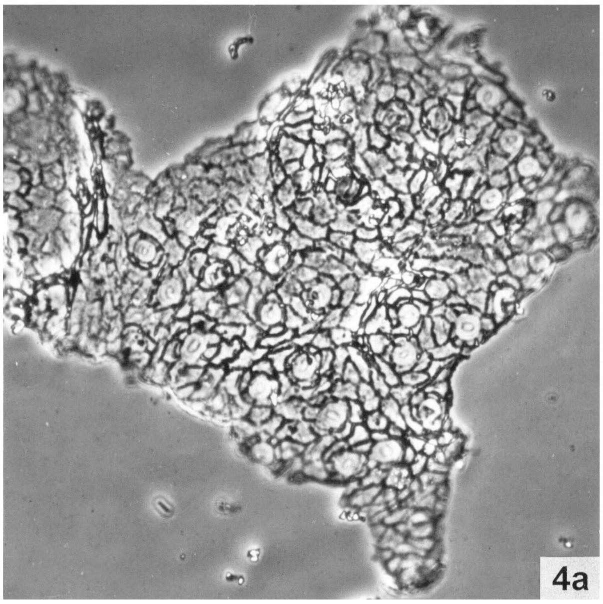
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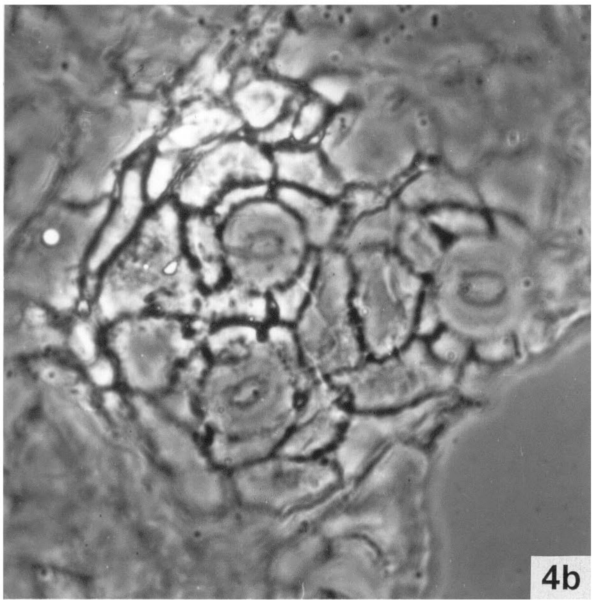

4b

Plate 13

“*Castanea*” *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček

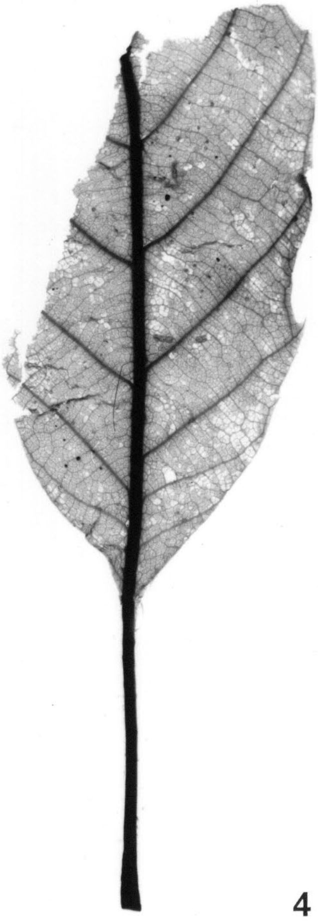
1. Specimen KRAM-P 214/33, × 1
2. Specimen KRAM-P 214/48, × 1
3. Specimen KRAM-P 214/27, × 1
4. Specimen KRAM-P 214/47, × 2
5. Specimen KRAM-P 214/71, × 1.5
6. Specimen KRAM-P 214/111, × 1
7. Specimen KRAM-P 214/164, × 1.5
8. Specimen KRAM-P 214/57, × 3
9. Specimen KRAM-P 214/38, × 1
10. Specimen KRAM-P 214/170, × 1.5
11. Specimen KRAM-P 214/37, × 3

1–11 phot. A Pachoński


1


2


3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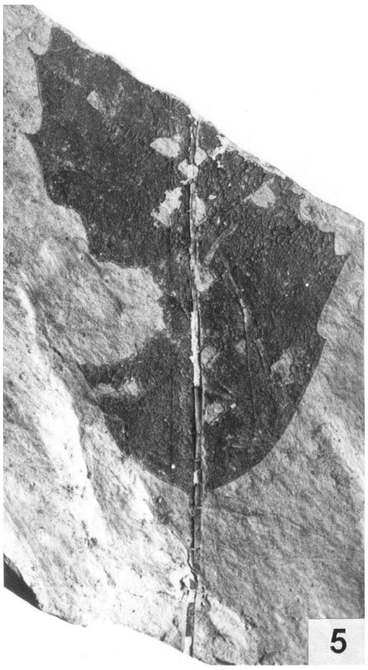
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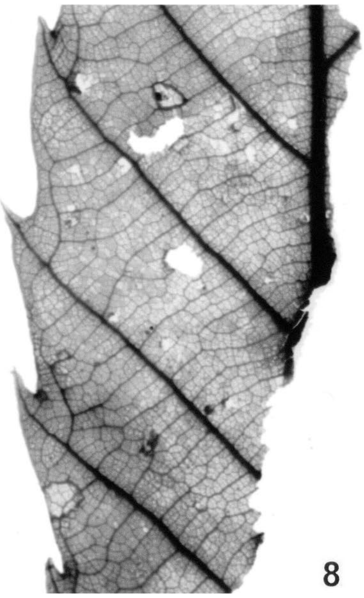
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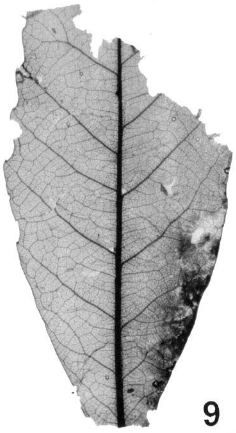
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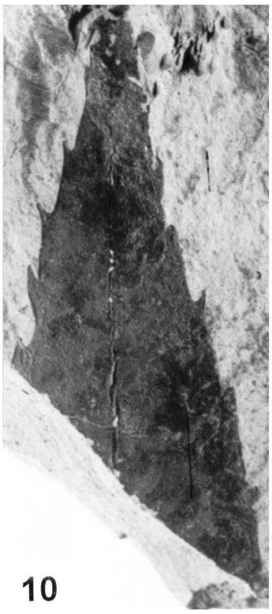
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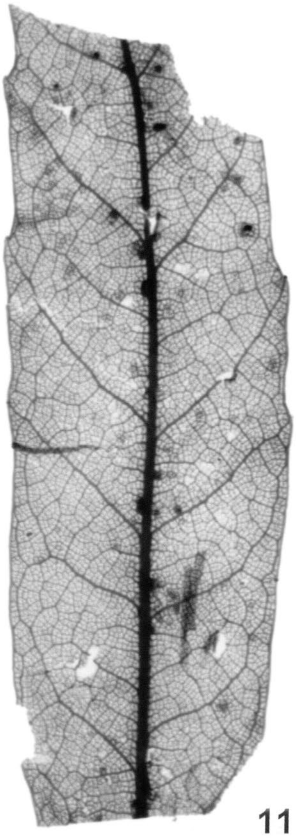
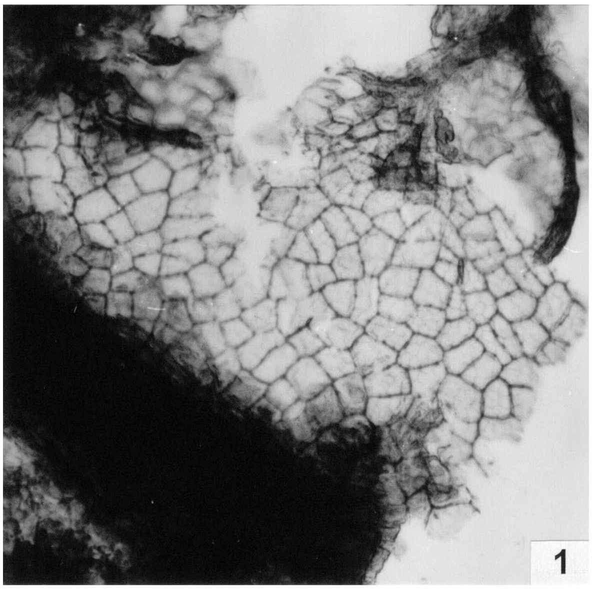

11

Plate 14

“*Castanea*” *kubinyii* Kováts ex Ettingshausen sensu Knobloch & Z. Kvaček

1. Upper epidermis with hypodermis, specimen KRAM-P 214/49, × ca. 180
1a. Upper epidermis with hypodermis, specimen KRAM-P 214/49, × ca. 720
2. Lower epidermis with stomata, specimen KRAM-P 214/58, × ca. 180
2a. Lower epidermis with stomata, specimen KRAM-P 214/58, × ca. 720
3. Lower epidermis with stomata, specimen KRAM-P 214/54, × ca. 720
4. Trichome, specimen KRAM-P 214/55, × ca. 720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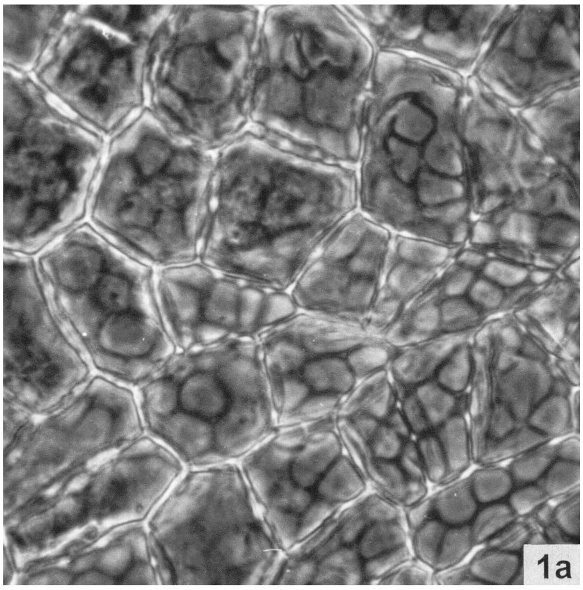
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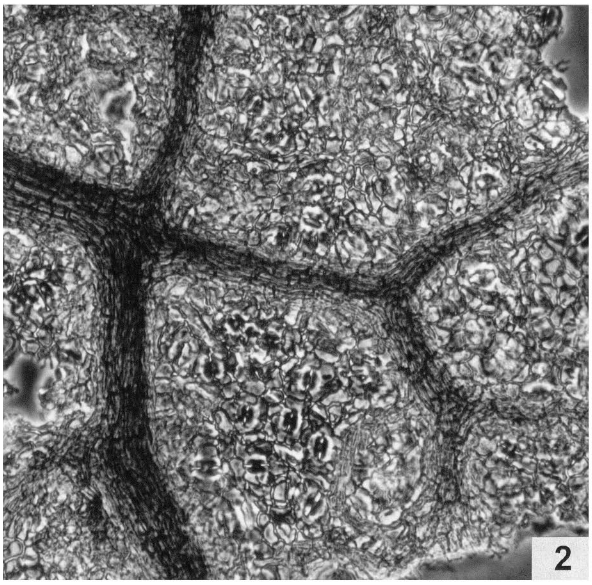
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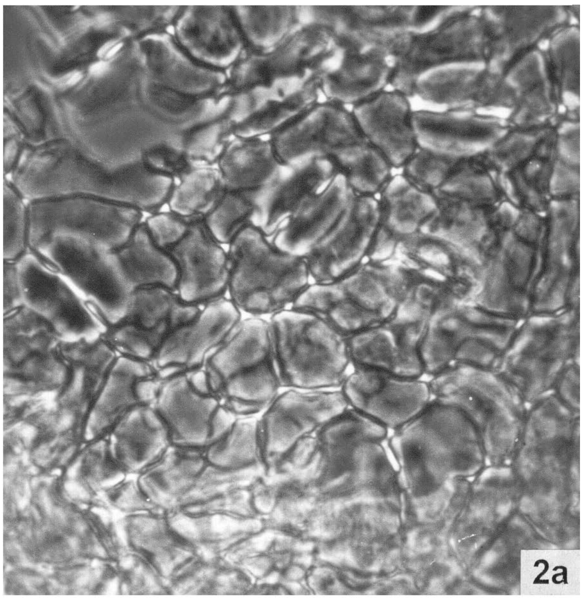
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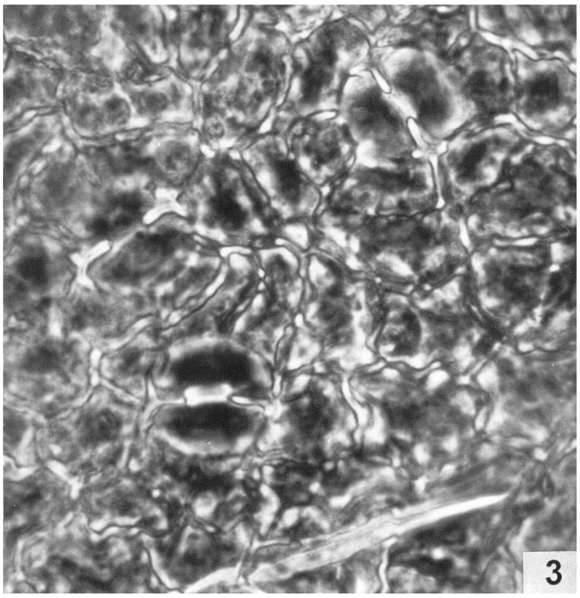
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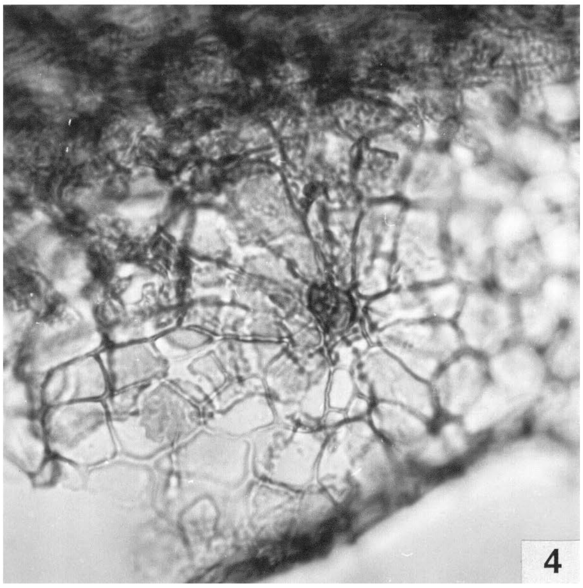

4

Plate 15

Quercus rhenana (Kräusel & Weyland) Knobloch & Z. Kvaček

1. Specimen KRAM-P 214/18, × 2
2. Specimen KRAM-P 214/42, × 1

2a. Lower epidermis with stomata, specimen KRAM-P 214/42, × ca. 180

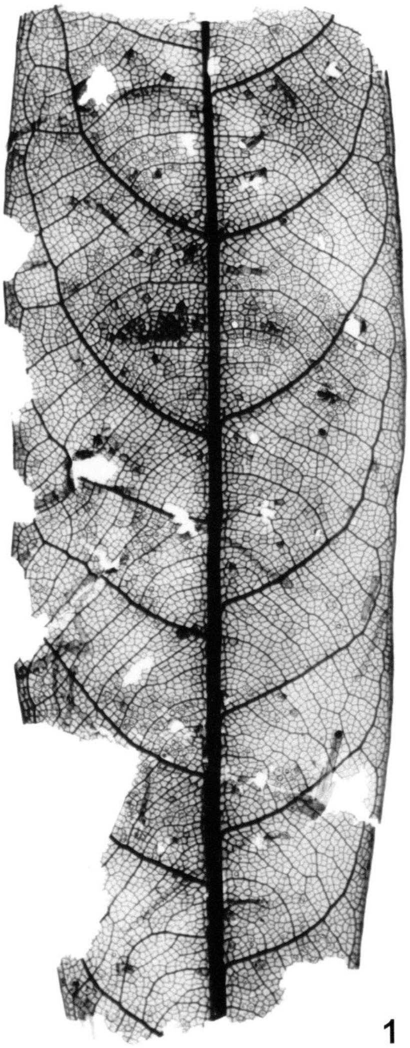
2b. Lower epidermis with hypodermis and stomata, specimen KRAM-P 214/42, × ca. 720

3. Upper epidermis with hypodermis, specimen KRAM-P 214/171, × ca. 720

Quercus sp. sect. *Cerris* Oersted vel sect. *Dentata* C.K. Schneid.

4. Specimen KRAM-P 214/129, × 2
5. Specimen KRAM-P 214/127, × 1.5
6. Specimen KRAM-P 214/128, × 1.5

1, 2, 4–6 phot. A Pachoński



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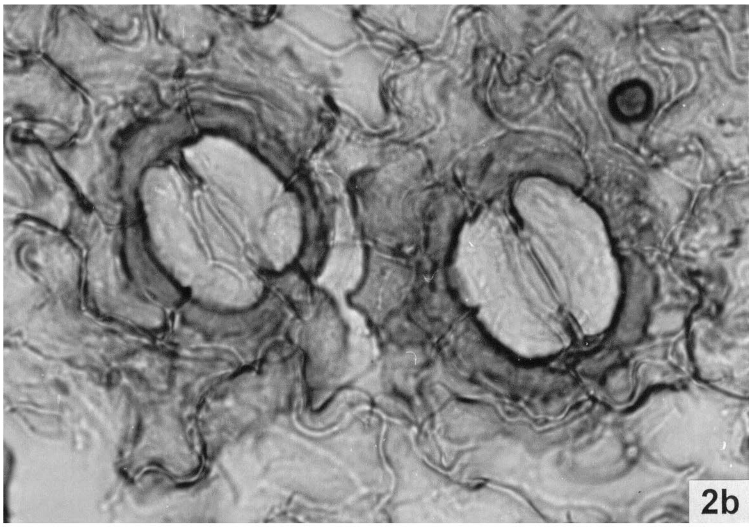

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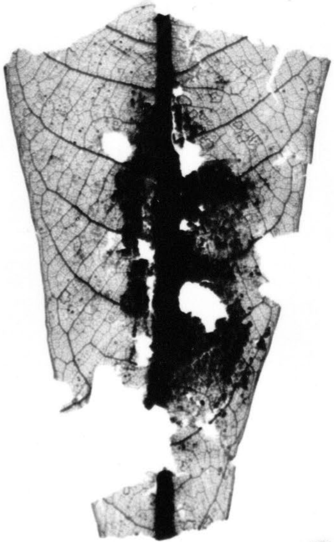

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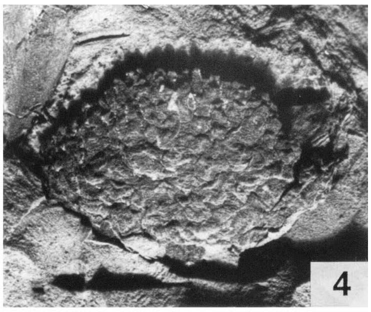

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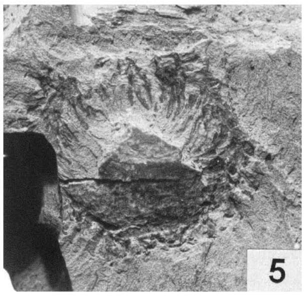

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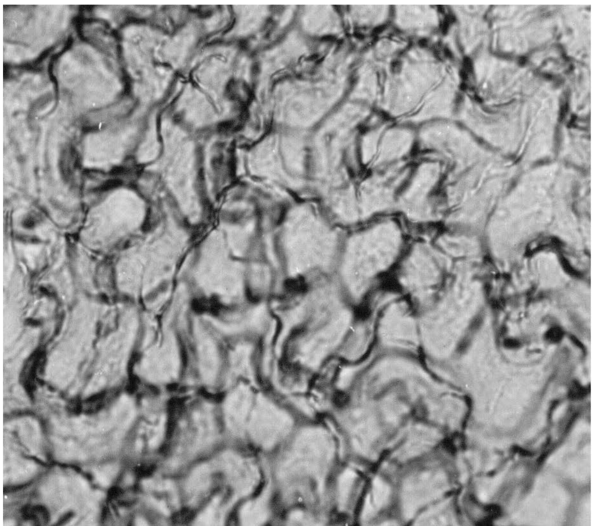

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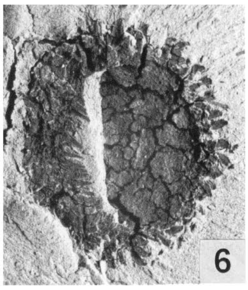

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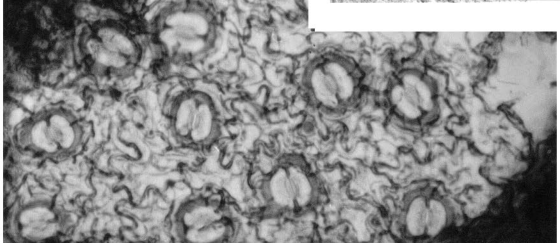


2a

Plate 16

Pterocarya paradisiaca (Unger) Ilinskaya

1. Upper epidermis, specimen KRAM-P 217/125/II, × ca. 180
1a. Lower epidermis with stomata and unicellular trichome base, specimen KRAM-P 217/125/II, × ca. 720
1b. Lower epidermis with unicellular trichome bases, specimen KRAM-P 217/125/II, × ca. 720

Kalmia cf. *saxonica* Litke

2. Lower epidermis with stomata and trichome base, specimen KRAM-P 217/28, × ca. 180
2a. Lower epidermis with stomata, specimen KRAM-P 217/28, × ca. 720

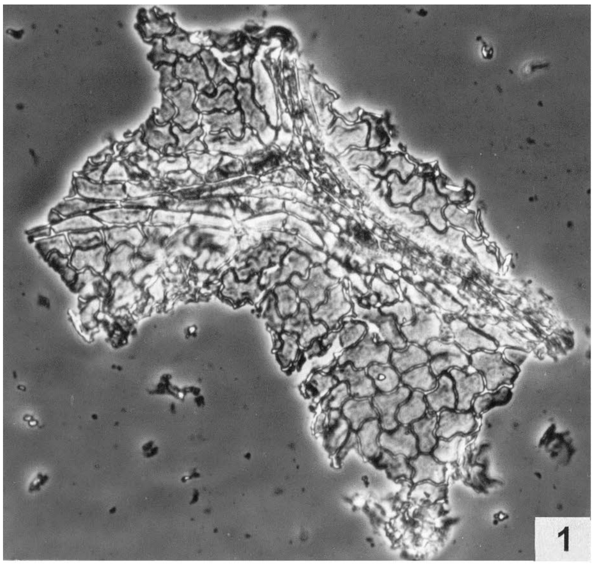
cf. *Carya serrifolia* (Goeppert) Kräusel

3. Specimen KRAM-P 214/133, × 2

Byttneriophyllum tiliaefolium (Al. Braun) Knobloch & Z. Kvaček

4. Specimen KRAM-P 217/19, × 1

3, 4 phot. A Pachoński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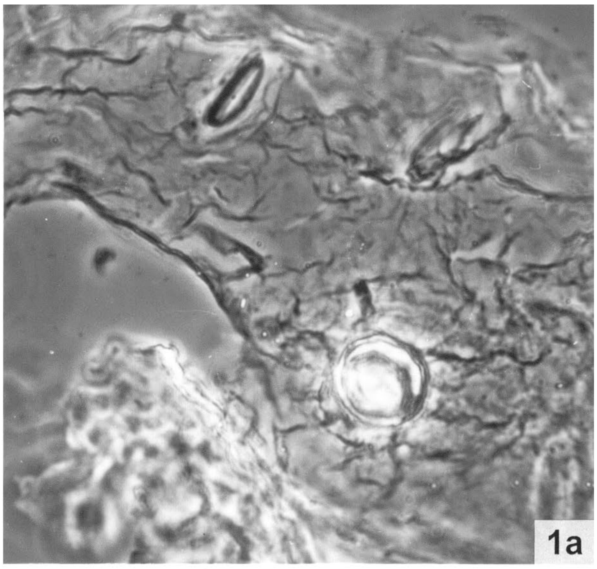
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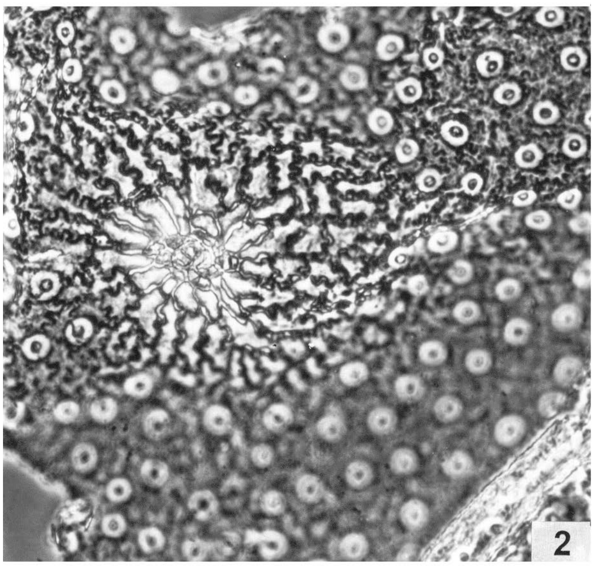
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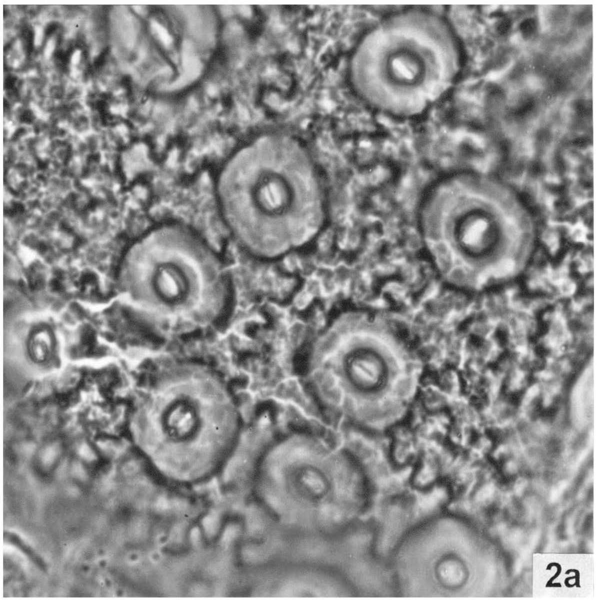
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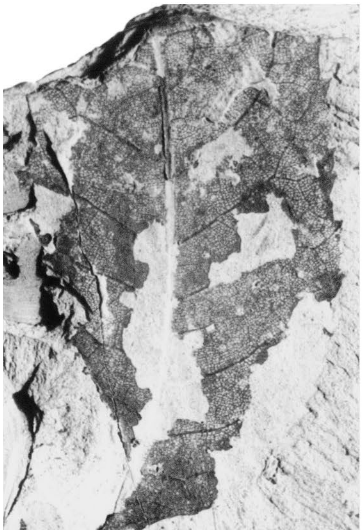
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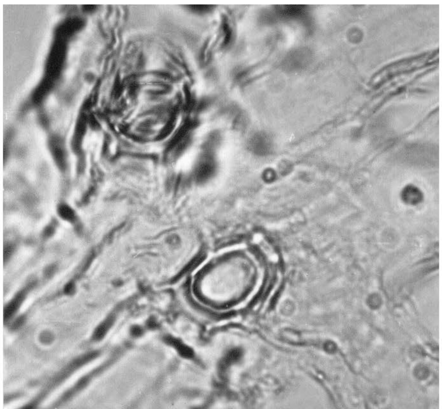

1b


4

Plate 17

Byttneriophyllum tiliaefolium (Al. Braun) Knobloch & Z. Kvaček

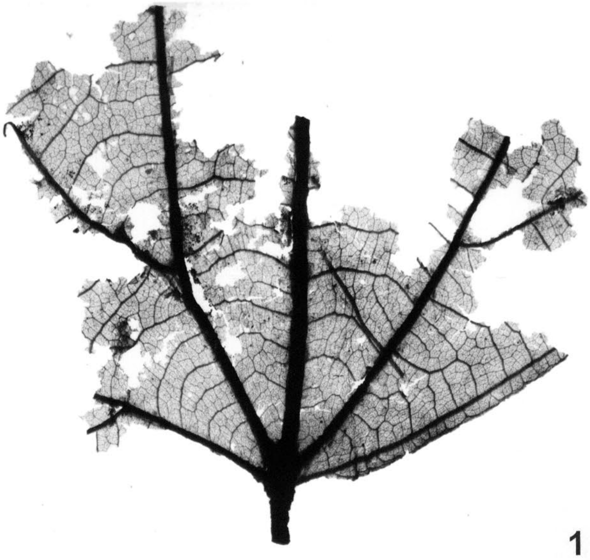
1. Specimen KRAM-P 217/17, × 2
2. Upper epidermis, specimen KRAM-P 217/260, × ca. 720

2a. Lower epidermis with stomata, specimen KRAM-P 217/260, × ca. 720
2b. Stellate trichome, specimen KRAM-P 217/260, × ca. 720
2c. Few-celled glandular, clavate-form trichome, specimen KRAM-P 217/260, × ca. 720
2d. Upper epidermis, specimen KRAM-P 217/260, × ca. 180

Viscophyllum pliocenicum (Engelhardt) Mädler

3. Epidermis, specimen KRAM-P 217/258, × ca. 180

1 – phot. A Pachoński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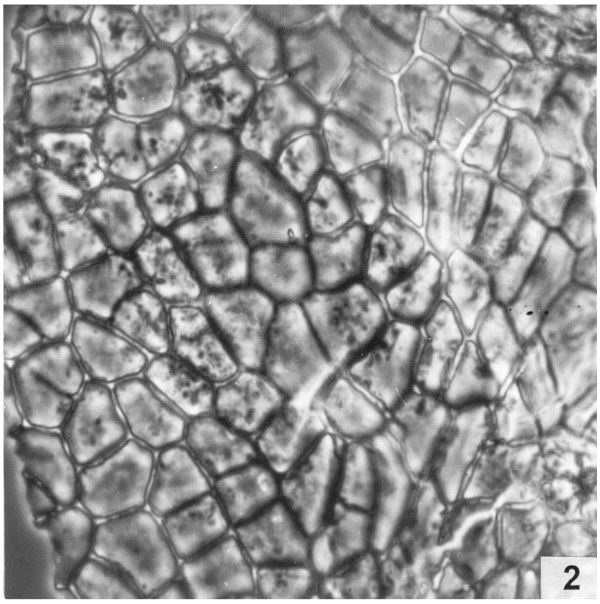
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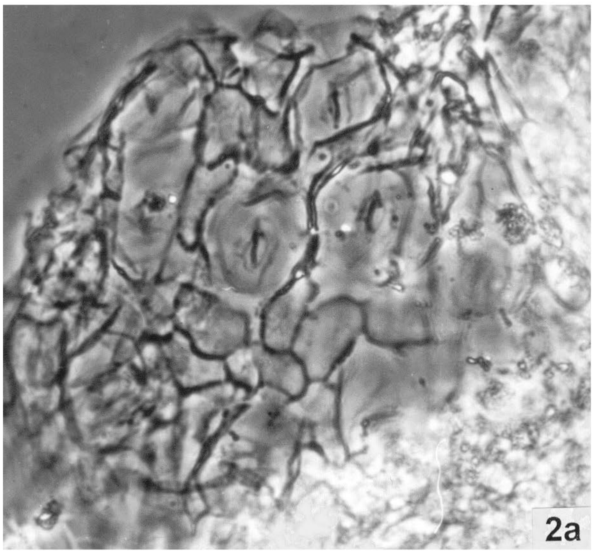
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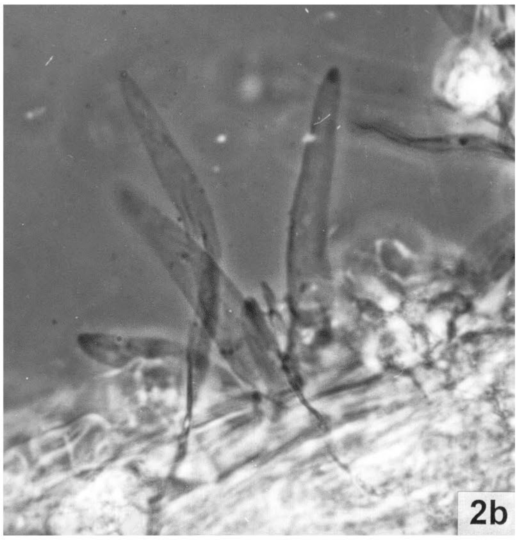
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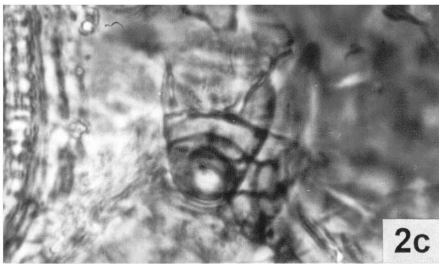
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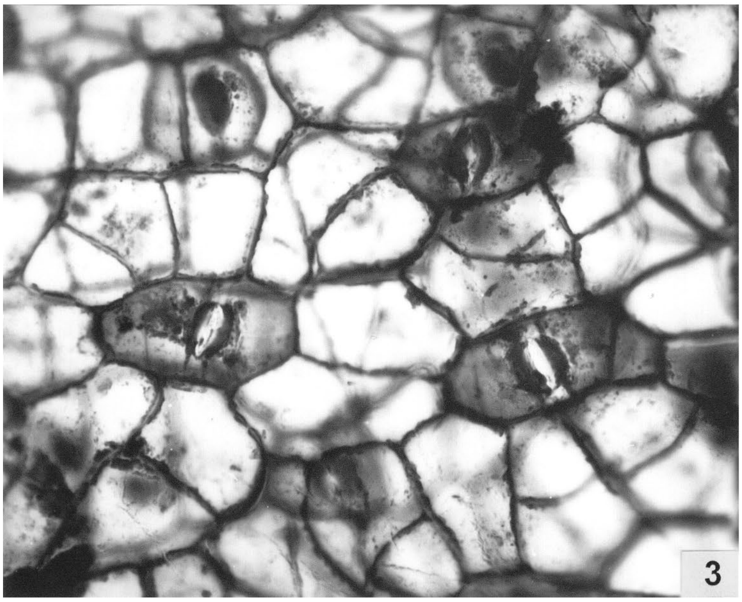
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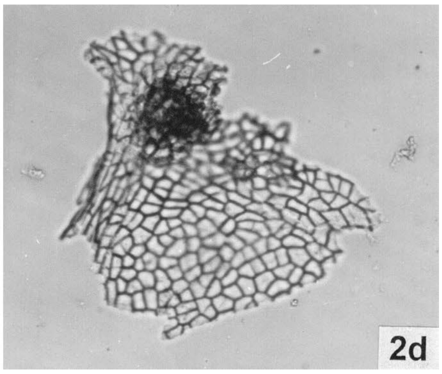

2d

Plate 18

Cyrilla thomsonii Kräusel & Weyland

1. Specimen KRAM-P 217/192, × 1
1a. Upper epidermis, specimen KRAM-P 217/192, × ca. 180
1b. Lower epidermis with stomata, specimen KRAM-P 217/192, × ca. 180
1c. Lower epidermis with stomata, specimen KRAM-P 217/192, × ca. 720

Cyrilla thomsonii Kräusel & Weyland (A) and *Sequoia abietina* (Brongniart) Knobloch (B)

2. Specimen KRAM-P 217/119, × 1.5

Diospyros anceps Heer

3. Specimen KRAM-P 217/24, × 1.5
4. Specimen KRAM-P 217/252/II, × 2

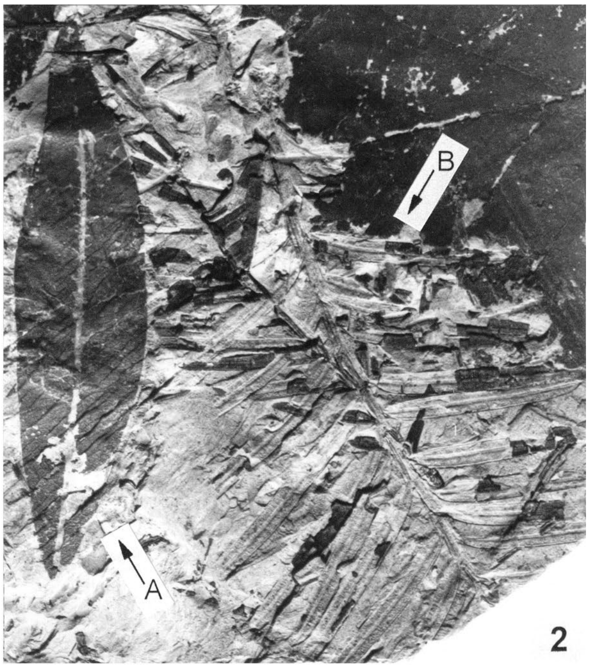
cf. *Diospyros anceps* Heer

5. Specimen KRAM-P 217/224, × 1.5

1, 2, 3–5 phot. A Pachoński


1


1a



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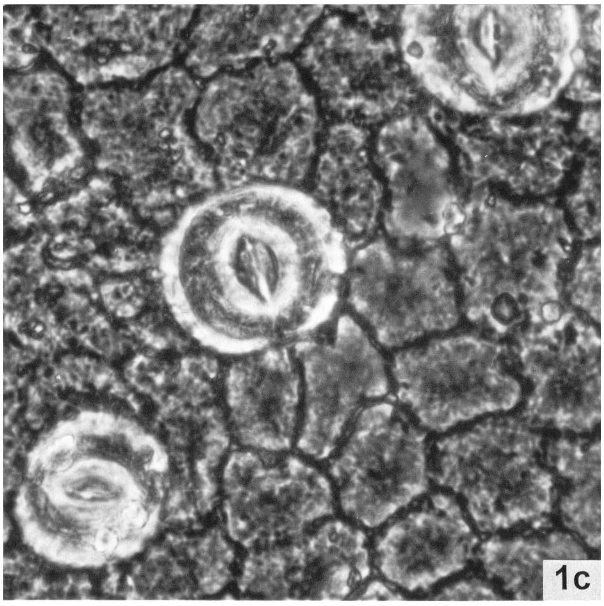
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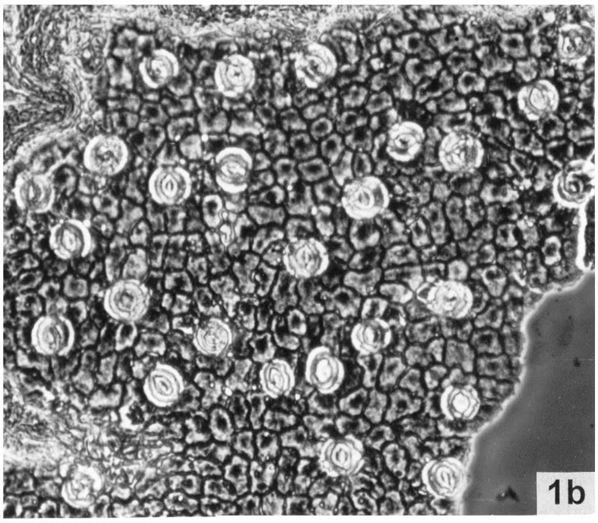
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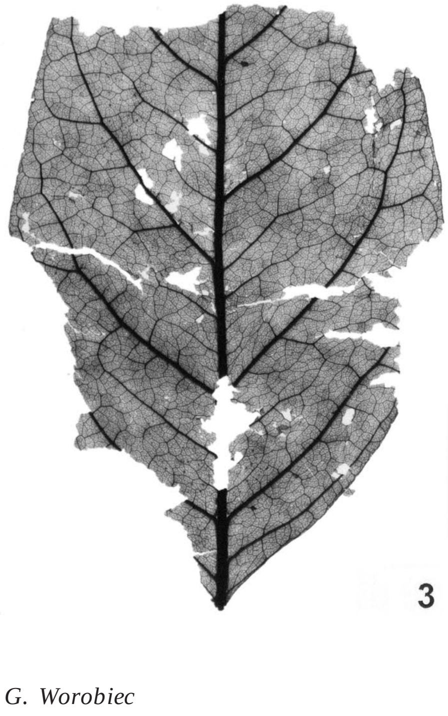
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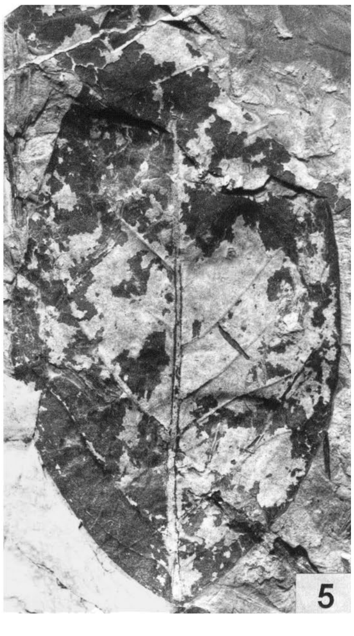
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Plate 19

Diospyros anceps Heer

1. Specimen KRAM-P 217/62, × 1.5
2. Specimen KRAM-P 217/124/II, × 1.5
5. Upper epidermis with unicellular trichome bases, specimen KRAM-P 217/138/II, × ca. 180

5a. Lower epidermis with stomata and unicellular trichome bases, specimen KRAM-P 217/138/II, × ca. 180

5b. Lower epidermis with stomata and unicellular trichome base, specimen KRAM-P 217/138/II, × ca. 720

Acer sp.

3. Specimen KRAM-P 214/132/II, × 5

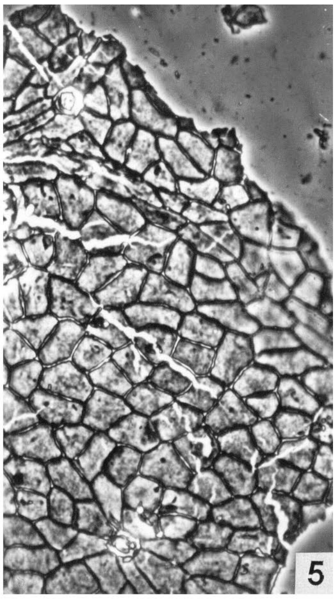
Acer tricuspidatum Bronn sensu Procházka & Bůžek

4. Specimen KRAM-P 214/172 a and b, × 1

1–4 phot. A Pachoński


1


4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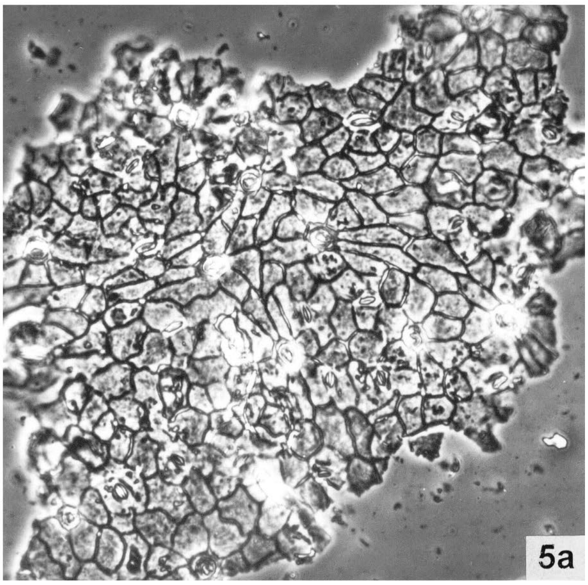
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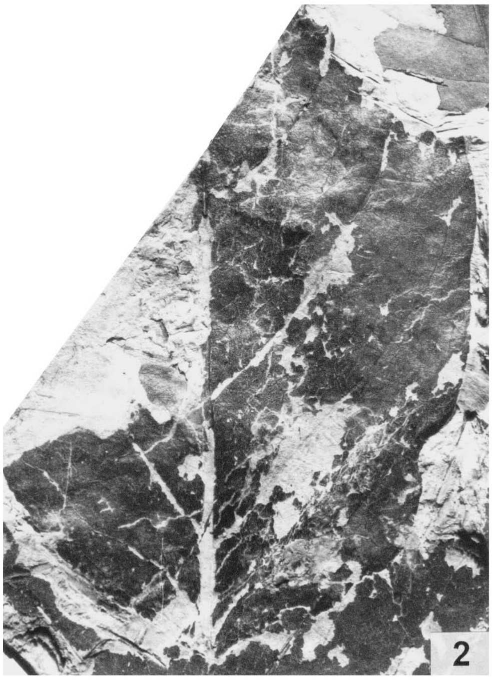
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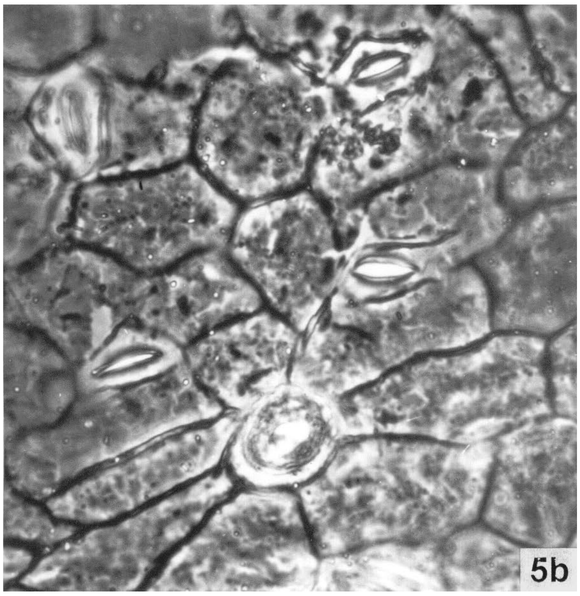
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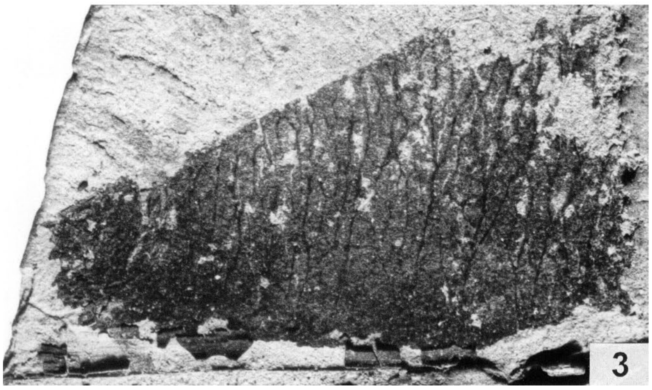
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Plate 20

Acer integrilobum O.Weber

1. Specimen KRAM-P 214/53, × 3

1a. Epidermis, specimen KRAM-P 214/53, × ca. 720

2. Specimen KRAM-P 214/61, × 1.5

3. Specimen KRAM-P 214/63, × 2

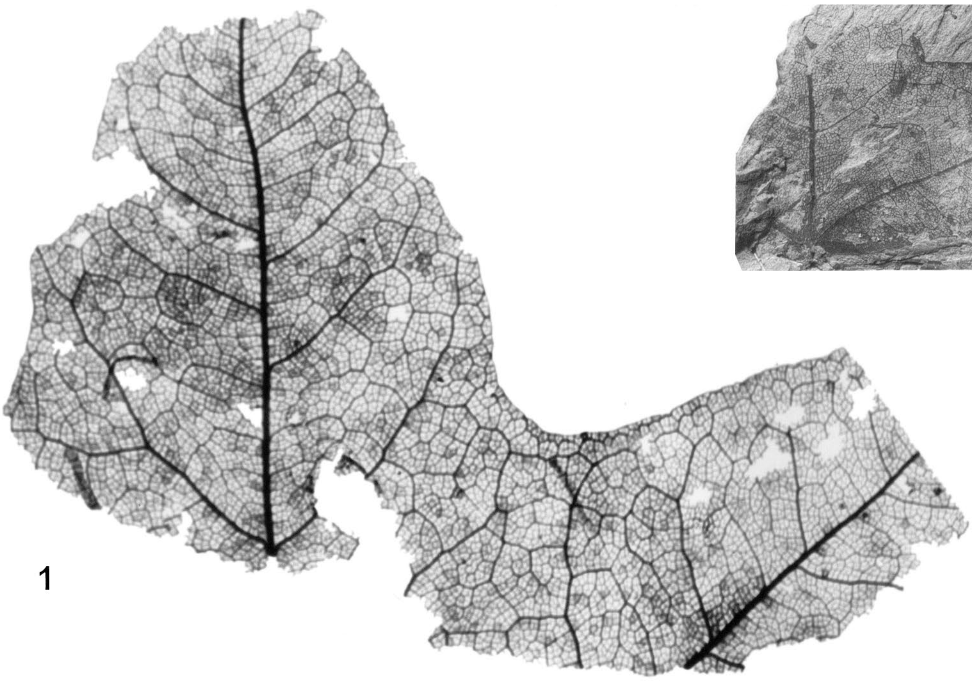
4. Specimen KRAM-P 214/15, × 3

5. Specimen KRAM-P 214/30, × 2

Acer tricuspidatum Bronn sensu Procházka & Bůžek

6. Lower epidermis with stomata and trichomes, specimen KRAM-P 214/172b, × ca. 720

1, 2–6 phot. A Pachoński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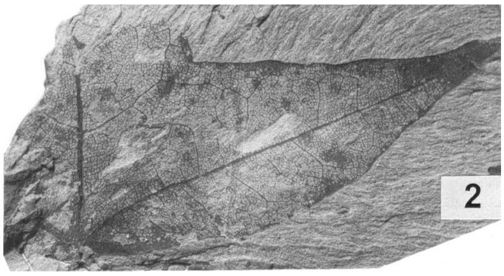
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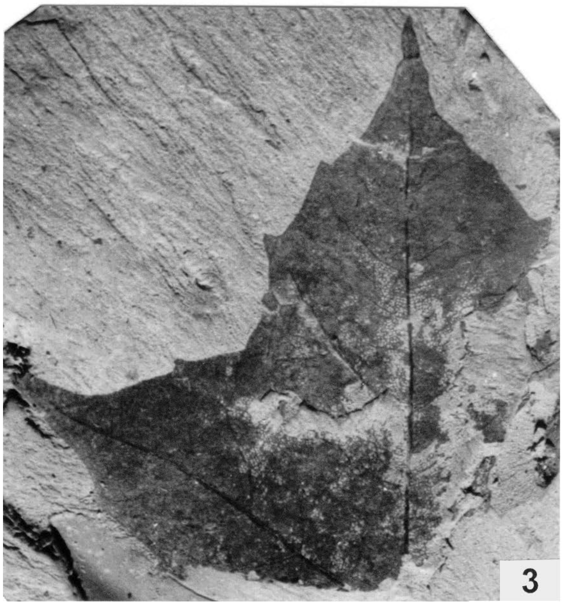
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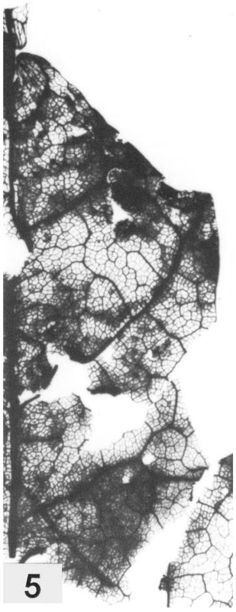
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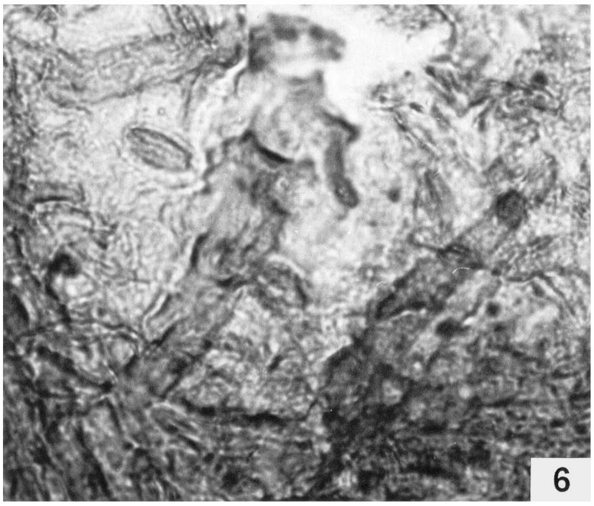
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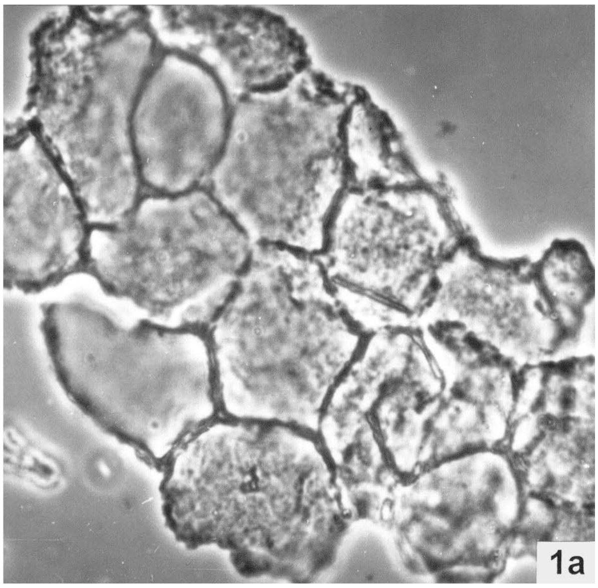
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Plate 21

Aesculus cf. *hippocastanoides* Ilinskaya

1. Upper epidermis, specimen KRAM-P 217/257, × ca. 180
1a. Stomatal apparatus, specimen KRAM-P 217/257, × ca. 720
1b. Upper epidermis, specimen KRAM-P 217/257, × ca. 720

"*Ficus*" *truncata* Heer sensu Bůžek

2. Upper epidermis, specimen KRAM-P 217/131, × ca. 720
2a. Lower epidermis with stomata, specimen KRAM-P 217/131, × ca. 720

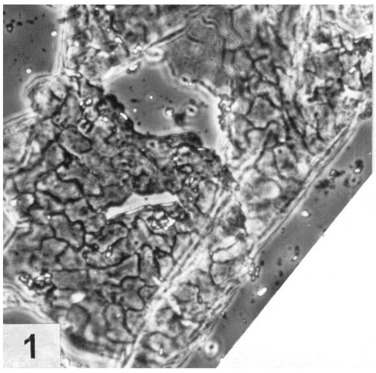
Dicotylophyllum sp. 2

3. Lower epidermis with stomata, specimen KRAM-P 214/120/II, × ca. 720

Symplociphyllum breddini (Weyland) Juchniewicz

4. Lower epidermis with stomata, visible cuticular striations, specimen KRAM-P 214/182, × ca. 180
4a. Stomatal apparatus, visible cuticular striations, specimen KRAM-P 214/182, × ca. 720

Plate 21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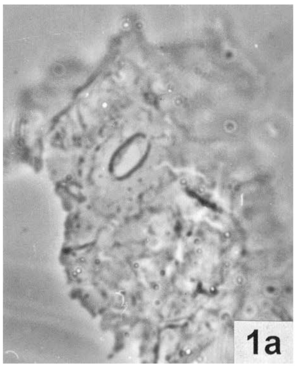
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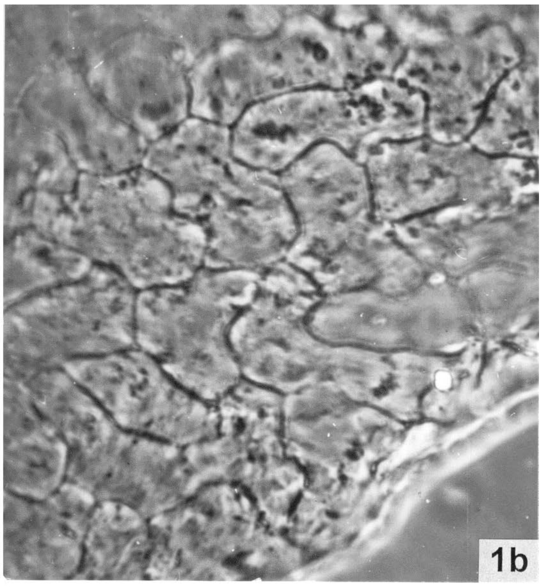
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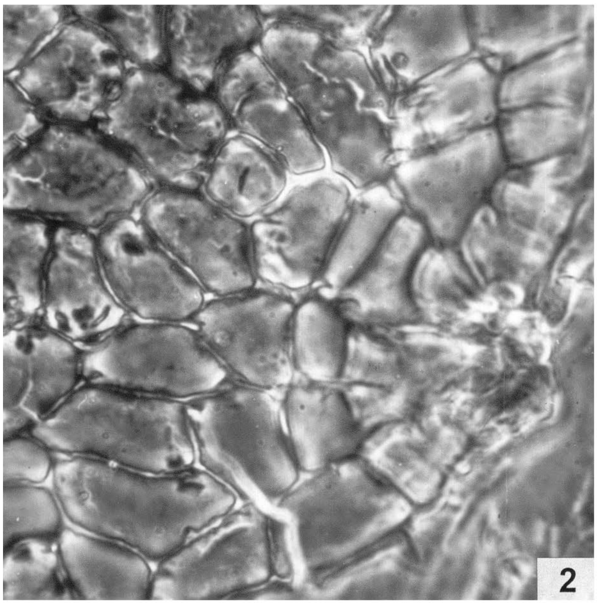
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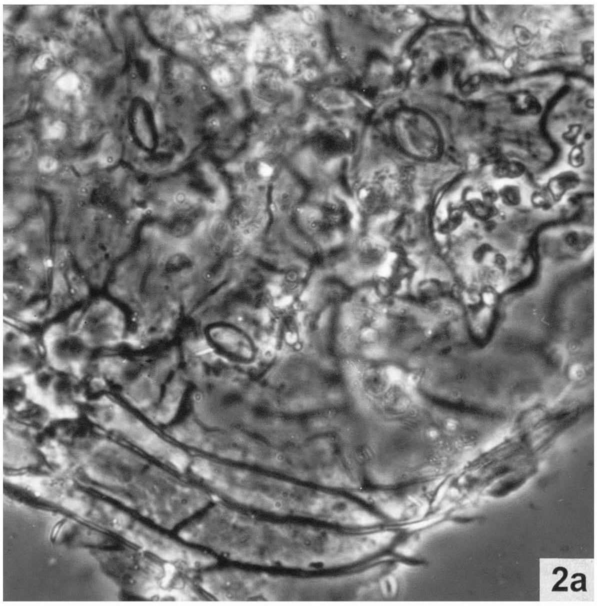
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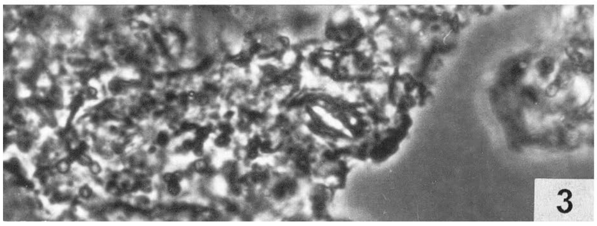
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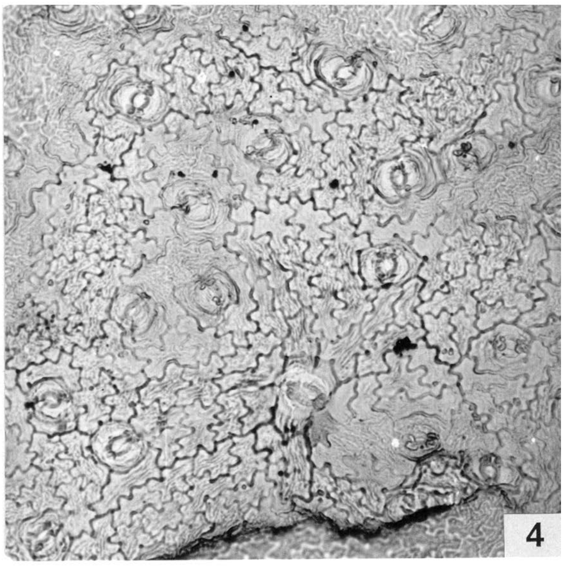
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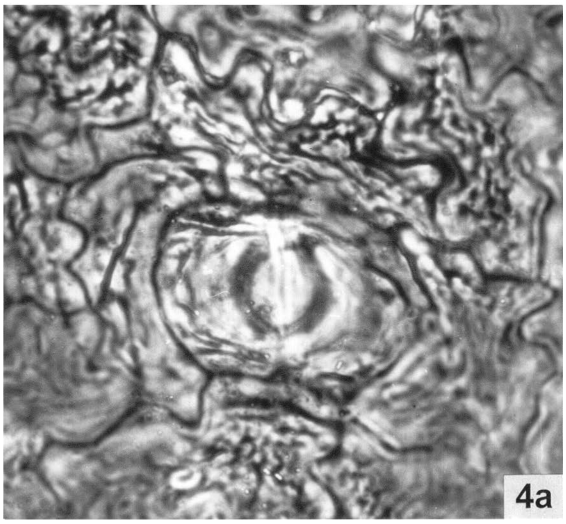
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Plate 22

Dicotylophyllum sp. 4

1. Upper epidermis, specimen KRAM-P 217/191, × ca. 720
1a. Lower epidermis with stomata, specimen KRAM-P 217/191, × ca. 720
1b. Trichome base, specimen KRAM-P 217/191, × ca. 1000

Dicotylophyllum sp. 1

2. Lower epidermis with stomata, visible epidermal structures of unclear origin and function, specimen KRAM-P 214/80, × ca. 200

Dicotylophyllum sp. 3

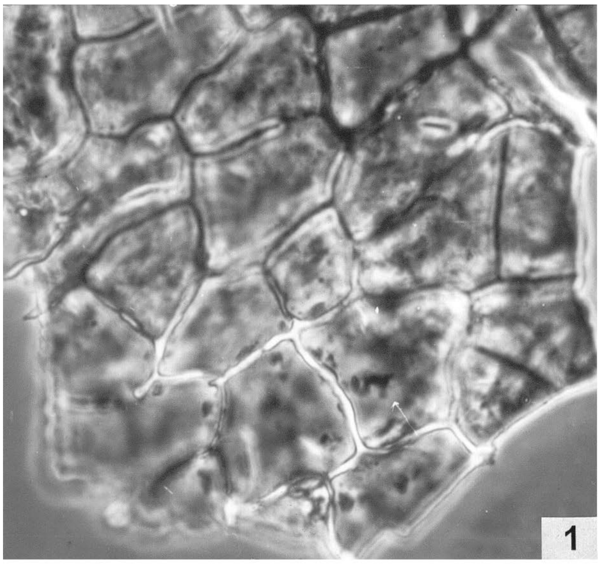
3. Upper epidermis, specimen KRAM-P 217/248, × ca. 180

Smilax sagittifera Heer sensu Hantke

4. Upper epidermis, specimen KRAM-P 214/192b, × ca. 180

Dicotylophyllum sp. 5

5. Epidermis, specimen KRAM-P 217/196/II, × ca. 720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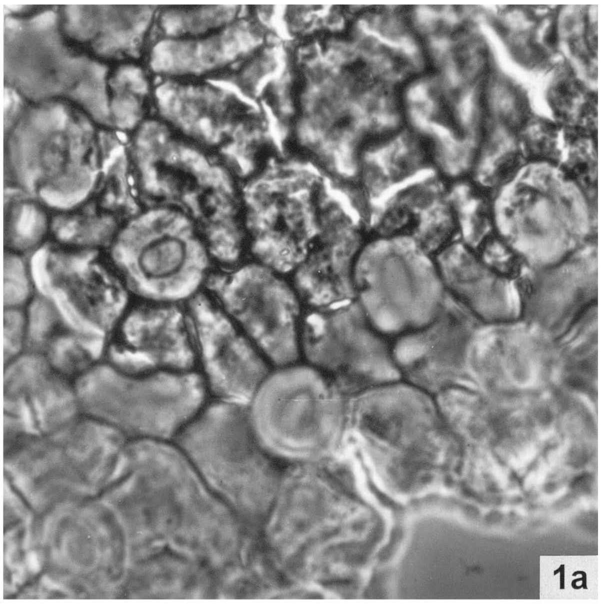
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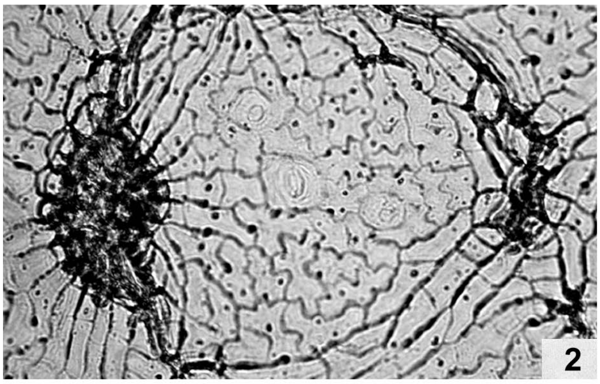
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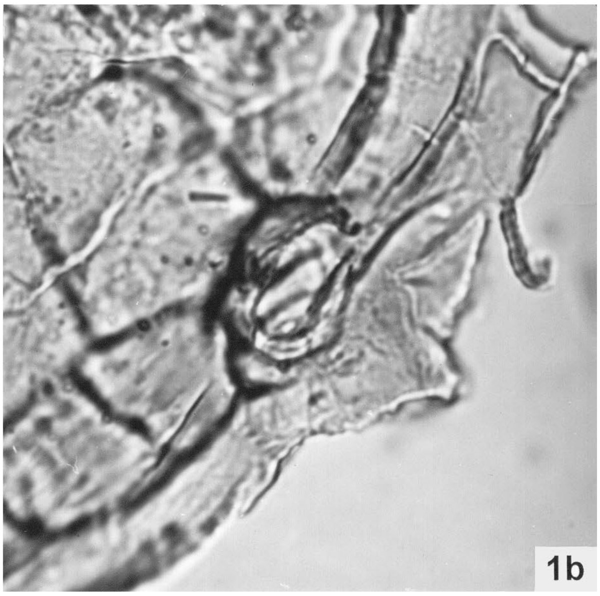
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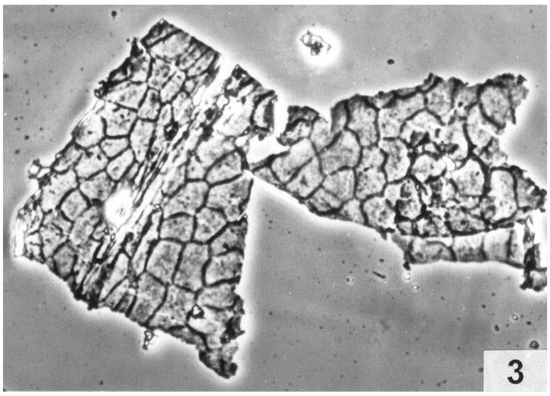
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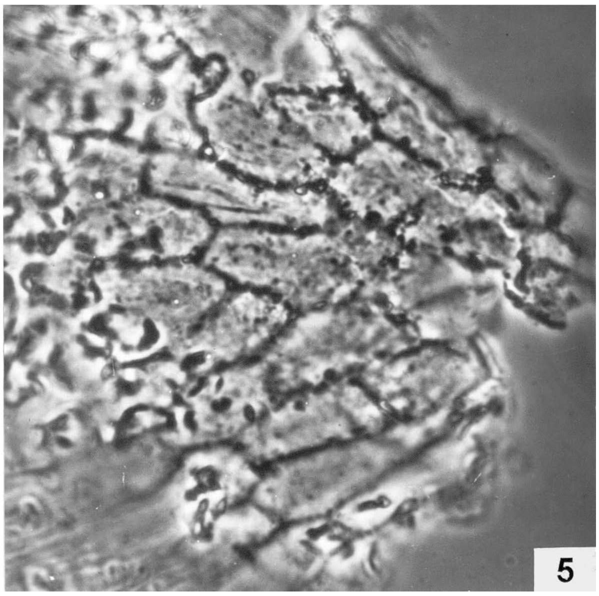
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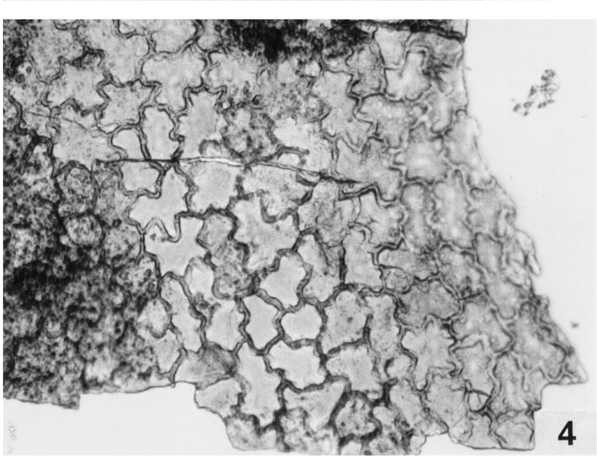
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Plate 23

Smilax sagittifera Heer sensu Hantke

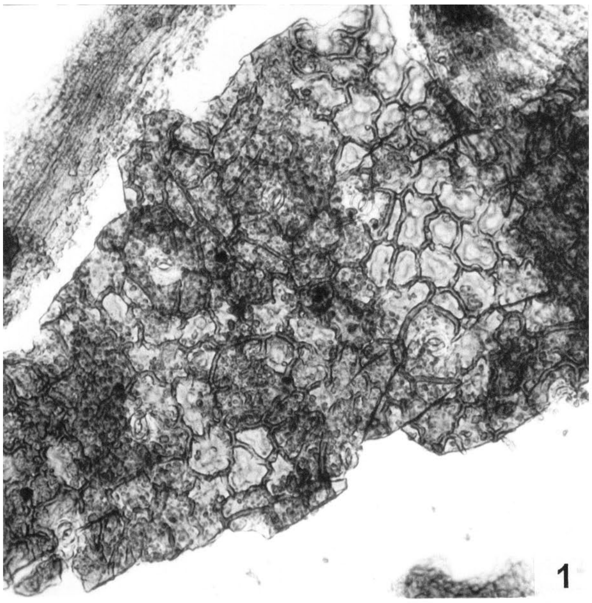
1. Lower epidermis with stomata, specimen KRAM-P 214/192b, × ca. 180
1a. Stomatal apparatus, specimen KRAM-P 214/192b, × ca. 720

Smilax cf. *weberi* Wessel in Wessel & Weber

2. Upper epidermis, specimen KRAM-P 217/142, × ca. 720
2a. Stomatal apparatus, specimen KRAM-P 217/142, × ca. 720

Smilax cf. *protolancaefolia* Kolakovsky

3. Upper epidermis, specimen KRAM-P 217/254, × ca. 180
3a. Lower epidermis with stomata, specimen KRAM-P 217/254, × ca. 180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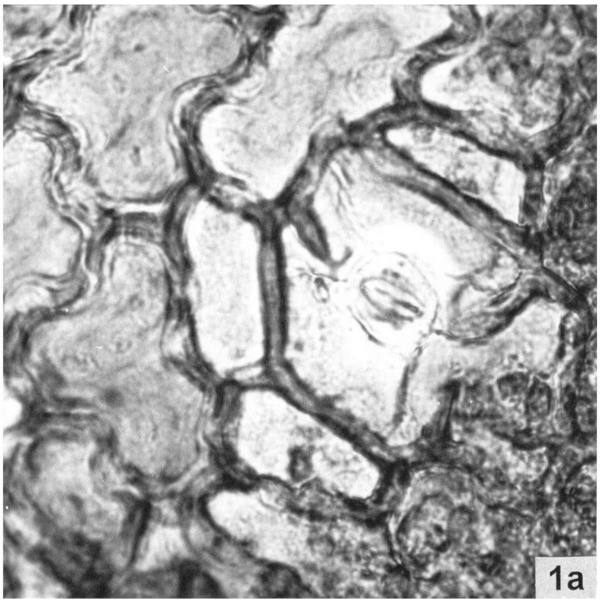
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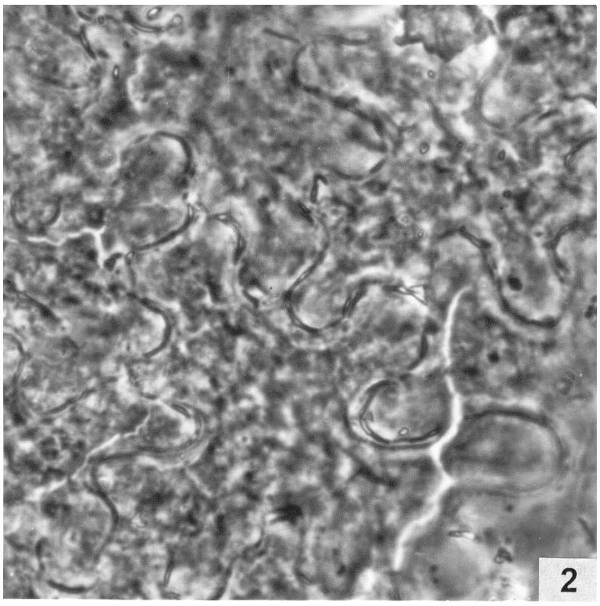
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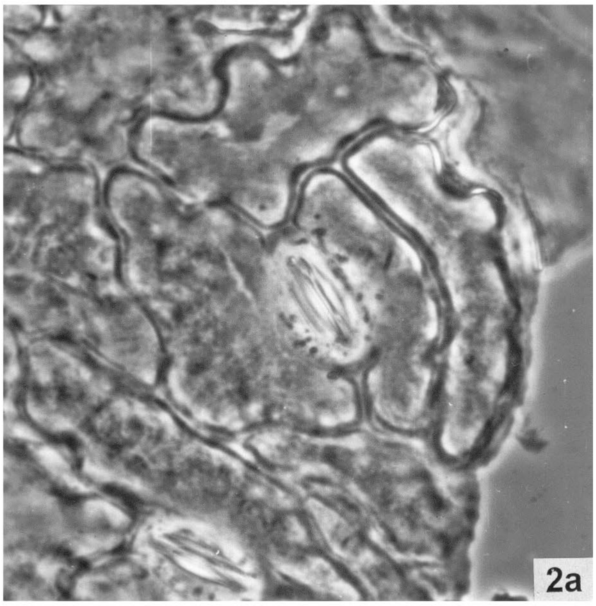
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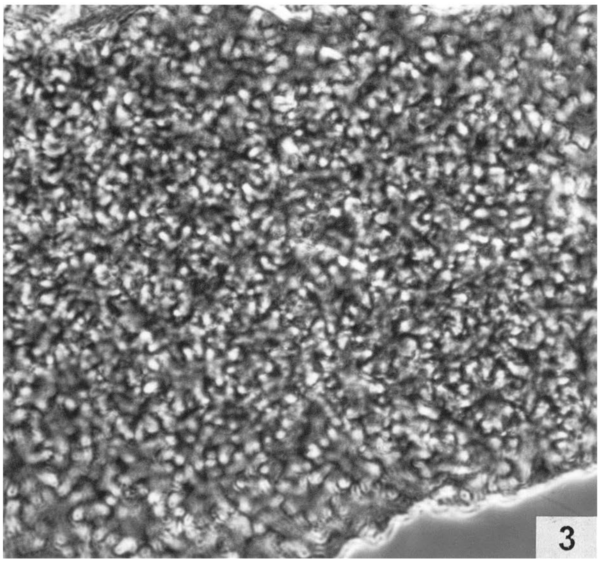
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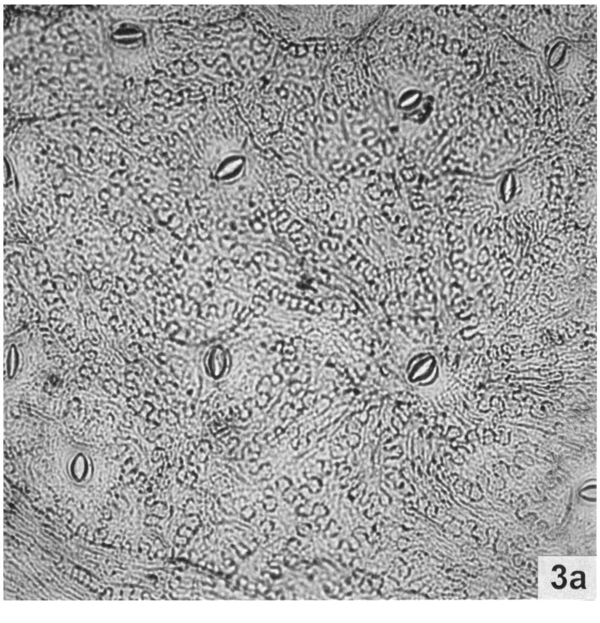
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Plate 24

Bambusa lugdunensis Saporta

1. Specimen KRAM-P 217/53, × 1.5
2. Specimen KRAM-P 217/225/II, × 1.5

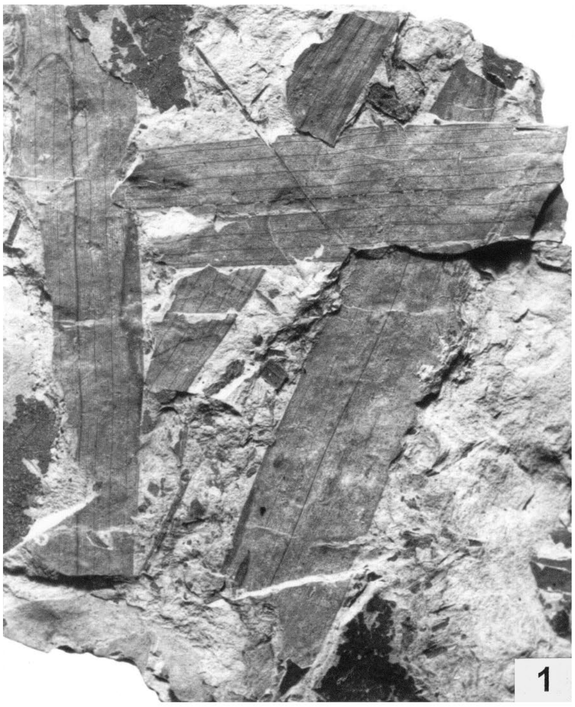
Stratiotes kaltennordheimensis (Zenker) Keilhack

3. Specimen KRAM-P 211/44, × 3

Alnus gaudinii (Heer) Knobloch & Z. Kvaček (A), *Alnus menzelii* Raniecka-Bobrowska (B), *Bambusa lugdunensis* Saporta (C)

4. Specimen KRAM-P 217/53, × 1

1–4 phot. A Pachoński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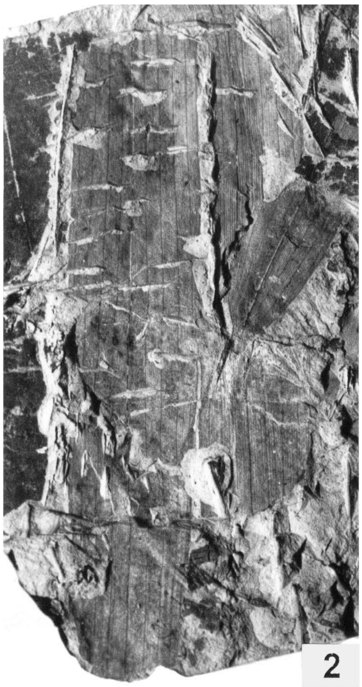
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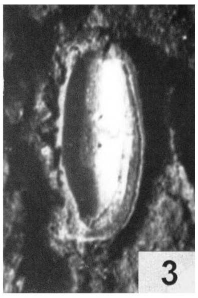
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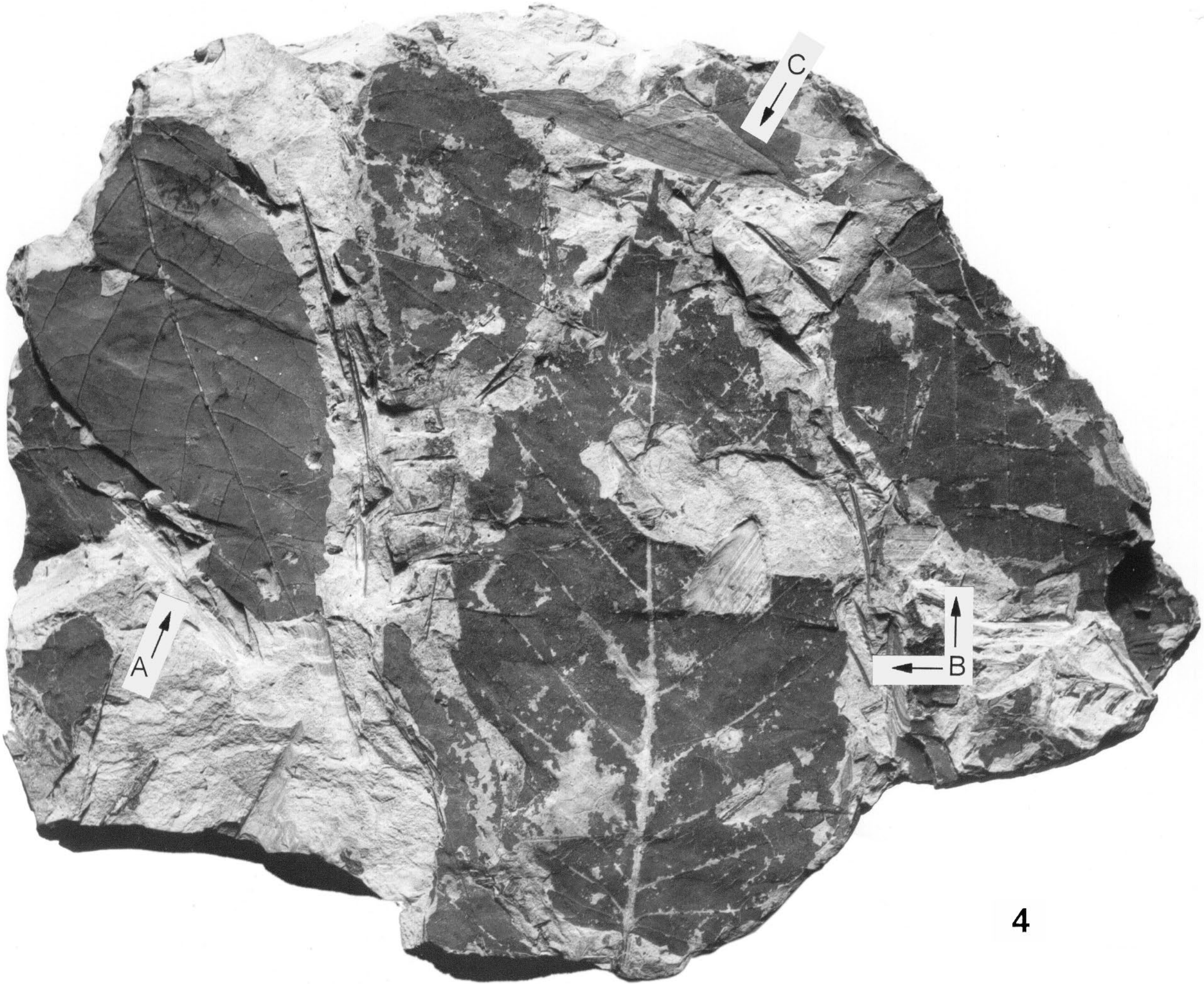

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