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NEOGENE LEAF FLORA FROM GNOJNA (OPOLE PROV., SW POLAND)

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ABSTRACT. The results of a study of the leaf assemblage of Gnojna (Opole Prov.) derived from deposits of the Gozdnica series are presented. The plant remains (impressions of leaves, shoots and fruits) have been assigned, on the basis of comparative morphological studies, to 29 taxa of the families: Taxodiaceae, Aceraceae, Altingiaceae, Betulaceae, Fagaceae, Hamamelidaceae, Platanaceae, Rosaceae, Salicaceae, Trapaceae, Ulmaceae and Poaceae. The leaves of Betulaceae are the dominant component. All taxa occurring at Gnojna belong to the arctotertiary element. They are comparable with the trees and shrubs growing at present in deciduous mesophytic and riparian forests in areas with a humid, warm-temperate to temperate climate. The age of Miocene-Pliocene transition or Uppermost Miocene is assumed for this flora.

KEY WORDS: fossil flora, leaves, Neogene, Gnojna

INTRODUCTION

The village of Gnojna lies about 47 km NW of Opole in the Opole Province in south-western Poland. In this village S. Dyjor of the Lower-Silesian Division of the State Institute of Geology, found a site with numerous leaf impressions in 1984. Besides Gozdnica, Ruszów and Kłodzko, it is the fourth site known so far, with plant macrofossils derived from formations of the so-called Gozdnica series of south-western Poland (Sadowska 1987).

The Gozdnica series is a characteristic complex of macroclastic formations, up to several tens of metres thick. In the area of the Fore-Sudetic Block these formations settled as alluvial fans of Sudetic pre-rivers in the Neogene. The development of the series was connected with the decline of an extensive basin of the Poznań series, which covered large areas of western and central Poland in the Tertiary (Neogene) and with the orogenic movements of the Wallachian phase of the Alpine orogenesis (Dyjor 1966a, 1968, 1986, 1987a, b; Oberc & Dyjor 1969, and others). The Gozdnica series from the eastern part of the Sudetic Forefield was initially defined as white gravels (Behr 1929) and in the western part as a series of white gravels and kaolin clays (Dyjor 1964, 1966a).

The objective of a number of studies was to determine the development, range and age of the Gozdnica series and the time of the beginning and ending of its sedimentation. The first references to gravels and quartz-feldspar sands of Lower Silesia appear in works from the first half of the twentieth century (e.g. Jentsch 1910; Weber 1928; Berg 1936; Berger 1938). The age of these sediments was then determined to be Pliocene.

Studies on the stratigraphy, regional spread and development of the Gozdnica series were carried out mainly by Dyjor (Dyjor 1966a, b, 1985; Dyjor et al. 1978, 1992; Oberc & Dyjor 1969). In earlier works the age of the series was assumed to be Middle or Upper Pliocene to Quaternary (Dyjor 1966b, 1968; Oberc & Dyjor 1969; Stachurska et al. 1967 and others). Numerous investigations of fossil floras from Gozdnica, Ruszów and Kłodzko in the forefield of the Sudetes made it possible to date the sediments of this formation more exactly (Dyjor et al. 1978, 1992; Jahn et al. 1984; Sadowska 1985, 1987, 1991, 1992; Hummel 1983, 1991; Baranowska-Zarzycka 1988; Łańcucka-Środoniowa & Zastawniak 1993).

The introduction of a new stratigraphic division of the Neogene of the Paratethys in 1985 (under the scheme of Project 25 IGCP) brought about changes in the stratigraphy of many Neogene floras (Dyjor & Sadowska 1986b). It is assumed now that the sedimentation within the range of alluvial fans in the

Sudetic Forefield began as early as the Late Miocene and lasted until the Late Pliocene (Dyjor et al. 1992; Dyjor 1995).

The macroclastic formations of the Gozdnica series are often devoid of organic remains. Hence the determination of the age of the deposits in the Gozdnica series occurring at Gnojna is essential for the dating of the initial phase of sedimentation of this formation in the eastern part of the Fore-Sudetic Block (Dyjor 1985). The upper part of the profile of the Gozdnica series from the Gnojna region was studied palynologically, resulting in an estimated age for the deposits of the Gozdnica series as Lower Pliocene (Sadowska 1985, 1991, 1992) and recently as at the Miocene /Pliocene boundary (Sadowska 1995).

The purpose of the present study was to carry out a floristic analysis of the leaf assemblage from Gnojna and, on its basis, to reconstruct the plant communities occurring in the immediate vicinity of the place of sedimentation and also to compare it with other fossil floras from this region and determine its age.

The work is the thesis for a doctor's degree presented at the W. Szafer Institute of Botany, PAScs, in Kraków on 19 Feb 1997.

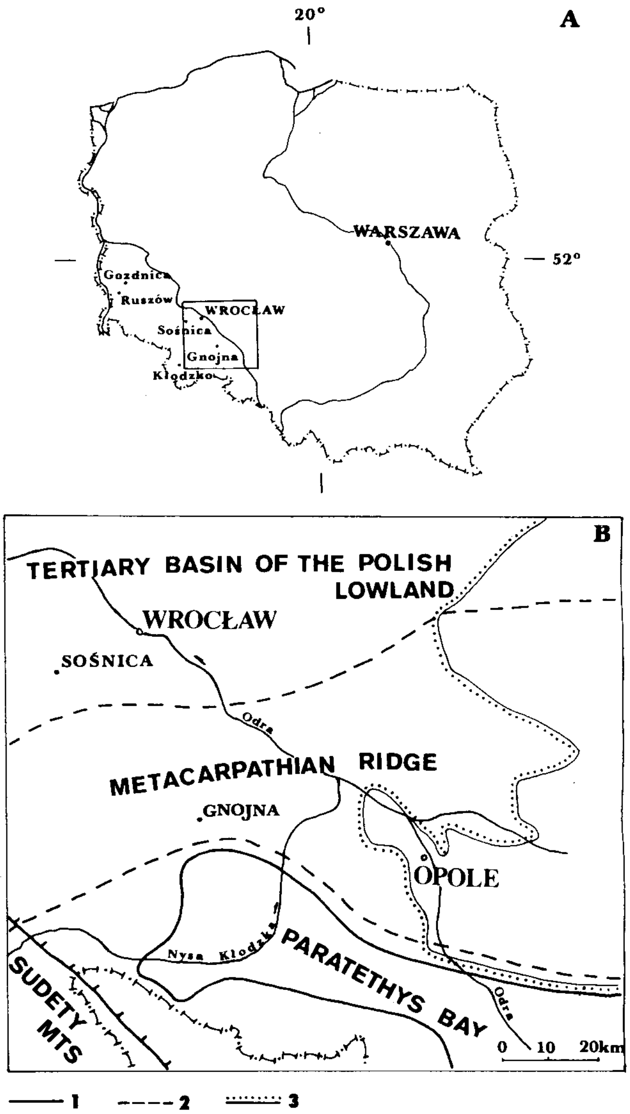

Fig. 1. Location of the fossil flora of Gnojna (A) and distribution of Neogene deposits in SW Poland (B) (after Sadowska 1992). **1** – extent of marine deposits of the Paratethys; **2** – extent of the Fore-Sudetic part of the Metacarpathian ridge; **3** – extent of continuous cover of the Poznań series

GEOLOGY OF THE SITE

The site with its leaf assemblage (Fig. 1) is situated in the eastern part of the Fore-Sudetic Block, a short distance from the fault zone of the middle Odra river. It lies within the Metacarpathian ridge which formed the watershed separating two palaeogeographical provinces in the Miocene: the Polish Lowland Basin, filled in its upper part with deposits of the Poznań series, and the Carpathian Foredeep. The site with the fossil flora is located near the south-western border of the continuous cover of the Poznań series. In this region Dyjor (1985) distinguished the occurrence of three links of the Younger Tertiary:

1. fragmentarily preserved Brown-coal seam Henryk (=Lusatian series I, the age of which is defined as Upper Badenian (Middle Miocene) (Dyjor & Sadowska 1986a, b),
2. formations of the so-called Poznań series and
3. bottom part of the Gozdnica series.

The Poznań series in the Gnojna region is more than 70 m thick and is represented by two lithostratigraphic horizons, the Green Clay Horizon and the Horizon of Flamy Clay (Dyjor 1985).

At the time of sedimentation of the Green Clay Horizon, when the basin of the Poznań series attained its maximal spread, a distinct depression appeared in the fault zone of the middle Odra within the Metacarpathian ridge. The lake of the Poznań series basin penetrated gradually into this depression, reaching the Paczków-Kędzierzyn graben (the Silesian part of the sub-Carpathian Foredeep) (Dyjor 1985, 1995; Dyjor & Sadowska 1986a). The initial tectonic movements of the Walachian phase caused the shallowing of the Poznań Series Basin in which flamy clays were then being

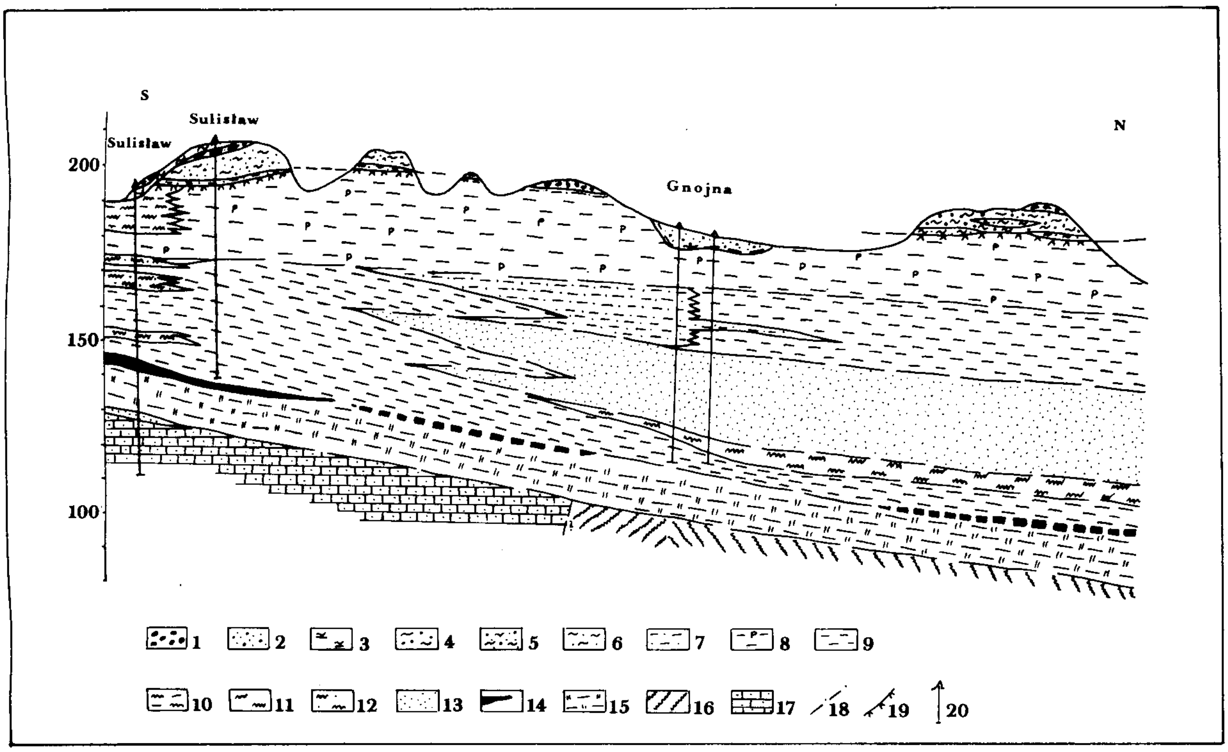

Fig. 2. Profile of the Poznań series and the Gozdnica series in the Gnojna region (after Dyjor 1985). **1** – gravels; **2** – sands and gravels; **3** – boulder clay; **4** – loamy gravels; **5** – sands and loamy gravels; **6** – sandy kaolin clays; **7** – sandy clays; **8** – flamy clays; **9** – green clays; **10** – clayey silts; **11** – silts; **12** – sandy silts; **13** – sands; **14** – brown coal; **15** – kaolinite clays; **16** – Old-Paleozoic metamorphic schists; **17** – Cretaceous sandstones; **18** – boundary between Quaternary and Tertiary deposits; **19** – boundary between Gozdnica series and Poznań series deposits; **20** – bore-holes

deposited (Dyjor & Sadowska 1986a; Dyjor 1987b). The series of deposits observed in the Gnojna region (Fig. 2) is, according to Dyjor (1985), a reduced Poznań series from the area of the Metacarpathian ridge.

The Gozdnica series deposits lie on the eroded surface of flamy clays. They are preserved on the tops of hills, at an altitude of 190–200 m and are about 8 m thick (Fig. 2). They were deposited in the deltaic fan zone of the pre-Nysa Kłodzka river, formed at the edge of the northward-retreating lake of the Poznań Series Basin (from the area of the Fore-Sudetic Block to that of the Silesian Lowland). This deltaic fan marks the end of the zone of extensive alluvial cover extending along the river channel from Gorzuchów through Kłodzko, Bardo and Ziębice (Dyjor 1985). The development of the deltaic fan of the pre-Nysa Kłodzka river and the alluvial fans of other Sudetic rivers was connected with the intensive tectonic movements of the Walachian phase, whose action involved, among others, the Sudetes, Fore-Sudetic Block and Carpathians. The uplift of the Sudetic area brought about an intensification of erosion in the mountains, an increase in the force of rivers and the formation of a series of macroclastic deposits at the foot of the mountains. As the Fore-Sudetic Block was being lifted, the alluvial fans of the Gozdnica series were shifted to the north and sometimes joined together in large alluvial covers (e.g. those of the Nysa Kłodzka and Biała Głuchołaska) (Oberc & Dyjor 1969; Dyjor 1966a, 1986, 1987b, 1995).

Dyjor (1985) dates the decline in sedimentation of the Poznań series to the Upper Sarmatian-Pliocene boundary and the beginning of the sedimentation of the Gozdnica series at Gnojna to the Lower Pliocene.

The Gozdnica series in the Gnojna region consists of varigrained sands and gravels of Sudetic origin, frequently clayey and intercalated with layers of sandy kaolin clays and silts (Dyjor 1985).

Teisseyre (1985) distinguished 10 layers of deposits in the Gozdnica series profile (Fig. 3); he found the occurrence of beach and dune deposits (layers 1 and 4), river deposits (layers 2, 3 and 7), deposits of pelagic suspension sedimented in stagnant water (layers 5, 8 and 10) and probably hybrid, aeolian-lacustrine deposits (layer 9). The material collected for the present study, consisting of plant remains,

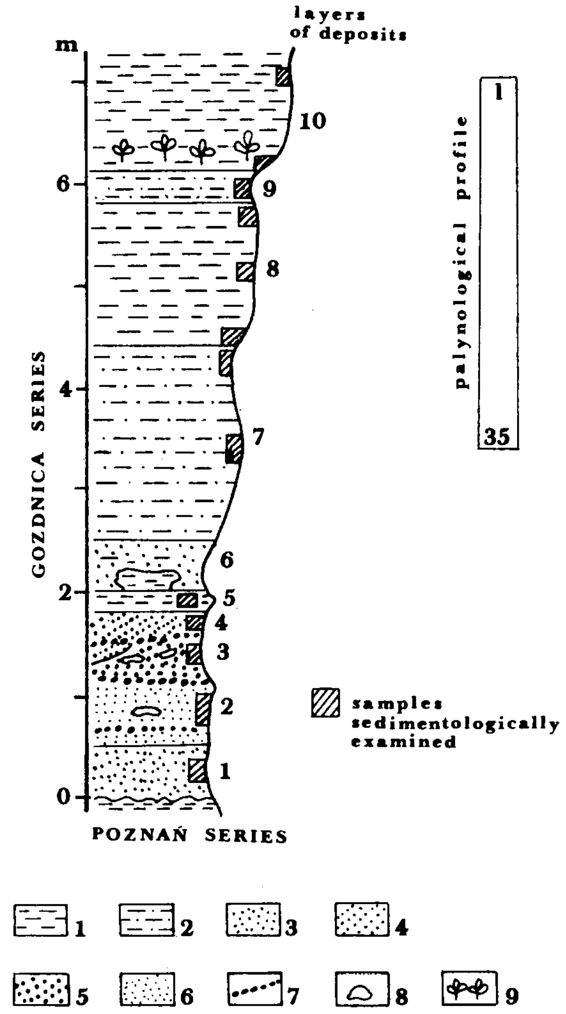

Fig. 3. Lithological profile of the lower part of the Gozdnica series (after Teisseyre 1985, somewhat changed). **1** – grey clays; **2** – sandy brown-grey dust; **3** – medium-grained sands; **4** – medium-grained light grey laminated sands; **5** – coarse-grained light grey laminated sands; **6** – fine-grained light grey laminated sands; **7** – grey clay balls; **8** – lignite; **9** – plant remains

chiefly leaf impressions, comes from the top part of the profile of this series, from layer 10, i.e. from the lower horizon of grey clays (Fig. 3). An earlier palynological analysis carried out by Sadowska (1985) included the upper part of the profile of the Gozdnica series, 3.5 m thick, from which 35 samples were taken (Fig. 3).

The lower part of the Gozdnica series profile comprises deposits of running water in a river environment, which is, in Teisseyre's (1985) opinion, indicated inter alia, by the presence of intraclastic channel pavements, the presence of large pieces of wood brought down by the river and partly mineralized, and the lithological features of the deposit, whereas the upper part of the profile is composed of sediments of stagnant water, giving evidence of the increasing depth of the lake and the shrinking land effect (Teisseyre op. cit.).

MATERIAL AND METHODS

Material for study was collected from the northern wall of an inactive clay-pit of a brick-kiln situated about 200 m south-east of the Gnojna collective farm in 1985 and 1987. The first collection of specimens was taken under the direction of Assist. Prof. S. Dyjor and Prof. A. Sadowska; 30 specimens were delivered for study to the Museum of the Earth, PAScs in Warsaw. The next batch of material (297 specimens) was gathered by K. Krajewska, J. Kurdziel, J. Wieser and M. Zurzycka under the direction of Assist. Prof. E. Zastawniak. The whole of the study material consisted of 327 specimens comprising about 385 plant remains.

Lumps of deposit with plant remains were wrapped up in paper and placed in foil packs. Next the material was prepared with the use of a scalpel, preparatory needle and brush. The fossil plant remains were mainly leaf impressions, for the most part fragments, impressions of whole leaves being rarities. Impressions of shoots of monocotyledons, shoots of conifers and fruits were less numerous. Vestigial organic matter survived in a few specimens.

The state of preservation of the venation varied, depending upon the coarseness of the grains of the deposit. In some specimens the venation of the third and higher orders was visible, in others only the venation of the first and second orders. The colour of the leaf impressions resembled that of the rock, i.e. it was pale yellow or somewhat darker, to dark brown.

The specimens studied are housed in the W. Szafer Institute of Botany, PAScs, in Kraków – collection KRAM-P 199/1–285 and in the Museum of the Earth, PAScs, in Warsaw – collection MZ.VII/71/1–43. Some of the specimens comprised more than one leaf impression or fragment; in these cases the specimen number was supplied with a figure from 1 to 6 as a suffix, according to the number of impressions. Several specimens cracked while being prepared. However, on the basis of the characteristics of leaf venation it was possible to reconstruct the original state, e.g. KRAM-P 199/17 and 199/19, 199/209 and 199/210, 199/191 and 199/192. Twin specimens were marked with the symbol "+".

The drawings of leaf outlines were made under an MST 130 (PZO, Warsaw) binocular microscope on transparent tracing paper placed directly on the specimen; the drawings of the outlines of fruits of *Trapa* were made with the help of the drawing apparatus of a WILD M3Z binocular microscope. Measurements of specimens were taken using a 12× ocular provided with a scale.

The taxonomic system applied follows those of Takhtajan (1987) and Szweykowska & Szweykowski (1993).

Hickey's (1973) terminology is used in the descriptions of leaves.

The comparative materials used in the course of this investigation came from the Museum of the Earth, PAScs, in Warsaw, Institute of Dendrology, PAScs, at Kórnik, Arboretum SGGW-AR at Rogów, Botanical Garden of Warsaw Univ. in Warsaw, Botanical Garden of the Jagiellonian Univ. in Kraków, Kew Garden in Great Britain and the botanical garden at Sukhumi (Kaukasus Region).

A sample of the deposit from Gnojna was flushed to check for the presence of fruits and seeds. The material was boiled in KOH solution until its comminution; next it was flushed with running water on sieves of 0.5 and 0.2 mm mesh. No carpological remains were found in the deposit.

SYSTEMATIC PART

MORPHOLOGICAL DESCRIPTION OF PLANT REMAINS

Pinopsida (=Coniferopsida)

Taxodiaceae F. Neger 1907

Taxodium dubium (Sternb.) Heer

Pl. 1, figs 1–1a, Fig. 4: 1–5

1823. *Phyllites dubius* Sternb.; Sternberg, Pl. 36, fig. 3
1853. *Taxodium dubium* (Sternb.) Heer; Heer, p. 136
1855. *Taxodium dubium* (Sternb.) Heer; Heer, p. 49, Pl. 17, figs 5–15

Material. MZ.VII/71/40; KRAM-P 199/2, 5, 8, 9, 32, 81, 151, 185, 186, 227_1 – eleven specimens

Description. Fragments of twigs, 1.0–3.5 cm long and 0.4–0.8 mm thick. Needles, arranged alternately on both sides of twigs, arise at irregular intervals of 0.5–2.0 mm at an angle varying from 20° to 60°. Needle bases twisted, forming ridges delicately marked on the twig and extending parallel to its axis. Needles flat, with entire margins, straight or slightly curved, linear or lanceolate, sometimes (in the lower part of the twig) narrowly obovate. In the apical part they narrow and form an acute or, more rarely, blunt tip. Midvein fairly distinctly marked. The needle length to width ratio fluctuates from 5 : 1 to 11 : 1; longest needles in the middle of the twig (10 × 1.0 mm); in the lower and apical parts of twigs the needles are shorter, (2.0–5.0 × 0.2 –1.2 mm).

Remarks. The fragments of short-shoots presented show a set of features typical of *Taxodium dubium* (Sternb.) Heer, a species widespread in the European Tertiary (mainly Miocene) floras. Characteristic, among other things, is the arrangement of needles on the twig, irregular and at rather acute angles, as well as the twisted needle bases descending parallel to the twig axis, the shape of the needles and the small thickness of the twigs (Heer 1868; Reichenbach 1919; Schweitzer 1974).

Taxodium dubium is comparable with two recent species: *Taxodium distichum* (L.) Rich. and *T. mucronatum* Tenore (Ilinskaya 1968; Ferguson 1971; Christensen 1976). At present *T. distichum* occurs in river swamps, on the banks of streams in the south-eastern part of North America, while *T. mucronatum* grows on the banks of rivers in the mountains of Mexico, at an altitude of 1400–2300 m (Krüssmann 1972).

Occurrence in the fossil floras of Poland. Cf. Hummel 1983; also Bełchatów (Stuchlik et al. 1990) and Gozdnica (Dyjor et al. 1992).

Magnoliophytina (=Angiospermae)

Magnoliopsida (=Dicotyledones)

Hamamelidaceae R. Brown 1818

Parrotia pristina (Ett.) Stur

Pl. 1, figs 2–3a, Fig. 4: 6–21

1852. *Styrax pristinum* Ett.; Ettingshausen, p. 10, Pl. 2, fig. 10
1867. *Parrotia pristina* (Ett.) Stur; Stur, p. 192, Pl. 5, figs 2, 3

Material. MZ.VII/71/1_1+2_1, 6_1, 25, 26+27, 28, 37+38, 39; KRAM-P 199/14+78, 63, 64, 65, 66, 102+103, 105_1, 107, 124, 143, 152, 153, 163, 170_3, 184, (?)188, 213, 222_2, 222_3, 236, (?)241_3, 244_2, 251+252, 264_2, 276_2, 277_1 – thirty-three specimens (six with twin impressions)

Description. Leaves varying in size, ranging from 1.3–2.0 cm to about 5.0 cm in width, measurements of best-preserved fragments: 5.0–6.0 × 3.0–4.0 cm. Petiole, preserved in 9 specimens, 0.5–0.8 cm long. Leaves mostly obovate, narrowly ovate or oblong. Leaf base rounded, weakly cordate or rounded-cuneate, often somewhat asymmetrical. Leaf apex usually rounded; margin entire all along the leaf base, in the apical part of the blade coarsely crenate; small teeth with rounded apices can be seen in several specimens.

Venation craspedodromous. Midvein straight or slightly curved, of moderate thickness. The lowest pair of secondary veins arise from the midvein opposite or subopposite, close to the base or, more frequently coinciding with it so that they form the leaf margin over a certain length (0.1–0.3 cm). The remaining secondaries (4–6 pairs) are most often alternate,

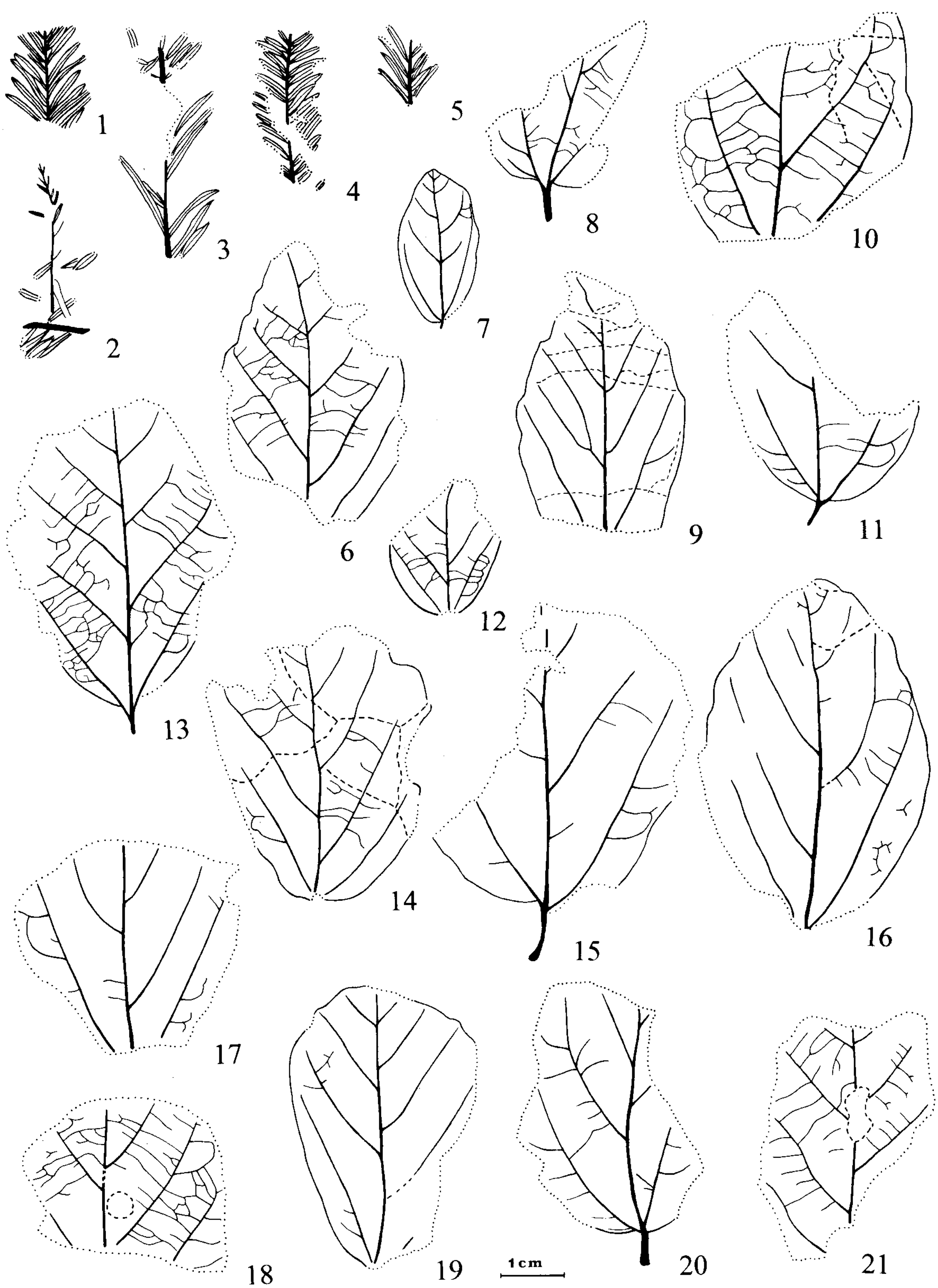

Fig. 4. **1–5** – *Taxodium dubium* (Sternb.) Heer: 1 – specimen No MZ.VII/71/40, 2 – specimen No KRAM-P 199/5, 3 – specimen No KRAM-P 199/32, 4 – specimen No KRAM-P 199/81, 5 – specimen No KRAM-P 199/151; **6–21** – *Parrotia pristina* (Ett.) Stur: 6 – specimen No MZ.VII/71/2_1, 7 – specimen No MZ.VII/71/25, 8 – specimen No MZ.VII/71/26, 9 – specimen No MZ.VII/71/37, 10 – specimen No MZ.VII/71/39, 11 – specimen No KRAM-P 199/14, 12 – specimen No KRAM-P 199/64, 13 – specimen No KRAM-P 199/103, 14 – specimen No KRAM-P 199/124, 15 – specimen No KRAM-P 199/143, 16 – specimen No KRAM-P 199/152, 17 – specimen No KRAM-P 199/163, 18 – specimen No KRAM-P 199/170_3, 19 – specimen No KRAM-P 199/213, 20 – specimen No KRAM-P 199/236, 21 – specimen No KRAM-P 199/251

sometimes, in the apical part of the leaf, opposite; straight or curved upwards, sometimes branched, spaced 0.4–2.0 cm apart. The angle of divergence between the secondary veins and the midvein is 30°–50° except for the veins of the lowest pair, which form a more acute angle with the midvein (25°–38°); this angle may be somewhat larger or smaller in the initial parts of veins. Tertiaries percurrent, simple or forked, sometimes irregularly branched. The tertiaries running from the lower side of the basal veins anastomose within the leaf base. Venation of higher orders rectangularly reticulate.

Remarks. The characteristic arrangement of the lowest pair of secondary veins, especially within the base, the shape of leaves and the configuration of the leaf margins indicate that the specimens described belong to *Parrotia pristina* (Ett.) Stur. It should, however, be added that morphologically similar leaves occur also in other genera from the family Hamamelidaceae: *Hamamelis* L. and *Fothergilla* L. (Tralau 1963). Leaves of this type are widespread in the Neogene floras of Europe and are comparable with the only present-day member of the genus *Parrotia* – *P. persica* (DC.) C. A. Mey., which grows in the Caucasus Mts.

Occurrence in the fossil floras of Poland. Cf. Hummel 1983; also Bełchatów (Stuchlik et al. 1990).

Altingiaceae Lindley 1846

Liquidambar europaea A. Br.

Pl. 1, figs 4–5, Fig. 5: 1–9

1836. *Liquidambar europaea* A. Br.; Braun in Buckland, p. 513

Material. KRAM-P 199/30_1, 69_3, 101+154_3, 119_5, 132, 176, 205+206, (207+209) and 210, 208+216_1, 273_1, 280_1+281_1 – eleven specimens (five with twin impressions)

Description. Leaves lobed, petiole partly preserved in one specimen, 1.3 cm long. Lobes narrowly ovate to narrow-oblong, with strongly attenuate apex, and narrowed at base; lobe width 0.7 to about 2.5 cm, terminal lobes wider than the rest. Blade base weakly cordate. Leaf margin regularly uniserrate. Teeth glandular, short, rounded at apex, 0.2–0.8 mm high, 1.0–3.0 mm wide at base; sinuses angular. Upper margins of teeth very short, lower margins longer, straight to slightly convex or concave.

Venation actinodromous. The number of primary veins is equal to the number of lobes, all arising from a single point at the extreme base of the leaf. In three specimens the primary vein of the basal lobe departs suprabasally from the abmedial side of the primary vein of the superadjacent lateral lobe. Primary veins of moderate thickness, terminating in the lobe apices; the veins running into the lateral lobes are somewhat thinner than the primary veins of the terminal lobes and deflected, arching abmedially. The angle between the primary veins of the terminal and adjacent lateral lobes amounts to (33°–) 40°–52°, while the angle between the primary veins of the terminal and basal lobes is 80°–90°. The venation in the lobes is semicraspedodromous. Secondary veins are curved abruptly upwards, distributed alternately at irregular intervals; they diverge from the primary vein at an acute angle of 35°–60°. Near the leaf margin these veins join together by means of loops or a series of loops, from which fine veins depart towards the teeth. Intersecondary veins are present between the secondaries. Tertiary veins are percurrent or forked. Venation of higher orders is randomly oriented.

Remarks. These fragmentary leaves have been assigned to *Liquidambar europaea* A. Br., the species very commonly occurring in the Tertiary floras of Europe, on the basis of the characteristic serration of the leaf margins, the shape of the lobes and the venation features. This species comprises both five- and three-lobed leaves (Menzel 1906; Meyer 1919; Kutuzkina 1964; Kolakovsky 1964; Bůžek 1971; Christensen 1976; Kovar-Eder 1988). Some authors (Gothan & Sapper 1933; Andreánszky & Novak 1957) have described the taxon with three-lobed leaves as a separate species. A study carried out by Bůžek (1971) on abundant material from several European localities showed that the ratio of three- to five-lobed leaves of *L. europaea* was gradually changing. The three-lobed leaves prevailed decidedly in the Early Miocene, whereas the five-lobes ones were much rarer; in the Late Miocene the five-lobed leaves became more numerous and in the Pliocene absolutely dominant.

Seven specimens from Gnojna are fragments of five-lobed leaves, the remaining ones are fragments of one or two lobes of which two (KRAM-P 199/273_1, 280_1+281_1; Pl. 1, fig. 5, Fig. 5: 9) probably also belonged to five-lobed leaves, while the fragmentary state of the other two (KRAM-P 199/30_1, 132; Fig. 5: 4) makes it impossible to decide whether they belonged to three- or five-lobed leaves.

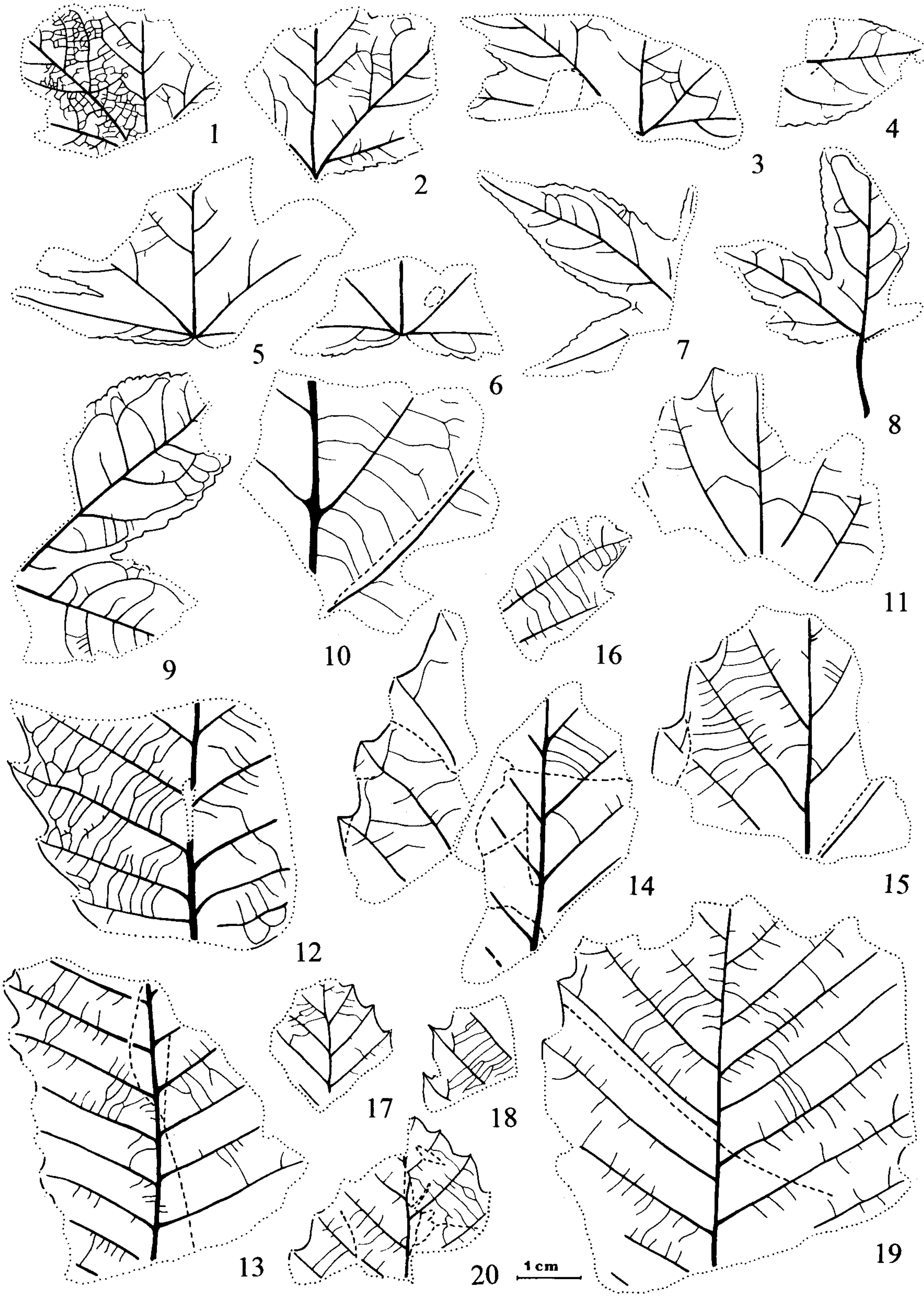

Fig. 5. **1–9** – *Liquidambar europaea* A. Br.: 1 – specimen No KRAM-P 199/101, 2 – specimen No KRAM-P 199/154$_3$ (specimens No KRAM-P 199/101 and 199/154$_3$ – twin impressions), 3 – specimen No KRAM-P 199/119$_5$, 4 – specimen No KRAM-P 199/132, 5 – specimen No KRAM-P 199/176, 6 – specimen No KRAM-P 199/206, 7 – specimen No KRAM-P 199/207, 8 – specimen No KRAM-P 199/216$_1$, 9 – specimen No KRAM-P 199/273$_1$; **10–11** – *Platanus leucophylla* (Ung.) Knobloch: 10 – specimen No KRAM-P 199/77, 11 – specimen No KRAM-P 199/240$_2$; **12–20** – *Quercus gigas* Goepp. emend. Walther & Zastawniak: 12 – specimen No MZ.VII/71/29, 13 – specimen No MZ.VII/71/36, 14 – specimen No KRAM-P 199/17 and 199/19, 15 – specimen No KRAM-P 199/18, 16 – specimen No KRAM-P 199/90$_1$, 17 – specimen No KRAM-P 199/100, 18 – specimen No KRAM-P 199/197, 19 – specimen No KRAM-P 199/240$_1$, 20 – specimen No KRAM-P 199/241$_2$

The five-lobed forms of *L. europaea* A. Br. are mostly comparable with the recent North American species *L. styraciflua* L. (Meyer 1919; Ilinskaya 1964; Knobloch 1969; Bůžek 1971, Zastawniak 1972; Christensen 1976 etc.) showing considerable morphological variability (Makarova 1957) and the leaves with three lobes with the Central American *L. macrophylla* Oerst. (=*L. styraciflua* L. var. *mexicana* Oerst.) (Bůžek 1971; Knobloch & Kvaček 1976).

Occurrence in the fossil floras of Poland. Cf. Hummel (1983), also Bełchatów (Stuchlik et al. 1990).

Platanaceae Dumortier 1829

Platanus leucophylla (Ung.) Knobloch

Pl. 1, fig. 6, Fig. 5: 10–11

1850. *Populus leucophylla* Ung.; Unger, p. 417
1971. *Platanus leucophylla* (Ung.) Knobl.; Knobloch, p. 264

Material. KRAM-P 199/77, 240_2 – two specimens

Description. Two fragments of the middle part of a leaf, 4 × 3 cm and 4 × 4 cm. Margin of one of them partly preserved, with two rather large teeth visible; they are 0.85 cm wide at the base and 0.3 cm high, their lower margins being straight and the upper slightly concave. Sinuses between teeth rounded.

The secondary veins, distributed at wide intervals (1.5–1.8 cm), are slightly curved upwards and form an angle of 30°–50° with the midvein. The tertiary veins are distinct, percurrent, simple or forked, often convex, departing at an acute angle from the abmedial side of the secondary veins and at an acute or right angle from their admedial side. Venation of higher orders is not preserved.

Remarks. The characteristically developed marginal teeth of the leaf and its secondary and tertiary venation suggest that the fragments described belonged to *Platanus leucophylla*. The fragmentary state of the specimens does not permit a precise determination of the shape and size of the leaves.

Leaves of *P. leucophylla* were initially commonly described after Goeppert (1855) under the name of *Platanus aceroides* Goepp. (Němejc 1951; Berger 1955a; Grangeon 1958; Knobloch 1963; Ilinskaya 1968 and other authors), then as *P. platanifolia* (Ett.) Knobl. (Knobloch 1969; Zastawniak 1972; Unger 1983). In 1971 Knobloch introduced a new combination, *P. leucophylla*, as a priority one.

P. leucophylla is a frequently found member of the Neogene floras of Europe. It has been reported, among other sites, from the Sarmatian of Moldova (Yakubovskaya 1955); Upper Miocene of Austria: Brunn-Vösendorf and Laaerberg (Berger 1952, 1955a; Kovar-Eder 1988); Greece: Likudi (Knobloch & Velitzelos 1986a); Germany: Massenhausen (Jung 1963), Aubenham (Knobloch 1988); Czech Rep.: Moravska Nova Ves (Knobloch 1969). This fossil species is most often considered to be comparable with the recent *P. occidentalis* L., growing in North America.

Occurrence in the fossil floras of Poland. Cf. Zastawniak 1972, 1980; also Bełchatów (Stuchlik et al. 1990), Stare Bystre (Worobiec 1994).

Fagaceae Dumortier 1829

Quercus gigas Goepp. emend. Walther & Zastawniak

Pl. 1, figs 7–9a, Pl. 2, figs 1–2, Fig. 5: 12–20

1855. *Quercus gigas* Goepp.; Goeppert, p. 16, Pl. 8 fig. 2
1991. *Quercus gigas* Goepp. emend. Walther & Zastawniak; Walther & Zastawniak, p. 160, Pl. 4, figs 1–3; Pl. 5, 6; Pl. 7, figs 1–3; Pl. 8–10; Figs 3–7

Material. MZ.VII/71/18, 29, 36; KRAM-P 199/4, 15, 17 and 19, 18, (?)22, 40_1, 53, 82, 90_1, 91, 100, (?)135, 197, 239_1+240_1, 241_2, 278 – nineteen specimens (one with twin impression)

Description. Leaves ovate to narrowly elliptic, about 2.0–7.0 cm in width and about 6.0–12.0 or 13.0 cm long. Apex, partly preserved in one specimen, probably acute; leaf base rounded or weakly cordate. Leaf margins uniserrate, entire at base. Teeth large, 1.5–3.5 mm in hight and about 1.0 cm wide at base, or somewhat smaller, oriented forwards and sometimes provided with awn-like endings 0.5–1.5 mm long. Upper margins of teeth mostly concave, sometimes straight; lower considerably longer, convex or acuminate, sometimes straight. Apical angle of teeth obtuse, right or acute. Smaller additional teeth occasionally present, arising from the abmedial branches of the secondary veins. Sinuses between teeth rounded.

Venation simple craspedodromous. Midvein stout or moderately so, straight or slightly bent, tapering towards the leaf apex. Secondary veins, alternate, opposite or sub-opposite, mainly straight, in some leaves recurved or slightly bending in an arc. They are distributed at intervals of 0.55–1.3 cm in larger leaves and about 0.35 cm in smaller ones, while their angles of divergence from the midvein range from 32°–63°, diminishing towards the leaf apex; close to the leaf base this angle is approximately right. The tertiary veins are percurrent, simple or forked, sometimes irregularly branched, perpendicular or oblique to the secondary veins. Five to seven tertiary veins fall in a 1 cm segment of a secondary vein. Near the leaf margin some veins often arise on the admedial side of secondary veins and extend slantingly upwards, sub-parallel to the sinuses between the teeth. These veins are initially fairly distinct, then they join with the veins originating on the abmedial side of the adjacent secondary veins, forming loops. In one specimen with a preserved leaf base there are veins departing from the basal veins and joining together in a series of loops within the base itself. Veins of higher orders form a rectangular reticulum.

Remarks. The leaves described belong to the fossil species *Quercus gigas* Goepp. emend. Walther & Zastawniak. It was described for the first time by Goeppert (1855) from the flora of Sośnica. Carrying out a revision of the family Fagaceae on the basis of Goeppert's (1852, 1855) original collection and a new assemblage from Sośnica, Walther and Zastawniak (1991) supplied Goeppert's diagnosis with a description of anatomical characteristics and supported the assignment of these leaves to the genus *Quercus*. Earlier, the leaves of *Q. gigas* had sometimes been identified as *Castanea gigas* (Goepp.) Ilinskaya (Ilinskaya 1980, 1982; Shvareva 1989). According to Walther and Zastawniak (1991), leaves from many Neogene sites of Europe, described as *Q. pontica miocenica* Kubát, *Q. kubinyi* (Kov.) Berger, *Q. czeczottiae* Hummel, *Castanea atavia* Ung. etc. belong to *Q. gigas*.

Leaves of *Q. gigas* are comparable with modern species of oak from the section *Cerris* Oerst. (Hummel 1983; Walther & Zastawniak 1991).

Occurrence in the fossil floras of Poland. Cf. Walther & Zastawniak 1991.

Betulaceae S. F. Gray 1821

Betula macrophylla (Goepp.) Heer

Pl. 2, figs 6–6a, Fig. 6: 1–3

1855. *Alnus macrophylla* Goepp.; Goeppert, p. 12, Pl. 4, fig. 6; Pl. 5, fig. 1

1868. *Betula macrophylla* (Goepp.) Heer; Heer, p. 416

Material. MZ.VII/71/32$_2$, 35; KRAM-P 199/20$_2$, 121, 167, 179 – six specimens

Description. Leaves broadly ovate with cordate base, about 2.0–4.5 cm long; greatest width 1.7–3.3 cm. One specimen with petiole 0.55 cm long. Leaf margins damaged. Teeth of variable size visible in places; primary teeth 1.6–2.0 mm wide at the base and 0.5–1.8 mm high, occasionally with an additional tooth present on the basal side. Somewhat smaller secondary teeth, 1.5–2.0 mm wide at the base and up to 0.8 mm high, occur between the primary teeth.

Venation simple craspedodromous. Midvein sinuous or straight, weak. Secondary veins, 8 pairs in a specimen preserved nearly whole, distributed at intervals of 0.2–0.7 cm; the intervals being somewhat smaller at the leaf base. The secondary veins diverge from the midvein at angles of 35°–60°, which decrease gradually towards the leaf apex. The lowest pair of secondary veins is visible in specimens with the base preserved: they depart at nearly a right angle and arch downwards. In the basal part of the leaf the secondary veins are opposite, in the middle and apical parts alternate. Close to the leaf margins the secondary veins send off distinct outer veins, which terminate in the marginal teeth. Tertiaries percurrent, mostly forked, oblique in relation to the midvein. Venation of higher orders rectangularly to randomly reticulate.

Remarks. The leaves of *Betula macrophylla* (Goepp.) Heer are characterized by their ovate-orbicular shape; they are widest in the lower half of the blade and taper gradually towards the apex. Base rounded to cordate, apex acute or acuminate; 8–10 pairs of almost straight secondary veins depart from the midvein; at the base they bend downwards and send outer veins towards the leaf margin (Reimann 1919).

The leaves of *B. macrophylla* were first described by Goeppert as *Alnus macrophylla* Goepp. from Sośnica in 1855. Heer (1868) included the leaves described by Goeppert in the genus *Betula* and, at the same time, acknow-

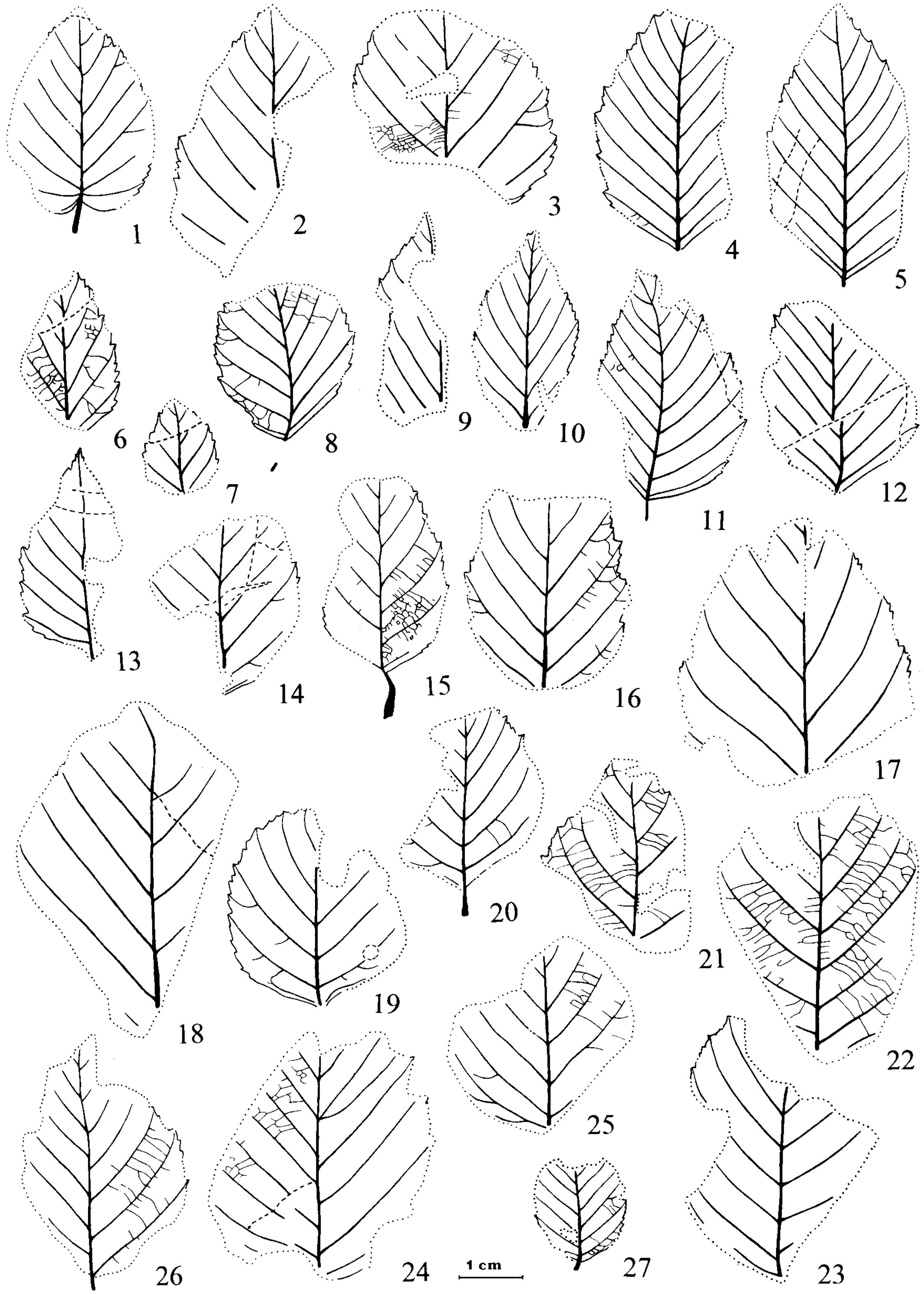

Fig. 6. 1–3 – *Betula macrophylla* (Goepp.) Heer: 1 – specimen No MZ.VII/71/35, 2 – specimen No KRAM-P 199/121, 3 – specimen No KRAM-P 199/167; **4–13** – *Betula subpubescens* Goepp.: 4 – specimen No MZ.VII/71/4, 5 – specimen No MZ.VII/71/17, 6 – specimen No MZ.VII/71/34$_2$, 7 – specimen No KRAM-P 199/119$_4$, 8 – specimen No KRAM-P 199/122, 9 – specimen No KRAM-P 199/148, 10 – specimen No KRAM-P 199/247$_3$, 11 – specimen No KRAM-P 199/250, 12 – specimen No KRAM-P 199/263$_2$, 13 – specimen No KRAM-P 199/277$_2$; **14–16** – *Betula* cf. *subpubescens* Goepp.: 14 – specimen No KRAM-P 199/129$_2$, 15 – specimen No KRAM-P 199/147, 16 – specimen No KRAM-P 199/242; **17** – *Alnus menzelii* Ran.-Bobr. – specimen No MZ.VII/71/2$_2$; **18–27** – *Alnus rotundata* Goepp.: 18 – specimen No MZ.VII/71/16, 19 – specimen No KRAM-P 199/28, 20 – specimen No KRAM-P 199/30$_2$, 21 – specimen No KRAM-P 199/133, 22 – specimen No KRAM-P 199/139, 23 – specimen No KRAM-P 199/142 (specimens No KRAM-P 199/139 and 199/142 – twin impressions), 24 – specimen No KRAM-P 199/203, 25 – specimen No KRAM-P 199/224, 26 – specimen No KRAM-P 199/257$_1$, 27 – specimen No KRAM-P 199/258

ledged them to be identical with leaves he had described from Iceland (Heer 1868, Pl. XXV, figs 11–19) as *Betula macrophylla* Heer, although these last have sharply serrated margins. Later, leaves of the same type from different sites were, following Heer, referred to *B. macrophylla* Heer, thus acknowledging that the leaves from Iceland and Sośnica represented one and the same species (Grangeon 1958; Krishtofovich & Baikovskaya 1965 and other authors) or they were regarded as a separate species and named *Betula macrophylla* (Goepp.) Heer (Kräusel 1938; Berger 1955a; Ilinskaya 1968; Sitár 1969 etc.).

The impressions of leaves from Gnojna differ from the type of *B. macrophylla* (Goepp.) Heer from Sośnica (Goeppert 1855, Pl. IV, fig. 6; Pl. V, fig. 1) in their smaller size and more distinctly cordate base, whereas they are very similar to the leaves of *B. macrophylla* (Goepp.) Heer from other sites: Zielona Góra, Warzęgowo, Strupina (Reimann 1919, Pl. 1, figs 1, 2, 4, 7, 8; Pl. 2, figs 13, 15); from the Late Pannonian and post-Pannonian floras of Transcarpathia (Ilinskaya 1968, Pl. XLVII, fig. 4) and from the Sarmatian flora of the Turciansky Basin in Slovakia (Sitár 1969, Pl. XXXI, fig. 2).

Betula macrophylla (Goepp.) Heer is for the most part considered comparable with the recent *Betula papyrifera* Marsh. (Reimann 1919; Kräusel 1920; Němejc 1949; Berger 1955a) growing in North America and, less frequently, with *B. lenta* L. (Ilinskaya 1968) occurring in the eastern part of North America.

Occurrence in the fossil floras of Poland. Sośnica (under the name *Alnus macrophylla* Goepp. – Goeppert 1855 and as *Betula macrophylla* /Goepp./ Heer – Reimann 1919; Kräusel 1920); Pierusza, Wyszonowice, Stróża, Warzęgowo, Strupina, Zielona Góra (Kräusel 1920).

The leaves described as *B. macrophylla* (Goepp.) Heer from Dobrzyń (Kownas 1956) belong to *Alnus menzelii* Ran.-Bobr. (Hummel 1991).

Betula subpubescens Goepp.

Pl. 2, figs 7–7a, Fig. 6: 4–13

1855. *Betula subpubescens* Goepp.; Goeppert, p. 11, Pl. 3, fig. 9

Material. MZ.VII/71/4, 17, 34_2; KRAM-P 199/87_1, 119_3+122, 119_4, 141_2, 148, 154_2, 169_2, 180, 247_3+248, 250, 263_2, 263_3, 277_2 – sixteen specimens (two with twin impressions)

Description. Leaves ovate, narrowly ovate, or more rarely elliptic (two specimens), (1.3–) 1.7–3.0 cm wide and (2.0–) 3.0–5.0 cm long. Petioles preserved fragmentarily in three specimens, to about 0.5 cm in length. Leaf base broadly cuneate, less frequently narrow-cuneate, apex probably acute, acuminate or attenuate. Leaf margins doubly serrate, entire at base. Primary teeth, at ends of secondary veins, somewhat acute, 0.5–1.3 mm high and 1.0–3.0 mm wide at the base. Margins of teeth mostly acuminate, 1, 2 and, more rarely, 3 or 4 finer toothlets present between the primary teeth. Sinuses between teeth angular.

Venation simple craspedodromous. Midvein straight or gently curved, of moderate thickness. 7–10 pairs of secondary veins can be seen in four nearly complete specimens, their largest number probably reaching 11 pairs. Secondary veins straight or slightly curved, opposite in the basal part of the leaf, opposite or alternate apically. The lowest pair of secondary veins extend parallel to the leaf base. The intervals between the secondary veins are 0.25–0.60 cm, most frequently 0.30–0.45 cm; the angle of divergence of the secondaries from the midvein ranges from (20°–) 30°–55° (–65°), diminishing towards the leaf apex. Veins of third order percurrent, simple or forked; venation of higher orders randomly reticulate.

Remarks. The specimens described correspond to the species *Betula subpubescens* Goepp. described for the first time from Sośnica (Goeppert 1855) and often found in the Neogene floras of Europe.

The leaves from Gnojna are characterized by the relatively large number of fairly densely distributed secondary veins (probably up to 11 pairs). Similar leaves were described by Kovar-Eder (1988) from the Late Miocene of Lohnsburg. Generally, however, this species has a somewhat smaller number of pairs of secondary veins, e.g. 9–10 (Pimenova 1954), 7–8 (–10) (Yarmolenko & Grubov 1956), c. 9 (Zastawniak 1980), 7 (Shvareva 1983) and 6–7 (–9) (Knobloch 1986b).

Two specimens from Gnojna: a pair of twin impressions (KRAM-P 199/247_3+248; Fig. 6: 10), and a specimen in a very poor state of preservation (KRAM-P 199/141_2), are distinguished by their leaf blades being narrower than in the remaining specimens, elliptic in shape narrow-cuneate at base, attenuate at apex and by the presence of seven pairs of secondary veins departing at an angle of 20°–42°, while in other specimens this angle is greater and ranges between 30° and 55° (–65°). The main teeth at the leaf margin (KRAM-P 199/247$_3$+248) have straight or slightly concave upper margins and concave or nearly straight lower margins. Finer teeth, up to four in number, occurring between the main teeth, have their upper and lower margins approximately straight. In the other leaves of *B. subpubescens* the margins of the teeth are mostly acuminate. In their leaf shape, leaf bases and apices, these specimens resemble the leaves described by Saporta (1867, Pl. V, figs 3, 3a, p. 159; 1891–1892) as *Betula elliptica* Sap. from the Tertiary flora of Bois d'Asson and Monosque (France), but they differ in their smaller dimensions and the somewhat different shape of teeth. Probably both specimens from Gnojna lie within the range of morphological variation of the fossil birch species *B. subpubescens*. As in other members of the family Betulaceae, the genus *Betula* exhibits a great variety of forms which occur among the leaves of one tree and even one twig (Schimper & Schenk 1890; Reimann 1919).

Betula subpubescens is comparable with several present-day birch species: *B. pubescens* Ehrh. (Reimann 1919; Yarmolenko & Grubov 1956; Kolakovsky 1964; Němejc 1949; Hummel 1991), occurring in Central Europe and Siberia (Krüssmann 1976), with the East-Asiatic *B. davurica* Pall. (Zastawniak 1980) and *B. schmidtii* Regel (Hummel 1991); some authors also consider *B. subpubescens* Goepp. to be comparable with *B. utilis* D. Don (Mädler 1939) growing at an altitude of 3000–4000 m in the Himalayas in Central Asia (Sokolov 1951) and with *B. verrucosa* Ehrh. (Němejc 1949) present in Europe and Asia Minor. The leaves from Gnojna seem most to resemble the recent Asiatic species *B. schmidtii* Regel and *B. utilis* D. Don.

Occurrence in the fossil floras of Poland. Sośnica (Goeppert 1855), Brzeg Dolny (Reimann 1919), Snicz (Biernat 1964), Młyny (Zastawniak 1980), Ruszów (Hummel 1991), Gozdnica (Dyjor et al. 1992).

Betula cf. ***subpubescens*** Goepp.

Fig. 6: 14–16

Material. KRAM-P 199/129$_2$, 146+147, 242, 273$_3$ – four specimens (one with twin impression)

Description. Leaves oblong-ovate to narrowly ovate, about 3.0 cm wide and probably 3.5–4-5 cm long. One specimen with an 8 mm-long petiole. Leaf base cuneate, apex not preserved in any specimen. Leaf margins doubly serrate. Primary teeth with acuminate or straight margins, at the ends of secondary veins. Secondary teeth smaller, 1–3 between consecutive primary teeth.

Venation simple craspedodromous. Midvein of moderate thickness, straight, in one specimen slightly sinuous. Secondary veins, 7–8 pairs, nearly straight or slightly curved, diverging from the midvein at an angle of 30°–57° at intervals of (0.3–) 0.4–0.75 cm. Tertiaries percurrent, forked or simple, oblique in relation to the midvein. With the secondary veins they form an obtuse angle on the abmedial side and a right or obtuse angle on the admedial side. Venation of higher orders is randomly reticulate.

Remarks. These leaves are most closely related to those of *B. subpubescens* Goepp. from which they differ in possessing fewer and more widely spaced secondary veins and having less acute teeth at the leaf margin. Similar leaves were often assigned to *Betula prisca* Ett. (Heer 1868, 1869; Knobloch 1980, 1990) and to *B. subpubescens* (Menzel 1906; Jung 1963).

Alnus menzelii Ran.-Bobr.

Pl. 2, figs 8–8a, Fig. 6: 17

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

Material: MZ.VII/71/1$_2$+2$_2$ – a pair of twin impressions

Description. Fragment consisting of middle and apical parts of leaf, probably ovate in shape. Size of fragment: 3.8 × 4.5 cm; leaf length supposedly about 6.0 cm. Apex and base not preserved. Leaf margin doubly serrate, primary teeth with acuminate or almost straight lower margin and acuminate or convex upper margin. Tooth width at the base 1.3–2.7 mm, height about 1.0 mm; tooth apices blunt. Additional teeth present on the lower or, more rarely, upper margins of teeth. Between two adjacent primary teeth on the preserved fragment of the leaf margin there are 5–6 somewhat smaller secondary teeth, 1.0–2.0 mm wide at the base and 0.5–0.8 mm high. The upper margins of the secondary teeth are short, almost straight, the lower margins longer, convex, often with additional toothlets. Sinuses between the teeth angular.

Venation simple craspedodromous. Midvein straight, weak. Seven secondary veins occur on one side of the midvein and four on the other. They are distributed 0.7–0.8 cm apart, nearly opposite in the middle part of the leaf and alternate in the apical part, and terminate in the apices of the primary teeth. The secondary veins leave the midvein at 32°–46°, the angle decreasing towards the leaf apex. The outer veins supplying the secondary teeth are indistinct. The tertiaries are thin, percurrent and arise on the admedial and abmedial sides of the secondaries at approximately right angles; they are frequently forked. Venation of higher orders is rectangularly reticulate with well developed areoles.

Remarks. *Alnus menzelii* Ran.-Bobr. was described by Raniecka-Bobrowska (1954) from the Miocene of Konin. As characteristic features of this species Raniecka-Bobrowska mentions the ovate leaves, cordate at base, with shortly acuminate apex, secondary veins exceeding 9 pairs in number, the basal veins departing from the midvein at 90° or slightly more, the not numerous outer branches of the secondary veins and the doubly serrate leaf margins. The leaf fragment from Gnojna matches the specimens from Konin well. The leaf shape and size are similar, as are the configuration of the margins and the characteristics of the venation (among others the somewhat indistinct, not numerous outer veins). The missing basal part of the leaf makes it impossible to determine whether the characteristic arrangement of the lowest pair of secondary veins is present in the Gnojna specimen. A very similar leaf was described from the Miocene of Senftenberg (Menzel 1906, Pl. II, fig. 8) as that of *Alnus rotundata* Goepp.. The leaves of *A. rotundata* from Gnojna differ in shape (they are mostly broadly obovate or broadly elliptic), in their non-indented margins, their differently shaped teeth and the venation of the second and higher orders.

Alnus menzelii is comparable with *Alnus subcordata* C. A. Mey. (Caucasus Mts, Iran) and *A. serrulata* (Ait.) Willd. (eastern states of the USA) (Raniecka-Bobrowska 1954; Hummel 1991).

Occurrence in the fossil floras of Poland. Konin (Raniecka-Bobrowska 1954), Koronowo (as *Corylus Mac Quarrii* Forbes, Menzel 1910), Ruszów (Hummel 1991), Bełchatów (Stuchlik et al. 1990). According to Hummel, the leaves from Dobrzyń, identified as *Betula macrophylla* (Goepp.) Heer (Kownas 1956), belong to *Alnus menzelii* Ran.-Bobr..

Alnus rotundata Goepp.

Pl. 3, figs 1–3a, Fig. 6: 18–27

1855. *Alnus rotundata* Goepp.; Goeppert, p. 12, Pl. 4, fig. 4

Material. MZ.VII/71/13, 16, 23; KRAM-P 199/28, 30_2, 123, 133, 139+142, 140_2, 145_2, (?)159, 203+204, 224, 257_1, 254+258 – fifteen specimens (three with twin impressions)

Description. Fragmentary leaves, (1.5–) 2.7–5.5 cm long and (1.4–) 1.9–3.8 cm wide. Presumed length of whole leaves (2.2–) 3.5–6.5 cm; width (1.5–) 2.8–4.5 cm. Leaves broadly obovate, broadly elliptic or suborbicular in outline. Petioles, approximately 0.6 cm long, preserved in two specimens. Leaf base broadly cuneate, apex probably acute or acuminate, in one specimen supposedly emarginate. Leaf margins doubly serrate, in most specimens damaged. Teeth fairly fine, acute, those of the first order 1.3–3.0 mm wide at the base and 0.8–2.0 mm high; upper margins of teeth acuminate, nearly straight or more rarely concave, lower margins acuminate or concave. Teeth of second order smaller, (0.9–) 1.4–2.1 mm wide at base and 0.4–0.8 mm high, with straight or concave upper margins and longer concave or acuminate, more rarely straight lower margins. Sinuses between the teeth angular.

Venation simple craspedodromous, secondary veins terminating in the apices of the primary teeth. Midvein straight, mostly of moderate thickness. Secondary veins, from 5 to probably 8 or 9 pairs, curved or straight, opposite, sub-opposite or alternate. They depart from the midvein at intervals of 0.30–0.90 cm, most frequently 0.45–0.55 cm, at an angle of 30°–60° (–68°), which increases towards the leaf base. (In a small leaf the intervals between the secondary veins were only 0.12–0.25 cm). Tertiary veins percurrent, straight, in some cases forked, prominent, arranged obliquely in relation to the midvein. They originate, on the abmedial side of the secondary veins, mostly at an acute angle and on the admedial side at a right or acute angle. Close to the leaf margin (particularly in the apical part of the leaf) the tertiary veins are slightly curved and delicate veins run from the point of curvature towards the secondary teeth. In the basal parts of leaves the tertiaries form loops, from which arise veins supplying the secondary teeth.

Remarks. The leaf fragments from Gnojna correspond to the leaves described from Sośnica as *Alnus rotundata* Goepp. (Goeppert 1855). They have similar venation, the same angle of divergence of the secondary veins and density of distribution and leaf shape and serration of margins. The holotype of *A. rotundata* has been lost and only its twin impression has survived (Reimann 1919).

According to Reimann (1919), *A. rotundata* combines characters of two genera: *Alnus* and *Betula*. Němejc (1949), too, wrote about the difficulty in determining leaves of this type because of their great similarity to the leaves of *Betula* and even *Carpinus*. That they belong in *Alnus* is suggested by such characters as their rounded shape, doubly serrate margin with acute teeth, and the number, distribution and course of the secondary veins. With regard to recent species of *Alnus*, according to Reimann (1919), *Alnus rotundata* is most closely related to *A. alnobetula* Hartig (= *A. viridis* /Chaix/ DC.) and *A. incana* (L.) Moench; on the other hand, it is also similar to the fossil species *Betula macrophylla* (Goepp.) Heer. Němejc (1949) compares the fossil leaves to the recent leaves of *A. alnobetula* Hartig, *A. incana* (L.) Moench and *A. rugosa* (DuRoi) Spreng.

The leaf impressions from Gnojna are most closely related to *A. rugosa* (DuRoi) Spreng., growing in the eastern part of North America (Pl. 3, fig. 4).

Occurrence in the fossil floras of Poland. Sośnica (Goeppert 1855, Reimann 1919, Kräusel 1920); Trzebnica, Brzeg Dolny-Kręsko (Kräusel 1920); Dobrzyń on the Vistula (Kownas 1956). The leaves of *A. rotundata* were also described by Raniecka-Bobrowska (1954) from the Miocene of Konin. In Hummel's (1991) opinion, they are wrongly determined, for they differ from the type species in the kind of serration of the leaf margins (margin weakly crenate). A similar configuration of leaf margins occurs in the remains from Koronowo, identified also as *A. rotundata* Goepp. (Menzel 1910).

Alnus sp. 1

Fig. 7: 1–2

Material. KRAM-P 199/75+76, 260 – two specimens (one with twin impression)

Description. Fragments of basal and middle parts of two leaves measuring 2.8 × 4.2 cm and 2.5 × 3.2 cm. Presumed width of leaves 4.5–5.0 cm, probably broadly oblong or ovate. Petiole 1.3 cm long. Base rounded, leaf margins damaged, a few teeth preserved fragmentarily.

Venation simple craspedodromous. Midvein straight. Secondary veins almost straight. A pair of basal veins depart from the midvein at a greater angle than do the remaining secondary veins (71°, 80°). In the middle part of the leaf this angle is 35°–45° and it decreases towards the leaf apex. The intervals between the secondary veins in the middle part of the leaf are fairly large, 0.65–1.25 cm, being smaller close to the leaf base, 0.25–0.50 cm. In the proximity of the leaf margin the secondary veins give off outer veins. Tertiary veins percurrent, often forked, perpendicular or oblique to the secondary veins. Venation of higher orders rectangularly reticulate, areoles well developed.

Remarks. The leaf fragments described belong to the genus *Alnus*, as indicated by the general leaf type, the arrangement of the veins, the presence of teeth on the leaf margins and the shape of the leaf base. In some respects (rounded base, fairly large intervals between secondary veins, basal veins nearly perpendicular to the midvein, arrangement of tertiaries) the remains from Gnojna resemble the leaves often described in the literature under the name *Alnus kefersteini* (Goepp.) Ung. (Unger 1847; Heer 1856; Ettingshausen 1866; Andreánszky 1959; Krishtofovich & Baikovskaya 1965). This name is unfounded, for the type specimens of the species *Alnites kefersteini* Goepp. are cones of *Alnus* (Goeppert 1836, Pl. XLI, figs 1–19) but Unger (1845), also described a leaf fragment under the name *Alnus kefersteini* (Goepp.) Ung. but presented no evidence that the fruits and leaves belonged to the same species of fossil alder.

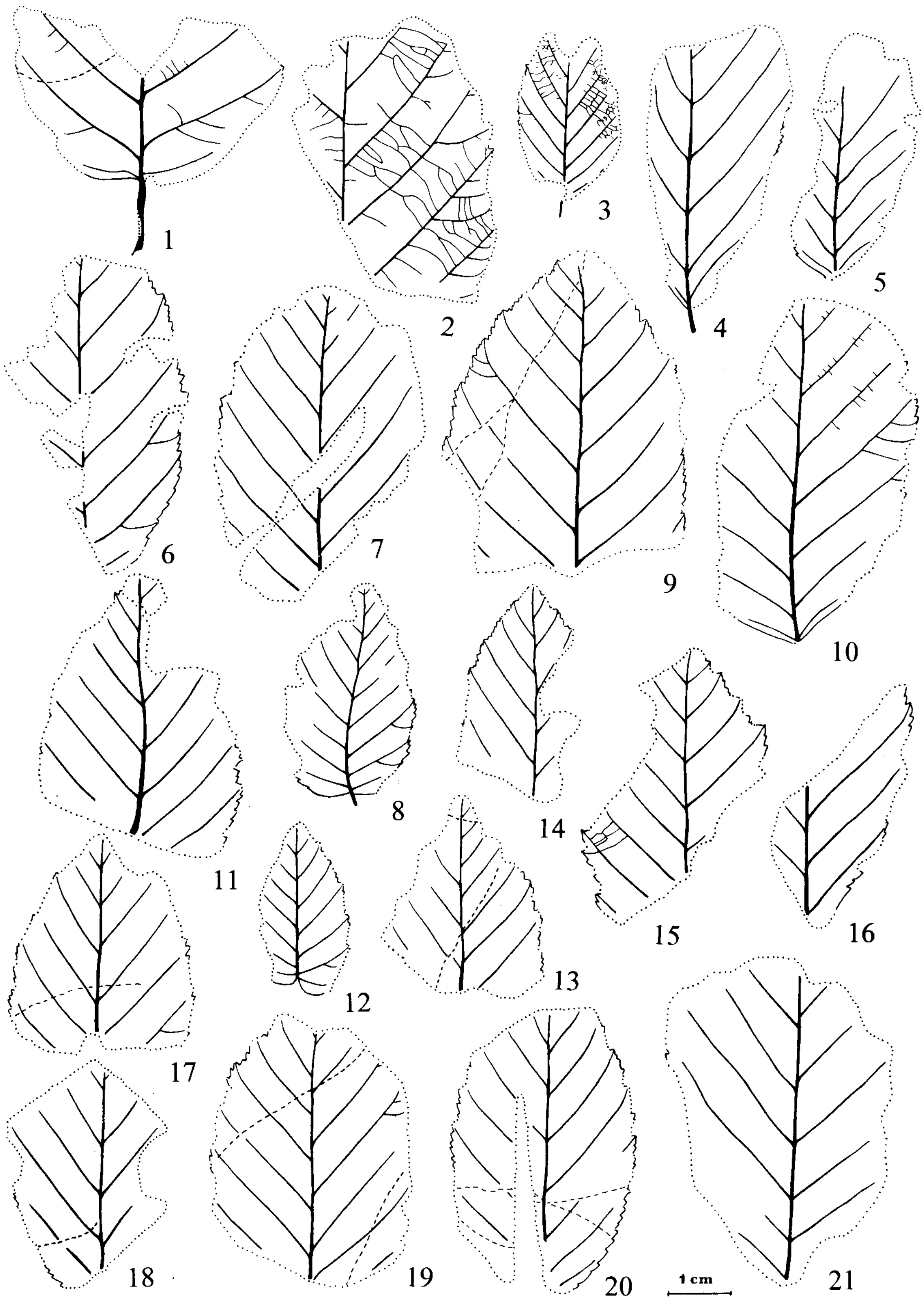

Fig. 7. 1–2 – *Alnus* sp. 1: 1 – specimen No KRAM-P 199/76, 2 – specimen No KRAM-P 199/260; **3** – *Alnus* sp. 2 – specimen No KRAM-P 199/253$_2$; **4–21** – *Carpinus grandis* Ung. emend. Heer: 4 – specimen No MZ.VII/71/5, 5 – specimen No MZ.VII/71/30, 6 – specimen No MZ.VII/71/31$_1$, 7 – specimen No MZ.VII/71/31$_2$, 8 – specimen No MZ.VII/71/31$_3$, 9 – specimen No MZ.VII/71/34$_1$, 10 – specimen No KRAM-P 199/60, 11 – specimen No KRAM-P 199/68, 12 – specimen No KRAM-P 199/79, 13 – specimen No KRAM-P 199/93, 14 – specimen No KRAM-P 199/96$_1$, 15 – specimen No KRAM-P 199/108, 16 – specimen No KRAM-P 199/109, 17 – specimen No KRAM-P 199/141$_1$, 18 – specimen No KRAM-P 199/145$_1$, 19 – specimen No KRAM-P 199/170$_2$, 20 – specimen No KRAM-P 199/171$_1$, 21 – specimen No KRAM-P 199/173

Alnus sp. 2

Fig. 7: 3

Material. KRAM-P 199/253_2 – one specimen

Description. Leaf 1.7 cm wide and probably about 3.5 cm long; width greatest about the middle, elliptic – narrowly ovate, base probably cuneate, apex missing. Leaf margin heavily damaged, a small number of teeth varying in size are visible. Teeth supplied by secondary veins, 1.5–2.0 mm wide at base and 0.7 mm high, having short, almost straight upper margins and considerably longer, acuminate lower margins; between the teeth supplied by two neighbouring secondary veins on the preserved fragment of the leaf margin are two finer teeth, about 0.3 mm in width at base and about 0.1 mm in height, with very short, nearly straight upper margins and longer concave lower margins. Apices of teeth acute, upwardly curved, sinuses between the teeth angular.

Venation simple craspedodromous. Midvein straight, moderately thick. Secondary veins straight, alternate, probably 9 pairs in number (5 veins preserved on one side of the midvein and 7 on the other), fairly regularly arranged at intervals of 0.25–0.40 cm. They depart from the midvein at an angle of 28°–43° which decreases towards the leaf apex. Tertiary veins percurrent, frequently forked, half way between neighbouring secondaries, from whose abmedial and admedial sides they arise at almost right or acute angles. Veins of higher orders form a rectangular reticulum, areoles well developed.

Remarks. The type of leaf, its venation and delicate, sharp serration of the leaf margin indicate that the specimen belongs to the genus *Alnus*. A comparison of the specimen from Gnojna with fossil species of *Alnus* shows some similarities with the leaves from the Sarmatian flora of Hungary described as *Alnus rosifolia* Andr. (Andreánszky 1959, Fig. 52). Its leaves are small (5 cm long and 2 cm wide), with about 8 pairs of secondary veins departing at an angle of about 50°; they are oblong, cuneate at base and have margins irregularly serrate-dentate.

Among the present-day species of *Alnus*, very nearly similar leaves occur in the Japanese *A. yasha* Matsum. (=*A. firma* S. & Z. var. *hirtella* Franch. et Sav.). The specimen from Gnojna is somewhat smaller and has fewer secondary veins. The leaves of *A. yasha* have 10–16 pairs of secondary veins, reaching 5–12 cm in length and are characterized by their narrowly ovate to ovate-lanceolate shape (Krüssmann 1976).

Carpinus grandis Ung. emend. Heer

Pl. 2, figs 3–4, Fig. 7: 4–21, Fig. 8: 1–3

1850. *Carpinus grandis* Ung.; Unger, p. 408
1852. *Carpinus grandis* Ung.; Unger, p. 39, Pl. 20, figs 4, 5
1856. *Carpinus grandis* Ung.; Heer, Pl. 71, figs 19b, c-e; Pl. 72, figs 2–11, 14, 16, 17, 19, 20, 22–24; Pl. 73, figs 2–4

Material. MZ.VII/71/3_1, 5, 7, 8, 9, 12, 22_2, 30, 31_1, 31_2, 31_3, 34_1; KRAM-P 199/12, 16, 20_1, 31_1, 31_2+33, 34_2, (?)35_1, 38, 60, 61, 67, 68+69_1, 69_2, 70, 79, 93, 94, 96_1, 97, 106, 108, 109, 110, 114, 118, 138, 140_1, 141_1, 145_1, 170_2, 171_1, 171_2, 171_3, 173, 178, 183_1, 217_2+218, 219+220, 221_1, 231, 232, 240_3, 241_1, 244_1+245, 247_1, 247_2, 259 – fifty-nine specimens (five with twin impressions)

Description. Leaves 1.3–4.5 cm wide and approximately 2.0–9.0 cm long. Petioles 0.35–0.7 cm long, preserved in seven specimens. Larger leaves mostly oblong, broadly oblong, ovate-oblong or, more rarely, elliptic; small leaves ovate or broadly ovate. The base of larger leaves is weakly cordate, rounded, cuneate or more rarely narrowly cuneate, sometimes slightly asymmetric; the base of small leaves is cordate. Leaf apex acute or acuminate; leaf margins finely doubly serrate. Lower margins of primary teeth acuminate or slightly convex, more rarely straight; upper margins mostly straight or slightly acuminate; height of teeth (0.4–) 0.7–1.5 (–1.9) mm, width at base 0.8–3.0 mm. Primary teeth sometimes slightly projecting. Secondary teeth somewhat narrower (width at base 0.9–2.3 mm) and shorter (height 0.2–0.8 mm) than primary teeth; they are supplied by faint outer branches. Upper margins of secondary teeth most frequently straight, sometimes acuminate or slightly convex, lower margins convex, straight to acuminate. Tiny additional teeth are often present on the lower margins of the teeth of the first and second orders and sometimes on the upper margins of the primary teeth. Sinuses between the teeth angular.

Venation simple craspedodromous. Midvein straight, sometimes slightly sinuous, mostly faint. Secondary veins, numbering approximately 9 pairs, depart from the midvein at in-

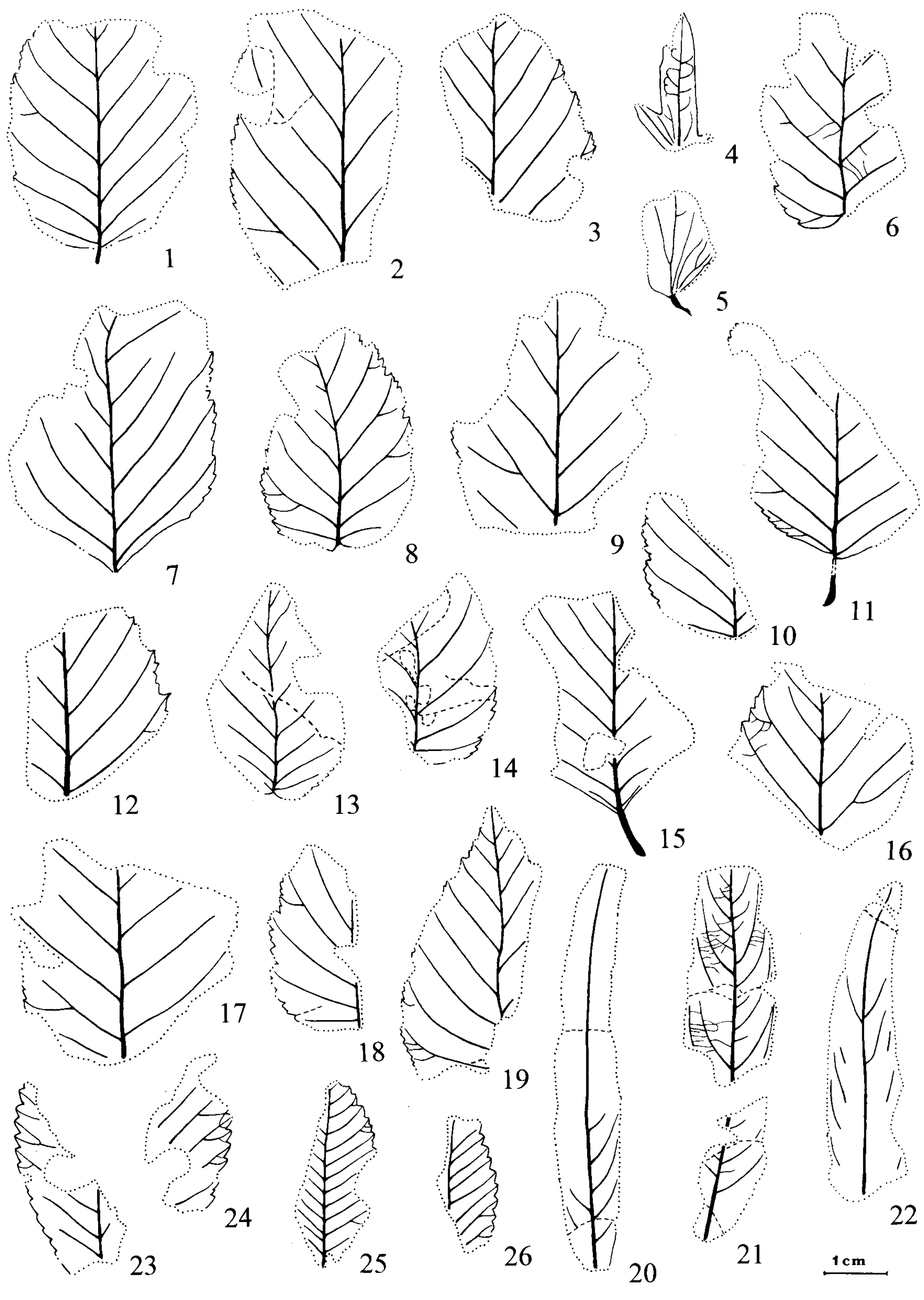

Fig. 8. **1–3** – *Carpinus grandis* Ung. emend. Heer: 1 – specimen No KRAM-P 199/241$_1$, 2 – specimen No KRAM-P 199/244$_1$, 3 – specimen No KRAM-P 199/259; **4** – *Carpinus grandis* Ung. sensu Berger – specimen No KRAM-P 199/275; **5** – *Carpinus parvifolia* (Ett.) Knobloch – specimen No KRAM-P 199/257$_2$; **6–19** – Betulaceae gen. et sp. indet.: 6 – specimen No MZ.VII/71/11, 7 – specimen No MZ.VII/71/20, 8 – specimen No KRAM-P 199/7, 9 – specimen No KRAM-P 199/62, 10 – specimen No KRAM-P 199/80, 11 – specimen No KRAM-P 199/92, 12 – specimen No KRAM-P 199/99, 13 – specimen No KRAM-P 199/119$_6$, 14 – specimen No KRAM-P 199/165, 15 – specimen No KRAM-P 199/172$_2$, 16 – specimen No KRAM-P 199/196, 17 – specimen No KRAM-P 199/223, 18 – specimen No KRAM-P 199/271, 19 – specimen No KRAM-P 199/285; **20–22** – *Salix varians* Goepp.: 20 – specimen No KRAM-P 199/144, 21 – specimen No KRAM-P 199/217$_1$, 22 – specimen No KRAM-P 199/221$_2$; **23–26** – *Ulmus plurinervia* Ung.: 23 – specimen No KRAM-P 199/128$_1$, 24 – specimen No KRAM-P 199/130$_1$ (specimens No KRAM-P 199/128$_1$ and 199/130$_1$ – twin impressions), 25 – specimen No KRAM-P 199/202, 26 – specimen No KRAM-P 199/214

tervals of 0.05–0.45 cm (in small leaves) and 0.35–1.1 cm (in larger ones); close to the leaf base the intervals are usually small (about 0.15 cm). The secondary veins form angles from 30° to 60° with the midvein; in leaves with a cordate base the lower pair of secondary veins depart approximately at right angles and sometimes arch downwards. The secondary veins extend parallel to one another, are straight or nearly straight and, sometimes, before reaching the teeth, they curve slightly upwards. Venation of the third and higher orders very delicate, in most specimens hardly visible. The tertiary veins are percurrent and the veins of higher orders form a regular reticulum with small rectangular areoles.

Remarks. The mostly oblong and ovate-oblong shape of the leaves, cordate or rounded (more rarely cuneate) at base, doubly serrate leaf margins, straight or almost straight secondary veins parallel to one another, delicate venation of the third order, the veins of higher orders forming a regular rectangular reticulum with small areoles – all these characters indicate that the specimens described belong to the genus *Carpinus*. The hornbeam leaves from the Neogene localities of Europe are for the most part included in the collective species *Carpinus grandis* Ung. emend. Heer. Leaves showing considerable morphological variation are often described under this name so it seems probable that this taxon embraces several fossil hornbeam species. The specimens from Gnojna are characterized by a smaller number of secondary veins in comparison with the type *C. grandis* (Unger 1852, Pl. XX, figs 4, 5) and the leaves illustrated by Heer (1856), in which 12–20 pairs of secondary veins are present. The leaves from Gnojna resemble those of *Carpinus grandis* occurring, among others, in the Mio-Pliocene flora of Sośnica (Reimann 1919), in the Miocene floras of Amvrosevka (Pimenova 1954), Erdöbénye (Andreánszky 1959), Čermniky (Bůžek 1971) and Achldorf (Knobloch 1986b) and in the Pliocene flora of Ruszów (Hummel 1991).

The leaves of *C. grandis* from Gnojna show fairly wide variability; a group of leaves (about 15 specimens) can be distinguished among them, which differ from the remaining leaves in their somewhat narrower blade, cuneate or narrowly cuneate base and steeper course of secondary veins, which run at greater distances from one another (mostly 0.7–0.9 cm against 0.5–0.7 cm prevailing in the other leaves). Goeppert (1855, Pl. IV, figs 7–10, p. 19) described similar leaves from the flora of Sośnica under the name *Carpinus ostryoides* Goepp. as a fossil hornbeam species distinct from *C. grandis*. Some authors (Schimper 1870–1872; Heer 1869; Menzel 1906) pointed to another difference between the leaves of *C. grandis* and *C. ostryoides*, namely, the fact that the primary teeth of the latter project more and form small lobes. Goeppert (1855), just as Menzel (1906) did later, considered the leaves of *C. ostryoides* to be comparable with those of the present-day species *C. betulus* L. (to which also *C. grandis* is comparable), at the same time indicating differences between the fossil and recent leaves in the shape of their base. According to Reimann (1919), the differences between *C. grandis* and *C. ostryoides* are not very pronounced. Moreover, the presence of forms with intermediate features creates difficulties in separating these two fossil species from each other. For this reason, Reimann (1919), carrying out a revision of the fossil flora of Sośnica, described both these forms of hornbeam leaves under one name – *C. grandis* Ung.. Leaves of *Carpinus* with projecting primary teeth and well separated secondary veins sometimes found among leaves with more numerous and more densely arranged secondary veins and doubly serrate margins, whose teeth do not form lobes, have also been described as *C. grandis* by other authors (e.g. Berger 1952; Pimenova 1954; Jung 1963).

Carpinus grandis Ung. is most often considered to be comparable with the recent European hornbeam species – *C. betulus* L. (e.g. Heer 1856; Reimann 1919; Berger 1952; Zastawniak 1972; Hummel 1991); some authors also regard the leaves of *C. grandis* Ung. as being comparable with those of other species of *Carpinus*, e.g. *C. orientalis* Mill. (Ilinskaya 1968), growing in south-eastern Europe and Asia Minor, and *C. caucasica* Grossh. (Hummel 1991), occurring in the Caucasus and Asia Minor; Andreánszky (1966) associates *C. grandis* from the Late Oligocene flora of the Eger region with the Japanese *C. japonica* Bl.

Occurrence in the fossil floras of Poland. Cf. Hummel 1991; in addition: Czernica (Raniecka-Bobrowska 1957), Domański Wierch (Zastawniak 1972), Stare Gliwice (Zastawniak 1980), Bełchatów (Stuchlik et al. 1990).

Carpinus grandis Ung. sensu Berger

Pl. 2, figs 5–5a, Fig. 8: 4

1850. *Carpinus grandis* Ung.; Unger p. 408
1953. *Carpinus grandis* Ung. sensu Berger; Berger, p. 14, Figs 5 A-G

Material. KRAM-P 199/275+276_1 – a pair of twin impressions

Description. Fragment of three-lobed fruit involucre; terminal lobe considerably larger (about 2.0 cm long and 0.6 cm wide) than lateral lobes, with rounded apex. Lateral lobes asymmetrical, one of them destroyed; length of free part of preserved lateral lobe about 0.5 cm, width 0.3 cm, lobe apex acute. Involucre base damaged. There is a tooth visible on the partly preserved margin of the terminal lobe, the margin of the lateral lobe being probably entire. Three sharply defined veins run from the involucre base to terminate in the apices of the lobes. Several shorter veins, somewhat thinner, unite with those departing from the midveins. The venation of the second order inside the lobes is brochidodromous; the secondary veins depart from the midveins of the lobes at approximately right angles and join the adjacent veins, forming loops; a delicate vein arising from such a loop runs to the tooth.

Remarks. The morphological features of the specimen described indicate that it belongs to the fossil species *C. grandis* Ung. sensu Berger, comparable with the recent *C. betulus* L. The fruit involucre from Gnojna, like specimens from other fossil sites (Jentys-Szaferowa 1958; Hummel 1991), differs from recent involucres in being somewhat smaller.

Occurrence in the fossil floras of Poland. Sośnica (Goeppert 1855; Reimann 1919), Ruszów (Hummel 1991).

Carpinus parvifolia (Ett.) Knobloch

Fig. 8: 5

1852. *Quercus parvifolia* Ett.; Ettingshausen, p. 6, Pl. 1, fig. 8
1986a. *Carpinus parvifolia* (Ett.) Knobloch; Knobloch, p. 27

Material. KRAM-P 199/257_2 – one specimen

Description. Poorly preserved fragment consisting of lower and middle parts of fruit involucre (1.7 × 1.0 cm), probably asymmetrical, without any lobes developed. Outside of involucre considerably wider than inner; margin destroyed. One distinct midvein runs from the base of the involucre and on the outside there are several thinner veins. Secondary venation invisible. Fragmentarily preserved peduncle about 0.5 cm long.

Remarks. In the Late Miocene flora of Laaerberg, near Vienna, Berger (1953) found many strongly asymmetrical involucres without any lobes formed and included them in the whole group of forms *Carpinus tschonoskii* Maxim.. Among them he distinguished and described 5 new species: *C. vindobonensis*, *C. kisseri*, *C. zabuschi*, *C. knolli* and *C. polzerae*. According to Jentys-Szaferowa (1958), there were no grounds for distinguishing new species, considering the lack of data about the variability of the involucres in the modern species *C. tschonoskii* Maxim. and the species related to it. Jentys-Szaferowa defined involucres of this type as *C.* cf. *tschonoskii* or *C. tschonoskii* aff..

Jung (1966) claimed that the species distinguished by Berger as a matter of fact constitute one species: *C. kisseri* Berger sensu amplo.

Not long ago Knobloch (1986a) found the oldest synonyms of fruit involucres of the type under discussion – *C. parvifolia* (Ett.) Knobl.. He established that the specimen described by Ettingshausen (1852; Pl. I, fig. 8) from the Sarmatian flora of Heiligenkreuz near Kremnitz (Hungary) under the name of *Quercus parvifolia* Ett. is in fact a fruit involucre of *Carpinus*, corresponding to the involucres presented earlier mainly as *C. kisseri* Berger or *C. vindobonensis* Berger.

Occurrence in the fossil floras of Poland. A fruit involucre of *Carpinus* from the group of forms *C. tschonoskii* was described from Kokoszyce (Reimann 1919; Jentys-Szaferowa 1958).

Betulaceae gen. et sp. indet.

Fig. 8: 6–19

Material. MZ.VII/71/3_2, 6_2, 11, 19+20, 21, 33; KRAM-P 199/6_2, 7, 21, 24_2, 54, 62, 80, 92, 96_2, 96_3, 98, 99, 111, 116_2, 119_6, 155, 165, 166_1, 172_2, 175, 187, 190, 196, 223, 237_2, 256, 264_3, 267, 270+271, 285 – thirty-six specimens (two with twin impressions)

Description. Leaves usually ovate, less frequently broadly ovate or broadly oblong, 1.5–

4.0 cm wide and probably from about 2.0 to 6.0–6.5 cm long. Leaf base cordate, weakly cordate or cuneate; apex acute or acuminate. Leaf margin doubly or irregularly serrate. Teeth varying in shape, directed forwards. Primary teeth 0.8–2.5 mm wide at the base and 0.5–1.4 mm high, supplied by secondary veins. Between the primary teeth occur somewhat smaller teeth, 0.3–0.8 mm high and 0.7–2.1 (–3.0) mm wide at the base. In some specimens the margin is slightly emarginate.

Venation simple craspedodromous. Midvein weak or of moderate thickness, straight or slightly curved or sinuous. Secondary veins arched or straight, arising from the midvein at intervals of 0.1–1.0 cm, most frequently 0.4–0.55 cm, at angles of 23°–63° which decrease towards the leaf apex. In specimens with a cordate base the lowest pair of secondary veins form approximate right angles with the midvein; in leaves with a cuneate base the the lowest pair of secondary veins extend parallel to the leaf base. Basal veins, running adjacent to the leaf base and somewhat thinner than the other secondary veins, are visible in some specimens. The tertiary veins are percurrent, the veins of higher orders form a rectangular or random reticulum.

Remarks. The leaf fragments presented show features characteristic of the family Betulaceae. It is impossible to determine their systematic – generic and specific – position more precisely. Leaves of such a morphological structure may occur in *Alnus*, *Betula* and also in *Carpinus*. Attempts to distinguish the leaves of *Betula* from those of *Alnus* are faced with the greatest of difficulties. Various authors were earlier engaged on this problem (e.g. Heer 1856; Schimper & Schenk 1890; Menzel 1906; Němejc 1949; Crane 1981; Hummel 1991). The leaves of *Betula* are generally widest in the lower part of the blade, have a cuneate to truncate base and broad teeth on the margins; on the other hand, the leaves of *Alnus* are mostly wide, attaining their greatest width in the middle or apical part of the blade and their margins are often provided with fine teeth. The number of secondary veins in the leaves of *Alnus* and *Betula* is somewhat smaller than in the leaves of *Carpinus*, being 7–12 (Menzel 1906; Reimann 1919, Němejc 1949). It should be emphasized that there are many exceptions to these rules and, in addition, the leaves show remarkable intraspecific morphological variability (Reimann 1919; Němejc 1949). In some cases an analysis of the venation of higher orders can prove helpful in distinguishing the taxa of the Betulaceae from one another (Hummel 1991).

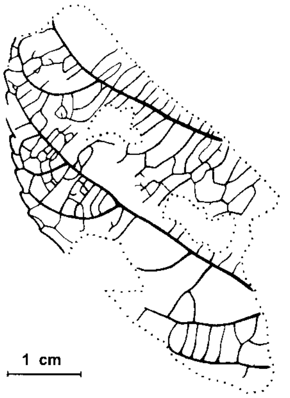

Fig. 9. *Populus* cf. *balsamoides* Goepp., specimen No KRAM-P 199/234

Salicaceae Mirbel 1815
***Populus* cf. *balsamoides* Goepp.**

Pl. 5, figs 3–3a, Fig. 9

Material. KRAM-P 199/234 – one specimen

Description. Fragment of blade of large leaf; fragment size 5.7 × 3.5 cm. Leaf margin serrate. Teeth small, directed forwards, with a very short upper margin and a longer, characteristically curved, convex lower margin. Teeth apices rounded, with traces of the remains of glands apparent. Width of teeth at the base 1.5–3.0 mm; nearer the leaf base the teeth are smaller, shorter and more distant. The specimen shows fragments of two anastomosing secondary veins, from which still more delicate veins anastomose or extend towards the apices of the teeth. Tertiary veins, more or less perpendicular to the secondaries, often forked, are fairly sparsely distributed. Venation of higher orders randomly reticulate.

Remarks. The presence of characteristically developed teeth with traces of glands and the nature of the venation refer the leaf fragment to the genus *Populus*. Most probably it is the species frequent in the Neogene floras of Europe, *Populus balsamoides* Goepp., comparable with the Chinese species *P. lasiocarpa* Oliv. (Ilinskaya 1968; Zastawniak 1972).

Occurrence in the fossil floras of Poland. Cf. Zastawniak 1972; *Populus balsa-*

moides Goepp. has also been described from Bełchatów (Stuchlik et al. 1990).

Salix variants Goepp.

Pl. 5, figs 1–2a, Fig. 8: 20–22

1855. *Salix variants* Goepp.; Goeppert, p. 26, Pl. 19, figs 17, 18; Pl. 20, fig. 1

Material. KRAM-P 199/59, 119_2, 120, (?)128_2+130_2, 144, 217_1, 221_2, (?)225+226, 253_1 – nine specimens (two with twin impressions)

Description. Leaves lanceolate, gradually narrowing towards the apex, 0.75–1.50 cm wide. The length of the best-preserved fragment (without the apical part) is approximately 6.0 cm. One leaf retains a petiole 0.85 cm long and another has a fragmentary petiole 0.6 cm in length. Base cuneate-rounded or rounded. Leaf margins serrate, in most specimens damaged. Teeth very fine, directed forwards, 4–7 teeth in a 0.5 cm length of the margin.

Venation brochidodromous. Midvein slightly curved, stout. Secondary veins arcuate, for the most part running fairly steeply upwards, for some distance parallel to the leaf margin, alternate or, more rarely, opposite. The secondary veins diverge from the midvein at angles of 35°–60°. Intersecondary veins, 1–2 in number, occur between the secondary veins; they depart from the midvein at greater angles than do the secondaries. Close to the leaf margin, from the secondary veins, arise delicate branches which supply the teeth. Tertiary veins percurrent, simple or more rarely, forked, more or less perpendicular to the secondary veins.

Remarks. The species *Salix variants* Goepp. was first described by Goeppert (1855) from Sośnica. Goeppert described additionally several other species of *Salix* (*S. wimmeriana* Goepp., *S. arcuata* Goepp., *S. acutissima* Goepp. and *S. arguta* Goepp.), which later authors recognized as various morphological forms contained within the range of variability of one species, *S. variants* (Heer 1856; Schimper 1870–1872; Menzel 1906; Meyer 1919).

Meyer (1919) also included the species *Salicites dubius* Goepp. from Malczyce (Goeppert 1852) in *Salix variants*, but this specimen is missing.

In the leaves of *Salix variants*, according to various authors there are 6–15 (Ilinskaya 1968), 7–10 (Mai & Walther 1978), 6–7 (Mai & Walther 1988), 3–15 (Meller 1989) teeth per 1 cm of leaf margin and in the specimens from Gnojna about 4–7 teeth per 0.5 cm of margin.

Salix variants Goepp. has been reported from many Tertiary floras of Europe, among others, from the Oligocene of Germany – Haselbach (Mai & Walther 1978) and Kazakhstan (Palibin & Ilinskaya 1956); from the Pannonian of Austria – Brunn-Vösendorf (Berger 1952), Laaerberg (Berger 1955a); the Pannonian and post-Pannonian of Transcarpathia (Ilinskaya 1968); the Pliocene of Abkhazia (Kolakovsky 1964) and Germany – Berga (Mai & Walther 1988).

S. variants Goepp. is comparable with different recent species of *Salix*: e.g. *S. fragilis* L. occurring in Europe and Asia (Meyer 1919; Palibin & Ilinskaya 1956; Zastawniak 1972), the Eurasian *S. triandra* L. (Meyer 1919; Palibin & Ilinskaya 1956) and *S. bonplandiana* H. B. K. growing in Mexico and Guatemala (Mai & Walther 1978, 1988).

Occurrence in the fossil floras of Poland. Cf. Zastawniak 1972; in addition, Bełchatów (Stuchlik et al. 1990)

Ulmaceae Mirbel 1815

Ulmus plurinervia Ung.

Pl. 4, figs 2–3a, Fig. 8: 23–26

1847. *Ulmus plurinervia* Ung.; Unger, p. 95, Pl. 25, figs 1–4

Material. KRAM-P 199/128_1+130_1, 201+202, 214, 216_2, (?)228 – five specimens (two with twin impressions)

Description. Leaves narrowly obovate to narrowly elliptic, tapering towards the base and apex. Measurements of leaf fragments preserved: 2.3 cm long (probable length of leaves up to 5.0 cm) and 0.8–1.4 cm wide (actual width of leaves up to about 3.0 cm). The best-preserved specimen has a slightly asymmetrical base, cuneate on one side of the blade and slightly rounded on the other, apex probably acute, and petiole about 0.3 cm long. Leaf margins serrate-dentate. Teeth with straight to convex sides and mostly blunt apices. Width of teeth at the base 1.7–2.5 mm, height to 1.0 mm. Sometimes a smaller additional tooth is present on the lower side of a tooth; the additional teeth are supplied by the outer branches of secondary veins. Both single teeth and those with additional teeth may occur on one and the same specimen. Sinuses between the teeth angular. Indistinct outer veins reach the sinuses.

Venation simple craspedodromous. Midvein straight, of moderate thickness. Secondary veins fairly numerous, 14 pairs visible in the best-preserved specimen, opposite or nearly opposite, more or less parallel to one another, 0.1–0.3 cm apart. These veins are straight, sometimes gently curved in the apical part of the leaf, often divided in two with the branches entering each of two neighbouring teeth; the secondary veins diverge from the midvein at angles of 45°–55°. Venation of higher orders reticulate.

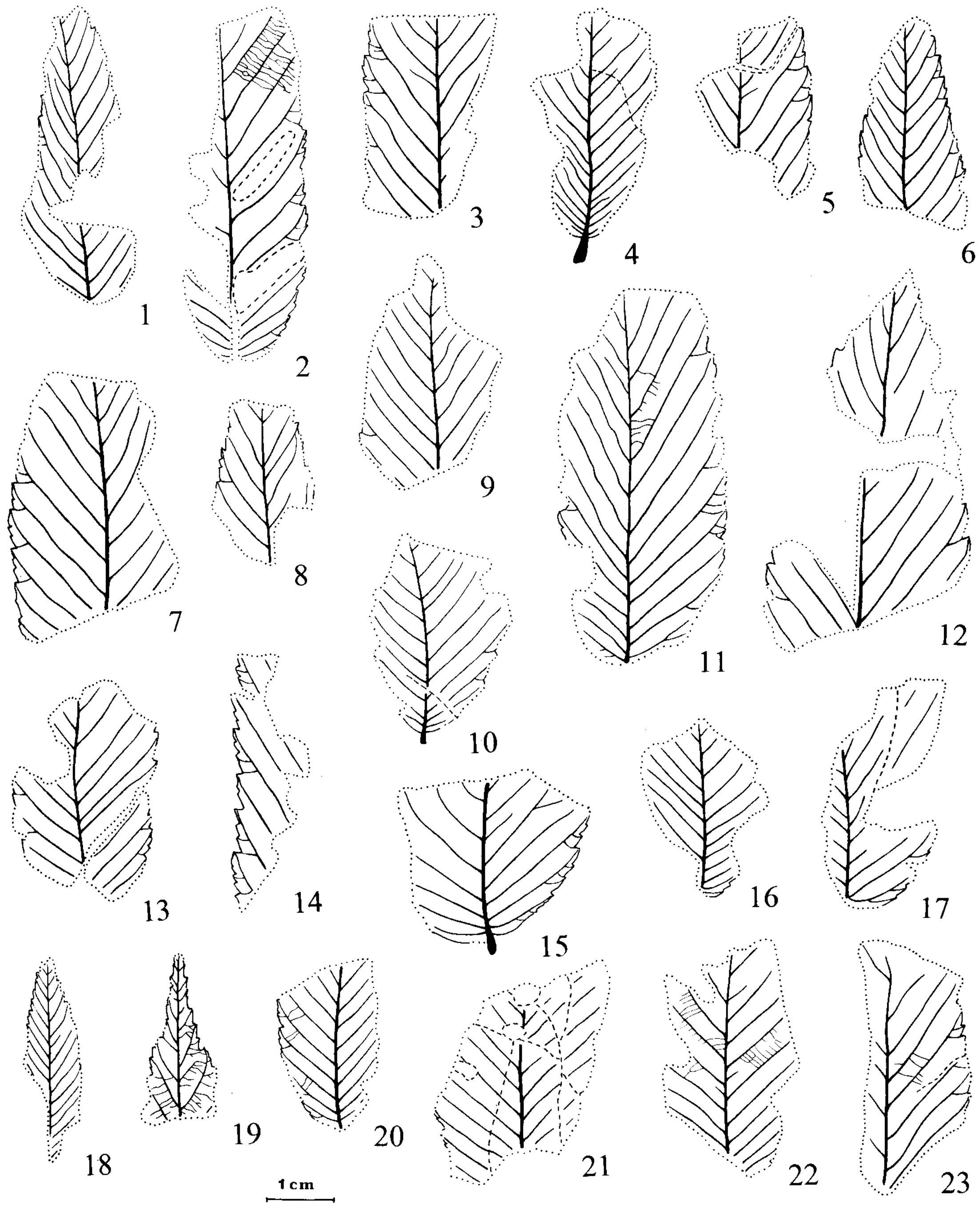

Fig. 10. **1–23** – *Ulmus pyramidalis* Goepp.: 1 – specimen No MZ.VII/71/22_1, 2 – specimen No MZ.VII/71/24, 3 – specimen No KRAM-P 199/25_1, 4 – specimen No KRAM-P 199/25_2, 5 – specimen No KRAM-P 199/27, 6 – specimen No KRAM-P 199/88, 7 – specimen No KRAM-P 199/104, 8 – specimen No KRAM-P 199/113, 9 – specimen No KRAM-P 199/115_1, 10 – specimen No KRAM-P 199/115_2, 11 – specimen No KRAM-P 199/119_1, 12 – specimen No KRAM-P 199/126, 13 – specimen No KRAM-P 199/129_1, 14 – specimen No KRAM-P 199/134, 15 – specimen No KRAM-P 199/136, 16 – specimen No KRAM-P 199/149_1, 17 – specimen No KRAM-P 199/149_2, 18 – specimen No KRAM-P 199/150_3, 19 – specimen No KRAM-P 199/154_1, 20 – specimen No KRAM-P 199/170_1, 21 – specimen No KRAM-P 199/199, **22** – specimen No KRAM-P 199/246, **23** – specimen No KRAM-P 199/279

Remarks. Characteristic of the specimens described above are their relatively small size, numerous sub-parallel secondary veins, densely distributed and sometimes branching; marginal teeth rather wide at the base, with blunt apices and mostly convex margins, occasionally provided with additional teeth. The features of venation and the configuration of the margins are typical of the leaves of *Ulmus*. A comparison of the specimens from Gnojna with fossil species of this genus seems to indicate that they most closely resemble the leaves of *Ulmus plurinervia* Ung. from the Miocene site at Parschlug (Unger 1847), particularly with regard to the size, shape and arrangement of the secondary veins. The leaves from Parschlug have, however, simply dentate margins. Nevertheless, leaves of *U. plurinervia* with doubly dentate margins have been reported by some authors (e.g. Kováts 1856; Andreánszky 1959; Zastawniak 1980).

The leaves of *U. plurinervia* Ung. most closely resemble the leaves of the East Asiatic species *U. parvifolia* Jacq. (Pl. 4. fig. 4) and *U. pumila* L.

Occurrence in the fossil floras of Poland. Młyny, Stawiany, Stare Gliwice (Zastawniak 1980).

Ulmus pyramidalis Goepp.

Pl. 3, figs 5–7a, Pl. 4, figs 1–1a, Fig. 10: 1–23

1855. *Ulmus pyramidalis* Goepp.; Goeppert, p. 28, Pl. 13, figs 10–12

Material. MZ.VII/71/10, 22_1, 24; KRAM-P 199/1, 23, 24_1, 25_1, 25_2, 26, 27, 29, 34_1, $88+189_1$, 89, 95, 104, 113, 115_1, 115_2, 116_1, 117, 119_1, 126+127, 129_1, 134, 136+137, 149_1+150_1, 149_2+150_2, 149_3+150_3, 154_1, 156, 157+158, 168_1, 168_2, 168_3, 168_4, 169_1, 170_1, 177_1, 189_2, 199, 227_2, 246, 263_1, 264_1, 273_2, 279 – forty-seven specimens (seven with twin impressions)

Description. Leaves narrowly oblong to lanceolate, often slightly asymmetrical, varying in size; width ranging from 1.0 to 3.5 cm. The best-preserved specimens are 4.5–6.0 cm long (the lengths of complete leaves, however, must have been greater). Petiole, more often than not, incomplete, 0.20–0.65 cm long (preserved in 6 specimens). Apex acute or acuminate, leaf base rounded or shallowly cordate, often asymmetrical. Leaf margins doubly serrate, sometimes simply serrate above. Primary teeth 1.3–2.3 (–2.8) mm wide at the base and 0.6–1.3 (–1.7) mm high, with slightly concave, straight or acuminate upper margins and mostly acuminate lower ones. Between two neighbouring primary teeth there are 1, 2, rarely 3 more secondary teeth which are smaller, narrower, 1.0–2.0 mm wide at the base and 0.3–0.7 mm high, with short upper margins and longer, straight or acuminate lower ones. Sinuses between teeth relatively shallow, angular.

Venation simple craspedodromous. Secondary veins very numerous (13–15 pairs can be seen in the best-preserved specimens), distributed at short intervals of (0.10–) 0.15–0.80 cm; near the leaf base the veins run more densely (intervals: 0.05–0.20 cm). The course of the secondary veins is straight or gently curved, they are sub-parallel to one another, sometimes branched. The lowest pair of secondary veins, more delicate and shorter than the others are distinctly curved. The secondary veins often turn upwards before entering the primary teeth. They form angles of (22°–) 30°–60° with the midvein in the middle part of the blade, 55°–96° in the basal part and 20°–35° in the apical part. The differences in the angle of divergence of the secondary veins between the two halves of the leaf blade are mostly of the order of about 5°. Near the leaf margins some veins arise on the abmedial side of the secondary veins and run to the secondary teeth, the lowest of these outer veins reaching the sinus between two teeth. Intersecondary veins are sometimes present, reaching a quarter to half the length of the secondary veins. The tertiary veins are delicate, percurrent and mainly forked. The veins of higher orders form a reticulum of well-developed areoles.

Remarks. The specimens described bear features characteristic of the leaves of *Ulmus*: serrate leaf margins, the presence of outer veins reaching the sinuses between the teeth and densely distributed secondary veins. They show fairly wide variation. According to Hantke (1954, Pl. VI, fig. 12), the variation of the leaf shape of *Ulmus* may be connected with their position on a twig. Beside the elongate, narrow leaves, dominant in the collection, there are some a little wider and small forms are present as well. Slight asymmetry is characteristic of most of the specimens involving the shape of the base, the varying width of the

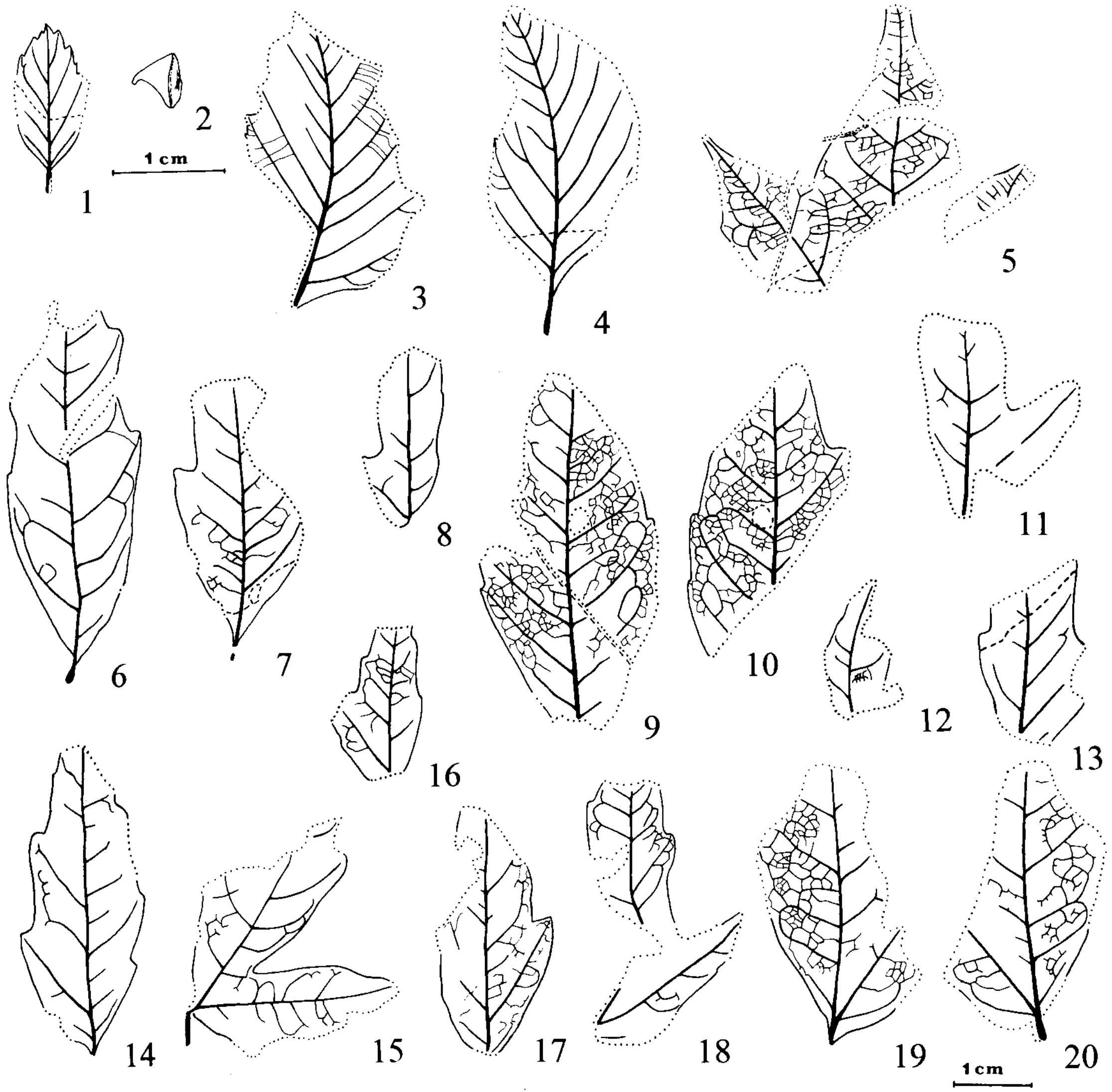

Fig. 11. 1–2 – cf. *Rosa* sp.: 1 – specimen No KRAM-P 199/71, 2 – specimen No KRAM-P 199/237; **3–4** – *Sorbus proaria* Pim.: 3 – specimen No KRAM-P 199/174_1, 4 – specimen No KRAM-P 199/200_1; **5** – *Acer integrilobum* Weber – specimen No KRAM-P 199/191 and 192; **6–20** – *Acer quercifolium* (Goepp.) Kovar-Eder: 6 – specimen No MZ.VII/71/32_1, 7 – specimen No KRAM-P 199/37, 8 – specimen No KRAM-P 199/43, 9 – specimen No KRAM-P 199/56 and 57 (specimens No KRAM-P 199/56, 199/57 and 199/58 – twin impressions), 10 – specimen No KRAM-P 199/58, 11 – specimen No KRAM-P 199/105_2, 12 – specimen No KRAM-P 199/112_2, 13 – specimen No KRAM-P 199/166_2, 14 – specimen No KRAM-P 199/174_2, 15 – specimen No KRAM-P 199/269, 16 – specimen No KRAM-P 199/274_1, 17 – specimen No KRAM-P 199/274_2, 18 – specimen No KRAM-P 199/280_3, 19 – specimen No KRAM-P 199/249, 20 – specimen No KRAM-P 199/282 (specimens No KRAM-P 199/249 and 199/282 – twin impressions)

two halves of the leaf blade and the angles of divergence of the secondary veins.

Leaves of this type are known under the name of *Ulmus pyramidalis* Goepp. (Goeppert 1855) and occur in large numbers in the Neogene floras of Europe (Hantke 1954; Jung 1963; Bůžek 1971; Christensen 1976; Knobloch 1986b etc.).

The fossil species is considered most frequently to be comparable with the recent North American species *U. alata* Michx. (Reimann 1919; Mädler 1939; Bůžek 1971), *U. americana* L. (Reimann 1919; Jung 1963; Bůžek 1971) and the Chinese *U. castaneifolia* Hemsl. (Mädler 1939; Němejc 1961; Jung 1963).

Occurrence in the fossil floras of Poland. Sośnica (Goeppert 1855); also Wyszonowice (Kräusel 1920), Swoszowice (Ilinskaya 1964) and Turów (Hummel 1975).

Rosaceae A. L. de Jussieu 1789

cf. ***Rosa*** sp.

Pl. 5, figs 4–5, Fig. 11: 1–2

Material. KRAM-P 199/71+72 (leaflet) – a pair of twin impressions KRAM-P 199/237_1 +238 (thorn) – a pair of twin impressions

Description. Leaflet (leaf?) elliptic-oblong, 2.0 cm long and 1.0 cm wide, with cuneate base and acute apex; petiole 0.4 cm long. Leaf margin irregularly serrate; teeth varying in size, 0.3–0.9 mm high and 1.5–4.0 mm wide at the base; margin of leaf base entire. Upper margins of teeth short, concave, convex or acuminate, lower margins much longer, nearly straight, concave or acuminate. Teeth apices acute, sinuses between teeth angular.

Venation simply craspedodromo-semicraspedodromous. Midvein of moderate thickness, gradually becoming more slender towards the apex, in the basal part of the leaf straight but sinuous apically. Secondary veins obscure, numbering 5 pairs, directed towards the teeth at intervals of 0.2–0.5 cm and departing from the midvein at an angle of 27°–43° which diminishes towards the leaf apex. The secondary veins of the lowest pair run sub-parallel to the leaf base. The venation of the third and higher orders is hardly visible.

Remarks. The specimen is probably the top leaflet of a compound leaf of *Rosa*. The type of leaf, the shape of its base and also in part the serration of the margins refer it to the fossil species *Rosa hilliae* Lesq., known from many Tertiary sites. This taxon was first described by Lesquereux (1883) from the Oligocene flora of Colorado. Becker (1963) included 12 American and Asiatic and 6 European Tertiary species of *Rosa* in *R. hilliae* assuming that they lie within its range of specific variation. It is very difficult to identify the specimen from Gnojna precisely, because the leaves of *Rosa* are characterized by great diversity and morphological variability. Of the present-day species of *Rosa*, *R. xanthina* Lindl. (northern China, Korea) and *R. micrantha* Sm. (west-central and southern Europe to northern Ukraine) have similar leaves.

An impression of a thorn, belonging in all probability to the genus *Rosa*, was also found (Pl. 5, fig. 5, Fig. 11: 2).

Occurrence in the fossil floras of Poland. Leaves of *Rosa* occur in the floras from Stare Gliwice (Szafer 1961) and Młyny (Zastawniak 1980). Thorns of *Rosa* spp. have been described from Mizerna (Szafer 1954), Krościenko (Szafer 1946, 1947), Konin (Raniecka-Bobrowska 1954) and Stare Gliwice (Szafer 1961).

Sorbus proaria Pim.

Pl. 5, fig. 6, Fig. 11: 3–4

1954. *Sorbus proaria* Pim.; Pimenova, p. 69, Pl. 18, fig. 7; Pl. 19, figs 1–5

Material. KRAM-P 199/174$_1$, 200$_1$ – two specimens

Description. Leaves slightly curved with elliptic blades, narrowly cuneate or decurrent at base and probably with acute apex. Size of fragments 2.0 × 3.6 cm and 2.0 × 4.0 cm; supposed width of leaf 2.0–2.5 cm, length about 4.0 cm; one specimen with a fragment of petiole 0.5 cm long. Leaf margins heavily damaged, fine teeth oriented forwards are preserved in places.

Venation simple craspedodromous. Midvein curved, of moderate thickness. Secondary veins numbering 8–11 pairs, curved, sometimes branched, departing from the midvein at a fairly acute angle, which decreases towards the apex; at the leaf base this angle is 40°–50°, in the middle and apical parts 22°–30°. Secondary veins opposite or nearly opposite, 0.2–0.5 cm apart. The secondary veins give off outer veins towards the teeth which sometimes anastomose before entering the teeth. Tertiary veins distinct, percurrent, forked, branched or simple, running at a right or acute angle from the admedial side of the secondary veins and at an approximate right angle from their abmedial side; within the base they anastomose. Veins of higher orders imperceptible.

Remarks. In their morphological structure the specimens presented resemble the leaves described by Pimenova (1954) from the Sarmatian flora of Amvrosevka as *Sorbus proaria* Pim., the species showing remarkable variability. The shape of the leaves, the number and arrangement of the secondary veins, their rather steep course, the presence of branches and the nature of the third order venation are similar. On the other hand, the size of the leaves and their basal shape are different; the leaves from Amvrosevka have rounded bases and are somewhat larger. Leaves of *Sorbus proaria* with a cuneate base have been described from some other floras, e.g. those of Młyny and Stawiany (Zastawniak 1980).

Sorbus proaria is comparable with recent species of *Sorbus* from the subgenus *Hahnia*, the majority of which occur in the Caucasus Mts at present (Pimenova 1954).

Occurrence in the fossil floras of Poland. Młyny and Stawiany (Zastawniak 1980).

Trapaceae Dumortier 1828

Trapa silesiaca Goepp.

Pl. 6, figs 3–10, Fig. 12: 11–19

1855. *Trapa silesiaca* Goepp.; Goeppert, p. 38, Pl. 25, fig. 14

Material. MZ.VII/71/31$_4$, 41, 42, 43; KRAM-P 199/6$_1$, 44, 46, 47+48, 49, 51, 55, 73, 74, 86, 162, 164, 177$_2$, 194, 211, 215, 233, 277$_3$ – twenty-two specimens (one with twin impression)

Description. Impressions of nuts, in some cases with organic matter preserved, (4.0–) 6.5–10.0 mm long (excluding neck), 6.0–15.0 mm wide (excluding horns). Nuts with four calyx horns. The two upper horns, preserved as impressions, are wide at the base and gradually taper upwards; length of preserved horn fragments up to 14 mm. In 13 specimens a circular depression is present between the neck and the hilum – it is the mark left after the detachment of a lower horn. There are two smaller and slightly deeper circular pits on both its sides – these indicate the position of additional tubercles; five specimens bear no visible scars. Nut neck up to 4.5 mm in length, with densely distributed longitudinal ridges on the surface. One specimen with a fragmentary pedicel, 1.2 mm long. Nut base rounded.

Additionally the apical part of a horn is preserved, 8.5 mm long and 0.3 mm wide at the base; it tapers towards the apex and is furnished with a row of hooks, about 2 mm long, directed towards the base (specimen No MZ.VII/71/31$_4$).

Remarks. Nuts of *Trapa silesiaca* Goepp. were first described by Goeppert from Sośnica in 1855. This species is chiefly known from the Miocene floras of Lower Silesia (Kräusel 1920) and Lusatia (Menzel 1906; Menzel et al. 1933).

The impressions from Gnojna show marked similarities to the specimens from Lower Silesia (Kräusel 1920, Pl. 23, figs 27, 30–32). They are similar in size and shape and have identically formed upper calyx horns. The similar specimens of *Trapa* from the Upper Miocene of Austria (Kovar-Eder 1988), described as *Trapa heeri* Fritsch, probably also belong to *Trapa silesiaca* Goepp..

Occurrence in the fossil floras of Poland. Sośnica (Goeppert 1855; Meyer 1919; Kräusel 1920; Łańcucka-Środoniowa et al. 1981), Kokoszyce, Pogalewo Wielkie, Bytom (Kräusel 1920), Konin (Raniecka-Bobrowska 1954), Bełchatów (Stuchlik et al. 1990).

Aceraceae A. L. de Jussieu 1789

Acer integrilobum Weber

Pl. 4, figs 5–5a, Fig. 11: 5

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

Material. KRAM-P (199/191 and 192) + 193 – a pair of twin impressions

Description. A fragment of the terminal and two lateral lobes (one lateral lobe in a vestigial state) of a lobed leaf. The leaf base and the middle part are not preserved. The size of the whole leaf is presumably 5.0–5.5 × 5.0–5.5 cm. Terminal lobe somewhat longer than the lateral one, narrowing towards the apex, which is probably attenuate. Lateral lobe strongly narrowed apically, with acuminate outer margin and attenuate apex. Only short segments of leaf margins preserved. Two blunt teeth were probably present far apart on the outer margin of the lateral lobe, as is suggested by the presence of fine vein branches leading to the leaf margin; otherwise the margin was most probably entire. Indentation between the lobes is approximately rectangular.

Venation actinodromous. The primary vein of the lateral lobe forms an angle of about 40° with the primary vein of the terminal one. The secondary veins are opposite or subopposite in the terminal lobe and alternate in the lateral; near the leaf margin they branch and anastomose. The veins of higher orders form a rectangular reticulum.

Remarks. The specimens have been referred to *Acer integrilobum* Weber in view of the characteristic shape of their lobes, strongly narrowed in the apical part to form an attenuate apex and the configuration of the leaf margin. The leaves of *Acer integrilobum* generally have entire margins but some leaves occur with undulate, sparsely serrate or dentate margins (Procházka & Bůžek 1975) or margins furnished with tooth-shaped projections (Knobloch 1985).

This species is fairly frequent in the floras of the Neogene of Europe; it has recently been reported from the Late Miocene flora of Greece – from Prosilion (Knobloch & Velitzelos 1986b), Germany – from Achldorf (Knobloch 1986b) and Austria (Kovar-Eder 1988).

Acer integrilobum is comparable with the present-day Asiatic species *Acer cappadocicum* Gleditsch and *A. longiceps* Rehd. (=*A. amplum* Rehd. var. *tientaiense* Rehd. (Walther 1972; Knobloch 1985).

Occurrence in the fossil floras of Poland. Kokoszyce (*Acer* sp. sect. *Palaeo-Platanoidea*, Kräusel 1920, Pl. 25, fig. 9; Walther 1972).

Acer quercifolium (Goepp.) Kovar-Eder

Pl. 4, figs 6–8, Fig. 11: 6–20

1855. *Rhus quercifolia* Goepp.; Goeppert, p. 37, Pl. 25, figs 6–9
1988. *Acer quercifolium* (Goepp.) Kovar-Eder; Kovar-Eder, p. 51, Pl. 6, figs 14–16

Material. MZ.VII/71/ 32_1; KRAM-P 199/10, 36+37, 43+45, (56 and 57) +58, 105_2, 112_2, 166_2, 172_1+174_2, 229+230, 268, 269, 272, 274_1, 274_2, 280_2+281_2, 280_3+281_3, 282+249, 283+284 – nineteen specimens (nine with twin impressions)

Description. Fragments of leaves (leaflets?) with petioles partly preserved in three specimens; in one the incomplete petiole is 0.4 cm long and forms an angle of about 150° with the primary vein of the leaf. Leaf fragments 7.0–8.0 cm long and about 2.5 cm wide. Base in some specimens slightly asymmetrical, cuneate, somewhat decurrent; apex missing, margins with asymmetrically distributed small lobes or rounded teeth varying in size and shape – 1–3 pairs visible in preserved fragments. Remaining specimens without petiole, bases strongly asymmetrical, broadly cuneate, cuneate or rounded-cuneate. On the outer margin of the leaves (leaflets?) there is often a characteristic, well-developed lobe, slightly narrowing towards the apex and up to about 3.0 cm in some specimens. Single teeth are present on the outer margins of the lateral lobes, their inner margins being entire or undulate; rounded teeth and small lobes are also visible.

Venation brochidodromous to simple craspedodromous-semicraspedodromous. Primary vein straight or slightly curved. In some specimens a prominent vein, running towards the apex of the lateral lobe, departs at an angle of 30°–50° from the middle primary vein, usually near the base or somewhat above. The secondary veins, often arching, diverge from the midvein at irregular intervals, mostly at angles of 40°–60° and anastomose near the margins. Single veins, running from the midvein often at somewhat smaller angles than those of the remaining secondary veins, enter the apices of the lobes and large teeth. The smaller teeth are supplied by delicate branches arising from the loops of the secondary veins. Intermediate veins are present between the secondary veins. The tertiaries form an irregular reticulum; its areoles are well developed, with no veinlets or with unbranching simple veinlets. Marginal venation looped.

Remarks. All the remains described are characterized by their identical venation and the occurrence of small lobes or rounded teeth on the margins. The remains are fragments of compound leaves. The specimens with petioles and subsymmetrical bases are terminal leaflets; the lateral leaflets are sessile, show marked asymmetry, which involves the shape of the base and whole leaflet, and the presence of only one lateral lobe.

The specimens from Gnojna resemble *Rhus quercifolia* Goepp. and *Rhus aegopodifolia* Goepp. described by Goeppert (1855) from Sośnica. In carrying out a revision of the Sośnica flora, Meyer (1919) found these two species identical and combined them in one taxon *Rhus quercifolia* Goepp; he indicated that the leaves showed some similarity to those of the recent species *Acer negundo* L. In recent years the systematic position of leaves of this type has been widely discussed (Andreánszky 1959, 1964; Kotlaba 1963; Knobloch 1969; Ilinskaya 1968; Kovar-Eder 1988) and have been described under various names (cf. Kovar-Eder et al. 1994). The presence of this fossil species of maple in Central Europe is confined to the floras of the period from the Middle Miocene to the Miocene-Pliocene boundary (Kovar-Eder et al. 1994).

Acer quercifolium is most frequently considered to be comparable with the recent Chinese species *Acer griseum* (Franch.) Pax from the section *Trifoliata* Pax (Ilinskaya 1968).

Occurrence in the fossil floras of Poland. Sośnica (under the names of *Rhus quercifolia* Goepp. and *Rh. aegopodifolia* Goepp., Goeppert 1855); Kokoszyce (as *Rh. aegopodifolia* Goepp., Meyer 1919); Młyny (as

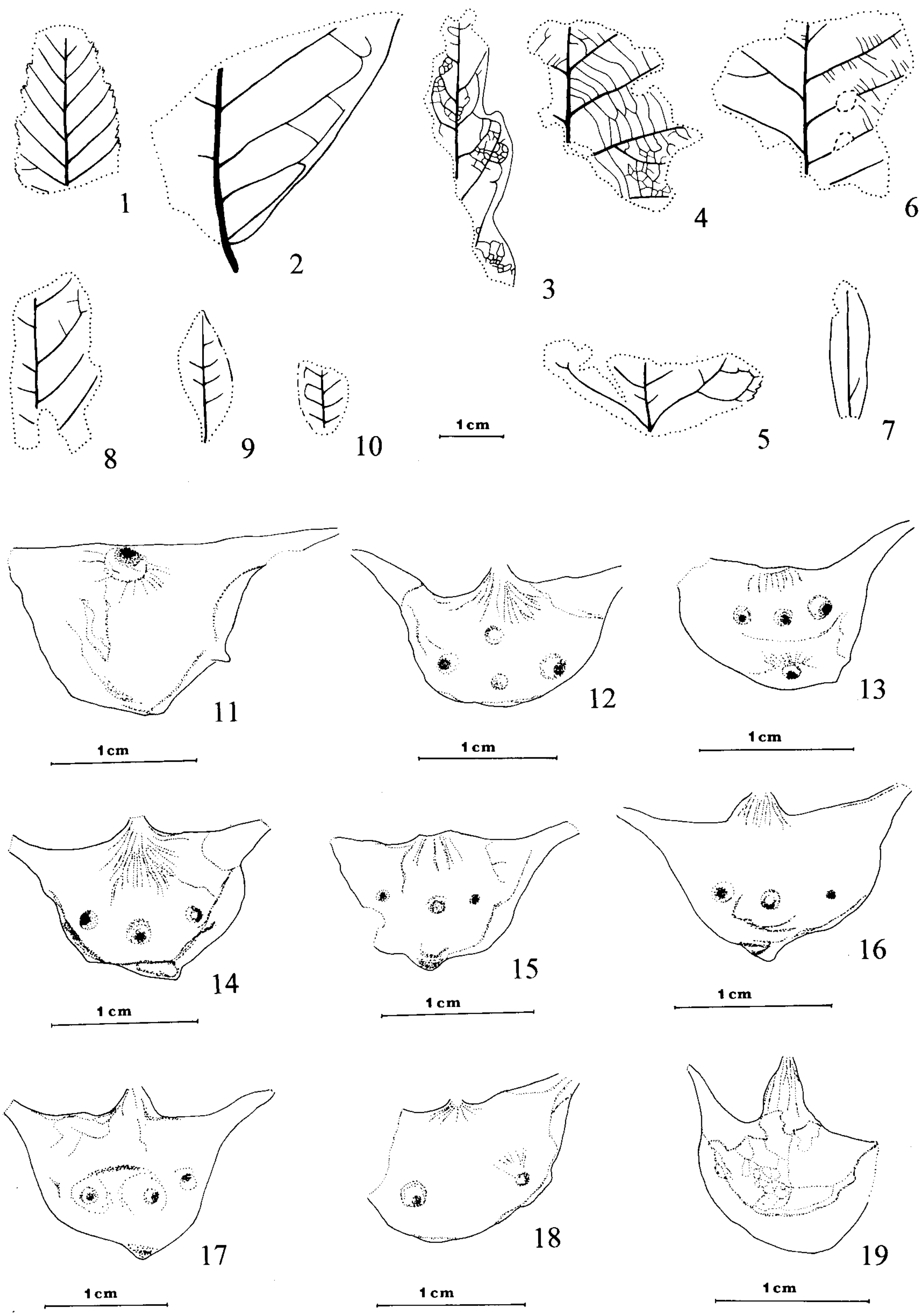

Fig. 12. 1–8 – Dicotyledones gen. et sp. indet.: 1 – specimen No MZ.VII/71/14, 2 – specimen No KRAM-P 199/3 (?*Juglans* sp.), 3 – specimen No KRAM-P 199/11, 4 – specimen No KRAM-P 199/83 (?*Platanus* sp.), 5 – specimen No KRAM-P 199/84, 6 – specimen No KRAM-P 199/90$_2$ (?*Quercus* sp.), 7 – specimen No KRAM-P 199/131 (?*Salix* sp.), 8 – specimen No KRAM-P 199/239$_2$; **9–10** – Leguminosae sensu Berger: 9 – specimen No KRAM-P 199/161, 10 – specimen No KRAM-P 199/200$_2$; **11–19** – *Trapa silesiaca* Goepp.: 11 – specimen No MZ.VII/71/42, 12 – specimen No KRAM-P 199/44, 13 – specimen No KRAM-P 199/46, 14 – specimen No KRAM-P 199/49, 15 – specimen No KRAM-P 199/51, 16 – specimen No KRAM-P 199/73, 17 – specimen No KRAM-P 199/74, 18 – specimen No KRAM-P 199/211, 19 – specimen No KRAM-P 199/215

Monopleurophyllum quercifolium /Goepp./ Kotlaba, Zastawniak 1980); also Bełchatów (Stuchlik et al. 1990); Stare Bystre (Worobiec 1994).

Dicotyledones incertae sedis

Leguminosae sensu Berger

Pl. 5, figs 7–7a, Fig. 12: 9–10

Material. KRAM-P 199/161, 200_2 – two specimens

Description. One specimen (199/161) is a nearly complete leaf (leaflet?) with an asymmetrical blade, elliptic shape, decurrent base, and probably acute apex. Width of leaflet 0.9 cm, length about 2.0 cm. Its margin, fragmentarily preserved, probably entire. Midvein stout, secondary veins inconspicuous, departing from the midvein at wide acute angles (within limits of 65°–70°). Veins of higher orders not preserved. The other specimen (199/200_2) is a small fragment of leaflet (or leaf) 0.8 cm wide. Length of fragment 1.3 cm, apex and base of leaflet missing. Margin probably entire, secondary veins anastomosing. Veins of third and higher orders imperceptible.

Remarks. The specimens from Gnojna have been assigned to the Leguminosae sensu Berger on the basis of such features as the size and shape of the leaflets (leaves?), probably entire margin and rather indistinct venation of the secondary and higher orders. According to Berger (1955b), in addition to the Leguminosae, some members of the families Oleaceae, Eleagnaceae, Ericaceae etc. have leaves of this type.

Occurrence in the fossil floras of Poland. Sośnica (Goeppert 1855; Meyer 1919), Rozewie (Heer 1869), Krywałd and Czernica (Raniecka-Bobrowska 1957), Młyny, Stare Gliwice (Zastawniak 1980).

Dicotyledones gen. et spec. indet.

Fig. 12: 1–8

Material. MZ.VII/71/14; KRAM-P 199/3, 11, 83, 84, 85, 90_2, 131, 198, 239_2, 243, 274_3 – twelve specimens

Remarks. Impressions of small fragments of leaves varying in morphology. Systematic position indeterminable.

Liliopsida (=Monocotyledones)

Poaceae Barnhart 1895

Phragmites oeningensis A. Br.

Pl. 5, figs 8–9

1851. *Phragmites oeningensis* A. Br.; Braun in Stizenberger, p. 75

1855. *Phragmites oeningensis* A. Br.; Heer, p. 64, Pl. 22, fig. 5; Pl. 24; Pl. 27, fig. 2b; Pl. 29, fig. 3e

Material. KRAM-P 199/41+42, 181 and 182, 183_2 – three specimens (one with twin impression)

Description. Fragments of leaves (specimens 199/181 and 199/182; 199/183_2) with parallel veins. The midvein is somewhat thicker than the secondary veins, which are distributed on both sides of it 0.6–1.0 cm apart; more delicate veins, 3–5 in number, occur between them.

Another specimen (199/41, 199/42 – a pair of twin impressions, Pl. 5, figs 8, 8a) is a portion of a rhizome, 0.6 cm wide, with venation similar to that in the leaf but less distinct. Two nodes are visible as are circular scars marking the points where adventitious roots preserved nearby became detached; there are also impressions of small fragments of adventitious roots.

Remarks. Leaves with venation similar to that of the specimen from Gnojna occur in *Phragmites oeningensis* A. Br.; the remains of rhizomes probably belong to the same taxon. Numerous shoots of *Ph. oeningensis* were described by Heer (1855) from the Middle Miocene of Switzerland. This species is widespread in the Tertiary floras of Europe and Asia; it has been reported from the Oligocene of Kazakhstan (Krishtofovich 1956); the Middle Miocene of Armavir (Kutuzkina 1964), Swoszowice (Ilinskaya 1964); the Late Miocene of Austria (Berger 1952, 1955a), Czech Rep. (Knobloch 1969), Greece (Knobloch & Velitzelos 1986a, b) etc.

Phragmites oeningensis is comparable with the recent cosmopolitan species *Ph. communis* Trin. (Ilinskaya 1968).

Occurrence in the fossil floras of Poland. Kunice Żarskie (Engelhardt 1877), Zielona Góra (Engelhardt 1887, 1892), Konin (Raniecka-Bobrowska 1954), Dobrzyń (Kownas 1956), Swoszowice (Ilinskaya 1964), Stawiany (Zastawniak 1980).

Monocotyledones incertae sedis

Pl. 6, figs 1–2a

Material. KRAM-P 199/39, 40_2 – two specimens

Description. Fragments of linear remains, 0.5–0.8 cm wide and 0.6–3.2 cm long, with parallel venation. Specimen 199/40_2 with a visible node and veins varying in thickness; between the thicker primary veins there are thinner secondary veins interconnected by transversely running anastomoses.

Remarks. In view of the linear shape and parallel venation characteristics of both leaves and stalks of the monocotyledons, the specimens were assigned to this group. A more precise identification is impossible because of the bad state of preservation of the remains.

GENERAL CHARACTERISTICS

The flora of Gnojna is composed mainly of leaf impressions but impressions of fruits, shoots and rhizomes of monocotyledons are also present in it. A total of 345 specimens have been identified; 11 of them have been included among the Coniferopsida (Taxodiaceae), 5 in the class Liliopsida (=Monocotyledones) and the remainder in the class Magnoliopsida (=Dicotyledones). This leaf assemblage shows a small taxonomic differentiation (Tab. 1). Nineteen species belonging to ten families have been distinguished among the Dicotyledones. The families are: Aceraceae, Altingiaceae, Betulaceae, Fagaceae, Hamamelidaceae, Platanaceae, Rosaceae, Salicaceae, Trapaceae and Ulmaceae. Some remains have been identified only to the level of genus (*Alnus* sp., cf. *Rosa*) or family (Betulaceae) and 2 specimens have been placed in the group of incertae sedis (Leguminosae). Twenty-two specimens are impressions of fruits (*Trapa* and *Carpinus*), 12 have been qualified as Dicotyledones gen. et sp. indet. The class Liliopsida is represented by a small number of specimens; one species of the family Poaceae (*Phragmites oeningensis* A. Br. – 3 specimens) has been distinguished,

Table 1. Taxonomic list of the leaf flora from Gnojna

	Taxon	Number of remains
1.	*Taxodium dubium* (Sternb.) Heer	11
2.	*Parrotia pristina* (Ett.) Stur	33
3.	*Liquidambar europaea* A. Br.	11
4.	*Platanus leucophylla* (Ung.) Knobl.	2
5.	*Quercus gigas* Goepp. emend. Walther & Zastawniak	19
6.	*Betula macrophylla* (Goepp.) Heer	6
7.	*Betula subpubescens* Geopp.	16
8.	*Betula* cf. *subpubescens* Goepp.	4
9.	*Alnus menzelii* Ran.-Bobr.	1
10.	*Alnus rotundata* Goepp.	15
11.	*Alnus* sp. 1	2
12.	*Alnus* sp. 2	1
13.	*Carpinus grandis* Ung. emend. Heer	59
14.	*Carpinus grandis* Ung. sensu Berger	1
15.	*Carpinus parvifolia* (Ett.) Knobl.	1
16.	Betulaceae gen. et sp. indet.	36
17.	*Populus* cf. *balsamoides* Goepp.	1
18.	*Salix varians* Goepp.	9
19.	*Ulmus plurinervia* Ung.	5
20.	*Ulmus pyramidalis* Goepp.	47
21.	cf. *Rosa* sp.	2
22.	*Sorbus proaria* Pim.	2
23.	*Trapa silesiaca* Goepp.	22
24.	*Acer integrilobum* Weber	1
25.	*Acer quercifolium* (Goepp.) Kovar-Eder	19
26.	Leguminosae sensu Berger	2
27.	Dicotyledones gen. et sp. indet.	12
28.	*Phragmites oeningensis* A. Br.	3
29.	Monocotyledones gen. et sp. indet.	2
	total	345

while two other fragmentarily preserved specimens proved indeterminable and were qualified as Monocotyledones gen. et sp. indet.

The leaves of the family Betulaceae are the dominant component of the fossil flora of Gnojna, amounting to about 45% of all the specimens (140 items). The fragments of leaves of *Carpinus* (59 specimens) are most numerous among them with the proportion of various species of *Betula* and *Alnus* somewhat smaller. The Ulmaceae are represented by large numbers (2 species of *Ulmus* – 52 specimens) and so are the Hamamelidaceae (33 specimens); less numerous are the remains belonging to the Aceraceae (2 species of *Acer* – 20 specimens), Fagaceae (*Quercus* – 19 specimens), Altingiaceae (*Liquidambar* – 11 specimens) and Salicaceae (*Salix* and *Populus* – 10 specimens altogether).

LIMITATIONS IN INTERPRETATION OF LEAF ORICTOCOENOSIS

The accumulation of fossil leaves in deposits permits but a rather limited reconstruction of plant communities. Studies carried out on the genesis and floristic composition of subfossil plant complexes indicate the various problems that may emerge during attempts to reconstruct vegetation on the basis of fossil plant remains. Burnham's study (Gastaldo 1992) on the accumulation of plant remains over a 20-kilometre segment of the Rio San Pedro in Mexico showed that the preserved subfossil leaves represented 13–51% (averaging 37%) of the local species of the surrounding vegetation, this proportion changing with the place where sampling was undertaken. Earlier, similar results were obtained by Roth and Dilcher (1978), who analysed the material deposited on the bottom of a small lake in the Bloomington region in Indiana (USA). There they found a less-than-50-percent representation of the arboreal plant species growing in the close vicinity of the water body; a selection of other plant remains was also noted: small leaves were over represented in the sample obtained from the middle part of the lake. Gastaldo (1992) determined the probability of the transition of plants into the fossil state to be 1/2, in some cases 1/10. The potential preservation of various parts of plants in the fossil state is conditioned by such factors as the strategy and life form of the plants, the environment in which they grow and traumatic agents (Ferguson 1985; Gastaldo 1992).

Leaf impressions of trees and shrubs are dominant in the fossil material from Gnojna; the leaves probably came from plants growing in the close vicinity of the water body or at a short distance from it. The presence of a body of stagnant or sluggish water is suggested by the nuts of *Trapa* and the shoots and rhizomes of *Phragmites*. Parts of trees and shrubs growing near water bodies have the best chance of transition into a fossil state as has been shown by investigations carried out by Roth and Dilcher (1978), Gastaldo (1992), Ferguson (1985) and Van der Burgh (1994). According to Ferguson (1985), in general, leaves are not carried by the wind to distances greater than the height of their parental tree; the distance over which they are transported depends mainly on their specific gravity: lighter leaves are transported by the wind for longer distances, whereas the shape of the leaves has no major influence on the distance they travel. Inside a forest the dispersal of leaves is impeded, since the branches of trees and shrubs obstruct their passage (Ferguson 1985).

In Ferguson's opinion, the waters of rivers and streams are an important factor in the spread of leaves, which can be carried by water for periods ranging in duration from several hours to several weeks and during that time undergo sorting out (Ferguson 1985; Gastaldo 1992). When carried by water leaves may get ragged, there being no correlation between the thickness of leaves and their resistance to crumbling (Ferguson 1971, 1985). Field studies and laboratory experiments conducted by Ferguson (1985) indicate that the length of leaf transport by water is influenced by such factors as the topographical features, turbulence of water (the more turbulent waters contain more dissolved oxygen and, as a result, the leaves float longer on the water surface), plant cover and the amount and distribution of precipitation. The marked fragmentation of the specimens from Gnojna may suggest water transport of the leaves. However, it should be emphasized here that the leaf impressions were often damaged during extraction from the outcrop. In my opinion, the origin of the material may be defined as autochthonous-subautochthonous, i.e. the place of origin was probably at close to the place of deposition – the “sedimentation reservoir” (Jung 1963).

According to Van der Burgh (1994), the transport of leaves takes place mainly above the canopy of the forest and the agent driving the leaves is the strong wind; after short-distance transport the leaves can fall into a water body and there be buried by sediments. They are best preserved in quiet waters by the shores of lakes, in oxbow lakes and bends in rivers with still waters, in silts and clayey sediments.

A leaf flora which is a complex of plant remains preserved in a deposit, or the so-called orictocoenosis, contains material in great measure impoverished in relation to the original complex of dead organic remains, the so-called tanatocoenosis. The lithological properties of the deposit in which the fossil material has been preserved may have influenced its floristic composition as well (Raniecka-Bobrowska 1962; Berger 1990). The features of the orictocoenosis can also be changed by diagenetic processes occurring after the remains have been buried by deposits (Gastaldo 1992). The state of preservation of the fossil material is dependent on various interacting factors, such as temperature, the turbulence and trophic condition of the water, the nature of the sedimentation, the number of necrophagous animals feeding on the leaves, the physicochemical properties of the leaves etc. (Ferguson 1985).

Van der Burgh (1994) claims that, on the basis of leaf assemblages, the compositions of certain plant communities only can be partly reconstructed, namely, those of floodplain forest, wet habitats, upland areas and forest margins. Nor do the fossil leaf floras accurately reflect the relative proportions which occurred among the various forest layers; a greater proportion of tree leaves of the canopy layer appears in them, with a simultaneous under-representation of herbaceous plants, understorey trees and shrubs (Van der Burgh 1994). The stalks of herbs have a poor chance of passing into the fossil state – they produce few leaves, are characterized by their small size and lack an abscission layer (Ferguson 1985; Van der Burgh 1994).

As far as the macrofossil floras are concerned, a considerably richer picture of vegetation can be acquired on the basis of studies of fruits and seeds. The carpological floras permit a reconstruction of a larger number of plant communities with more complete compositions, including, not just trees of the forest canopy, but also numerous shrubs and herbs (Van der Burgh 1994).

PLANT COMMUNITIES REPRESENTED AT GNOJNA

In the light of the foregoing analyses, the leaf flora from Gnojna, like other leaf floras, cannot be the basis for a complete reconstruction of the vegetation of that time. A floristic analysis of the material and a comparison with the requirements of the present-day genera or species related to the fossil taxa occurring at Gnojna, point to the presence of two types of forest community: mesophytic deciduous broad-leaved forest and riparian forest. In the forest of the first type *Carpinus* probably played an important role, the proportion of *Parrotia* being also significant; they were accompanied by *Quercus* and various species of *Acer* and *Betula*. Some members of the genus *Ulmus* (*U. plurinervia*), the family Rosaceae (cf. *Rosa*, *Sorbus*), *Liquidambar*, and, at drier sites, plants with Leguminosae-type leaves, were also present. In more humid habitats, in the close neighbourhood of the water body, the mesophytic forest changed into a riparian forest, where the trees of another species of elm (*U. pyramidalis*) and *Alnus* probably dominated and were accompanied by *Liquidambar*, *Salix*, *Betula*, *Populus* and *Platanus*. The wettest habitats were occupied by *Taxodium* trees, *Phragmites* grew in the reed swamp zone, while *Trapa* occurred in pools of stagnant or sluggish water.

A comparison of the results of the studies of the leaf flora with those obtained from a pollen analysis for the upper portion of the deposits of the Gozdnica series from Gnojna (Sadowska 1985, 1991, 1992, 1995) shows them to be mutually consistent to a fairly high degree. Specifically the natures of the plant communities are similar and a high proportion of the same arctotertiary genera of such deciduous trees and shrubs as *Carpinus*, *Ulmus*, *Betula*, *Alnus* and *Quercus* occur. In the pollen diagram *Fagus* and *Carya*, missing from the leaf flora under study, also play a very significant role among deciduous trees, and *Pinus*, *Abies*, *Picea* and Taxodiaceae-Cupressaceae among conifers, while Poaceae, Labiateae, Liliaceae, *Sphagnum* and Polypodiaceae form the most abundantly represented herbaceous plants. The components of mesophytic forest, notably *Carpinus*, *Quercus* and *Parrotia* prevail in the upper part of the profile (Fig. 3), corresponding partly with the layer containing fossil leaves, and are accompanied by a diminished proportion of taxa characteristic of marsh and peat-bog communities. Palynological analyses, however, permit a marked enrichment of the picture of the plant cover of that time. To the composition of mesophytic forest they add, among other taxa, trees of *Fagus*, *Tilia*, *Ostrya* and *Carya*, and such shrubs and creepers of scrub as *Ilex*, *Rhus*, *Staphylea*, Caprifoliaceae, Ericaceae and Oleaceae, and to that of forest growing in wet and swampy habitats, trees of *Nyssa* and *Pterocarya*. They show the presence of bog-mosses and ferns in the herb layer. Only the pollen flora revealed a slight proportion (below 1%) of thermophilous taxa from the genera *Arceuthobium*, *Engelhardia*, *Magnolia*, *Reevesia*, *Rhus* and *Symplocos* as well as *Tricolporopollenites edmundii* and *Tricolpopollenites liblarensis* (Sadowska 1985, 1991, 1992).

A forest community with a high proportion of *Carpinus*, *Quercus*, *Parrotia*, *Acer*, *Betula*, *Fagus* and *Carya*, and a small admixture of thermophilous taxa may, in accordance with Mai's (1981, 1995) classification, be counted under the category of mixed forest qualified as beech-oak-hornbeam forest. In these forests tall trees of *Abies*, *Keteleeria*, *Picea* and *Tsuga* were of great significance among conifers; thermophilous species with laurel-type leaves were limited to the understorey. In such forests the dominance and both generic and specific composition varied with the geographical situation and age of the fossil flora. The beech-oak-hornbeam forest communities were already sporadically present in the Late Oligocene of Europe; in the Late Miocene they were widespread in and characteristic of the territory of Central Europe; they also belonged to fairly important types of forest from the Pliocene until the Early Pleistocene (Mai 1981).

The forest of humid and wet habitats, whose presence was found at Gnojna, with *Ulmus* and *Alnus* playing a significant role and an admixture of species from the genera *Salix*, *Betula*, *Platanus*, *Populus* etc., may be included in the category of riparian forest representing azonal vegetation (Mai 1981, 1995). The composition of riverside forest varied according to the location of the fossil flora. Apart from the taxa present at Gnojna, they could comprise species from the genera *Fraxinus*, *Juglans*, *Sassafras*, *Myrica*, *Cyclocarya* etc. Evergreen taxa played a minor role in them, whereas shrubs, creepers and herbaceous plants were well represented. Species rich riparian forest belonged to a type widespread in Europe from the Early Oligocene to the Early Pleistocene (Mai 1995). On the other hand, trees of the genus *Taxodium* may have contributed to the composition of riparian forest or, together with *Nyssa*, formed swamp cypress forest typical of the territory of Europe from the Late Oligocene to the Pliocene (Mai 1981).

THE LEAF FLORA FROM GNOJNA COMPARED WITH PRESENT-DAY PLANT COMMUNITIES

In the leaf flora from Gnojna there are some plant species whose modern equivalents are associated with the regions of the temperate and temperate-warm climate of the Holarctic. They represent the so-called arctotertiary element (Mai 1981); no taxa of a distinctly thermophilous nature, evergreen and characteristic of the areas with a subtropical or tropical climate, have been found.

Most genera present in the flora from Gnojna have a Pan-Holarctic distribution at present. They are *Acer*, *Betula*, *Populus*, *Quercus*, *Salix*, *Sorbus* and *Ulmus* (Krüssmann 1976–1978; Mai 1981). Disjunctive distribution is now characteristic of *Platanus* (eastern North America – Asia Minor), *Liquidambar* and *Carpinus* (eastern North America – Asia Minor – eastern Asia) (Mai 1981). The present-day range of *Taxodium* is confined to the south-eastern part of North America and that of the genus *Parrotia* to Asia Minor (Krüssmann 1972, 1977). At present the genus *Trapa* occurs in natural habitats in Eurasia and northern Africa, while *Phragmites* is cosmopolitan (Engler 1964).

The flora from Gnojna comprises some plant taxa which are comparable with the trees and shrubs now growing in mixed deciduous forest in south-western and eastern Asia, in eastern and south-eastern North

America and in southern and central Europe (Tab. 2).

Forests resembling the mesophytic forest from Gnojna can be found now, above all, in the Talysh Lowland (Hyrcanian area). The dominant components of these forests are *Quercus castaneifolia* C. A. Mey. and *Parrotia persica* (DC.) C. A. Mey., whereas *Carpinus caucasica* Grossh., *Zelkova hyrcana* Grossh. & Jarm., *Z. carpinifolia* (Pall.) K. Koch, *Ulmus elliptica* K. Koch, *Populus hybrida* M. B., *Acer velutinum* Boiss., *Alnus subcordata* C. A. Mey., *Fraxinus excelsior* L., *Albizia julibrissin* Durazz. etc. constitute a significant admixture (Walter 1974; Tutayuk 1975). *Quercus castaneifolia* and *Parrotia* are also basic components of forests of the lower zone of the Talysh Mts, up to an altitude of 600–700 m. They are accompanied by *Fagus orientalis* Lipsky, *Acer campestre* L., *Tilia platyphyllos* Scop., *Diospyros lotus* L. and *Gleditsia caspia* Desf. (Tutayuk 1975). *Alnus subcordata*, an important component of the Hyrcanian forests, comparable with the fossil *A. menzelii*, forms also, together with *A. glutinosa* Gaertn., the so-called Hyrcanian alderwoods, growing in damp habitats near the shore of the Caspian Sea (Walter 1974).

Another region where the genera and species related to the taxa present at Gnojna occur comprises the eastern and south-eastern parts of North America. Floristically rich forest communities characterized by heterogeneous compositions changing with geographical situation and biotopic conditions grow in the belt of deciduous forest there. They are composed of various species of *Acer*, *Aesculus*, *Betula*, *Carpinus*, *Carya*, *Celtis*, *Cornus*, *Fagus*, *Fraxinus*, *Juglans*, *Liquidambar*, *Liriodendron*, *Magnolia*, *Nyssa*, *Platanus*, *Quercus*, *Sassafras*, *Tilia*, *Ulmus* etc. and the conifers *Tsuga*, *Pinus*, *Taxodium* etc. (Braun 1964). At present, numerous genera represented in the fossil flora of Gnojna grow in these forests.

Riverside elm-maple woods grow on fertile soils in river valleys, and their components are *Ulmus americana* L., *Platanus occidentalis* L., and *Liquidambar styraciflua* L.; *Acer saccharinum* L., *Acer negundo* L. var. *violaceum* Schwer., *Fraxinus americana* L. also play a major role in them, while *Celtis occidentalis* L., *Juglans nigra* L. and *Aesculus glabra* Willd. constitute an admixture (Knapp 1965). *Liquidambar styraciflua*, the species comparable with the fossil *L. europaea*, also grows as an important element in oak/tulip-tree forest; moreover, it occurs in beech-magnolia and oak-elm-hickory forest. In addition to *Quercus*, *Liquidambar* and *Liriodendron*, various species of *Castanea*, *Acer*, *Tilia*, *Fagus*, *Carpinus*, *Carya*, *Fraxinus* and *Ostrya* come into the composition of the species rich oak/tulip-tree forest (Knapp 1965).

Taxodium distichum (L.) Rich., the species comparable with the fossil *T. dubium*, forms, together with *Nyssa aquatica* L., swamp cypress forest in the south-eastern part of North America. They grow in areas inundated for a considerable part of the year where the water is 30–100 cm deep (Kearney 1901; Knapp 1965). *Taxodium* is also an important element of mixed species rich forest, extending through the alluvial valleys of rivers and the low wet banks of streams in the south-eastern part of the USA, where it is accompanied by various species of *Populus*, *Salix*, *Quercus*, *Celtis*, *Betula*, *Alnus* (among others, *A. rugosa* /DuRoi/ Spreng.) *Ulmus* (*U. americana* L., *U. alata* Michx.), *Acer*, *Liquidambar styraciflua* L. and *Platanus occidentalis* L. (Sargent 1933; Braun 1964).

Taxodium mucronatum Tenore, another species comparable with *T. dubium*, grows at present in the riverside woods of Central America, together with *Alnus*, *Fraxinus*, *Populus*, *Platanus*, *Salix* (among other taxa, *S. bonplandiana* H. B. K.), *Ulmus*, and *Juglans* (Knapp 1965).

In the valleys of small rivers and streams in the eastern part of North America there occur birch-alder riverside woods, which are composed of *Betula nigra* L. and *Alnus serrulata* (Ait.) Willd., the latter species comparable with the fossil *A. menzelii*. *A. serrulata* is also a component of carr thickets on the banks of rivers, together with *Salix*, *Cornus*, and *Cephalanthus* (Knapp 1965).

Betula papyrifera Marsh., the species comparable with the fossil *B. macrophylla* occurs in various types of forest community on the banks of rivers, lake margins and swamps (Sargent 1933). This birch also grows in *Abies*- and *Larix*-dominated mixed pine forest of the boreal belt of coniferous forest (Sokolov 1951).

The eastern areas of Asia are a third region where the taxa related to the fossil genera and species from Gnojna occur. They grow in a for-

Table 2. Geographical distribution and occurrence of the present-day plants compared with the fossil taxa from the leaf flora of Gnojna

Fossil plants	Recent taxa	Occurrence
Taxodium dubium (Sternb.) Heer	*Taxodium distichum* (L.) Rich.	south-eastern North America; forest in river swamps, in river valleys, on low wet banks of streams
	Taxodium mucronatum Tenore	Mexico, 1400–2300 m; forest in river valleys, on banks of streams
Parrotia pristina (Ett.) Stur	*Parrotia persica* (DC.) C. A. Mey.	northern Iran, Talysh Lowland, Talysh Mts up to 600–700 m; mesophytic deciduous forest
Liquidambar europaea A. Br.	*Liquidambar styraciflua* L.	south-eastern North America; forest in river valley bottoms, on the borders of swamps and low wet marshes
Platanus leucophylla (Ung.) Knobl.	*Platanus occidentalis* L.	south-eastern North America; frequently forest in river valleys, on borders of streams, lakes, in rich valley bottoms
Quercus gigas Goepp. emend. Walther & Zastawniak	*Quercus* from *Cerris* section	eastern Asia, Asia Minor, southern Europe; Mixed Mesophytic Forest (MMF), mesophytic deciduous forest, submediterranean broad-leaved deciduous forest
Salix varians Goepp.	*Salix fragilis* L.	Europe, Asia; river valley carr, forest in river valley bottoms
	Salix triandra L.	Europe, Asia; river valley carr, forest in river valley bottoms
	Salix bonplandiana H. B. K.	Central America (Mexico, Guatemala); forest on river banks and streams
Betula macrophylla (Goepp.) Heer	*Betula papyrifera* Marsh.	eastern and central North America; forest on stream sides, lakesides and swamps
Betula subpubescens Goepp.	*Betula schmidtii* Regel	Japan, Korea, Manchuria; Mixed Northern Hardwood Forest (MNHF)
	Betula utilis D. Don	Himalayas, Central Asia; broad-leaved forest on mountain slopes up to 4300 m
Alnus menzelii Ran.-Bobr.	*Alnus subcordata* C. A. Mey.	Caucasus, Iran; Hyrcanian forest, hyrcanian alderwoods
	Alnus serrulata (Ait.) Willd.	eastern North America; deciduous forest, carr in river valleys, on banks of streams
Alnus rotundata Goepp.	*Alnus rugosa* (DuRoi) Spreng.	eastern North America; forest in river valleys, swampy lowlands
Carpinus grandis Ung. emend. Heer	*Carpinus betulus* L.	Europe, western Asia; well-drained forest, mixed deciduous forest
Ulmus plurinervia Ung.	Ulmus parvifolia Jacq.	China, Japan, Korea; Mixed Mesophytic Forest (MMF)
	Ulmus pumila L.	eastern Asia; Mixed Mesophytic Forest (MMF)
Ulmus pyramidalis Goepp.	*Ulmus alata* Michx.	south-eastern North America; deciduous forest on dry gravelly uplands, in alluvial soil on the borders of swamps, banks of streams, in swamps with standing water
	Ulmus americana L.	eastern North America; deciduous forest in river valleys, on banks of streams
	Ulmus castaneifolia Hemsl.	China
Acer quercifolium (Goepp.) Kovar-Eder	*Acer griseum* (Franch.) Pax	central China
Acer integrilobum Weber	*Acer cappadocicum* Gled.	Asia Minor, Asia; broad-leaved forest
	Acer longiceps Rehder	China; Mixed Mesophytic Forest (MMF)

mation of deciduous broad-leaved forest extending from the valley of the river Yangtze to south-eastern Siberia (Wang 1961).

Ulmus parvifolia Jacq. and *U. pumila* L. (comparable with the fossil *U. plurinervia*), *Acer longiceps* Rehd. and *A. cappadocicum* Gleditsch (comparable with *A. integrilobum*), some oaks of the section *Cerris* (resembling the fossil *Q. gigas*), occur in the so-called Mixed Mesophytic Forest (MMF). This forest, very rich and variable in floristic terms, additionally contains various species from such genera as *Acer*, *Alnus*, *Betula*, *Carpinus*, *Carya*, *Celtis*, *Cercidiphyllum*, *Fagus*, *Fraxinus*, *Kalopanax*, *Liquidambar*, *Magnolia*, *Nyssa*, *Ostrya*, *Phellodendron*, *Populus*, *Pterocarya*, *Quercus*, *Salix*, *Sorbus*, *Tilia*, *Ulmus*, evergreen trees and shrubs from the genera *Castanopsis*, *Michelia*, *Pasania* etc. as well as coniferous trees including *Pinus*, *Tsuga*, *Cryptomeria*, and *Taxus* (Wang 1961).

The present-day Mixed Mesophytic Forest seems to be marked by its manifold richer composition than that of the forest which grew in the Gnojna region and by the lack of dominant elements. The canopy of Mixed Mesophytic Forest contains over 50 genera of broad-leaved and about 12 genera of coniferous trees (Wang 1961). However, it should be kept in mind that the orictocoenosis from Gnojna represents the vegetation of that time only to a certain degree.

Betula schmidtii Regel, comparable with *B. subpubescens*, is a component of the so-called Mixed Northern Hardwood Forest (MNHF), distinguished by Wang (1961) in a deciduous broad-leaved forest formation. Various species of *Acer*, *Tilia*, *Betula*, *Juglans* and *Maackia* play a significant role in this forest; *Ulmus pumila* L. is also a frequent component (Wang 1961).

Betula utilis D. Don, another species comparable with *B. subpubescens*, grows in temperate forest extending above 700 m in the Himalayas (Wang 1961).

Acer griseum (Franch.) Pax, comparable with the fossil *A. quercifolium*, and *Ulmus castaneifolia* Hemsl. comparable with *U. pyramidalis*, are associated with eastern Asia (central China) (Schneider 1906; Krüssmann 1976).

Some fossil taxa from Gnojna are comparable with recent species whose range of distribution includes Europe; *Carpinus betulus* L., *Salix fragilis* L. and *Salix triandra* L.; some species of *Quercus* from the section *Cerris* belong here as well.

Carpinus betulus is the basic component of well-drained forest, where it is accompanied by *Quercus*, *Acer*, *Fraxinus*, *Tilia*, *Ulmus* etc.; *C. betulus* occurs also in mixed deciduous forest, frequently with *Quercus* in beech forest; it may also constitute an admixture in alder-ash and other forest (Walter 1968; Medwecka-Kornaś 1972). *Salix fragilis* and *S. triandra* are components of riparian forest and carr which grow at the riverside and in old-river beds where regular flooding occurs, mostly with various species of *Populus*, *Alnus*, *Fraxinus* and other taxa (Medwecka-Kornaś 1972).

The recent taxa comparable with the fossil forms from Gnojna occur mostly in forest growing in regions with a fairly humid climate – the annual precipitation ranges from 700 to 1500 mm and the mean annual temperature fluctuates within wide limits, from 6.3°C to 19.8°C.

The climate prevailing in the Talysh Lowland is mild, with a mean annual temperatures of 14°C, the mean temperatures of the warmest and coolest months are 26°C and 3°C respectively; short-lived spells of frost occur sometimes; rainfall, totalling 1250 mm annually, occurs irregularly with the greatest precipitation in automn. Drought prevails in summer (Walter 1974).

The climate dominating in the eastern part of North America, within the belt of deciduous broad-leaved forest, is characterized by fairly high rainfall which occurs mainly in the summer months (700–1000 mm per year); the mean annual temperature is 6.3°C to 11.9°C; the mean temperature of the warmest month ranges from 18°C to 27°C, that of the coolest month from 0°C in the southern part of the region to -10°C in the north. The climate of the south-eastern part of North America is humid, the annual precipitation being 1200–1500 mm with most occurring in summer; the mean annual temperature is 16.9°C to 19.8°C; the mean temperature of the warmest month ranges from 25°C to 26°C and that of the coolest month from 5°C to 15°C (Knapp 1965).

The eastern regions of Asia, in areas with the dominant Mixed Mesophytic Forest (MMF), experience a mean annual temperature of 11°C to 16°C; rain falls mainly in the summer months with the annual precipitation ranging from 1000 to 1500 mm (Wang 1961).

The requirements of two genera growing at present, *Liquidambar* and *Taxodium*, are indicators which, in my opinion, make the climatic conditions prevailing during the period of development of the plant communities from Gnojna more familiar to us. The lowest mean annual temperature within the present-day range of *Liquidambar styraciflua* is 11°C (Hantke 1954). The lowest mean annual temperature in the area of the present-day range of *Taxodium* is 13.3°C; it is generally 15°C to 17.8°C and the mean temperature of the coolest month ranges from 4.9°C to 9.9°C (Mai 1995).

AGE OF THE FLORA FROM GNOJNA

The precise determination of the age of deposits comprising leaf remains generally presents difficulties, notably with regard to Central Europe and the Upper Miocene-Pliocene period. Hardly any of the plant taxa occurring in the leaf flora of that age are of stratigraphic significance. There is, however, a method which allows a comparison of various Neogene leaf floras from Europe and forms a basis for the dating of fossil floras. It does not take into account taxonomic determinations, but makes it possible to describe the nature of plant communities represented in the given flora. This method was introduced by Gregor (1982). It is particularly helpful in the interpretation of leaf floras because it does not rely on taxonomic determinations, which, as far as the taxa of fossil leaves are concerned, may be somewhat subjective or even erroneous. Gregor distinguished and appropriately named 23 types of leaf according to their morphological features: the course of primary venation, configuration of the margin, thickness of the blade and size of leaves. Furthermore, he applied a four-grade scale of frequency; Grade 1 for the most frequent elements of the flora (above 100 specimens), Grade 2 for frequent elements (11–100 specimens), Grade 3 for elements comprising 2–10 specimens and Grade 4 for the rarest components (1 specimen).

Nine of the 23 leaf types distinguished by Gregor (op. cit.) are represented at Gnojna: d – coniferoid (*Taxodium*), g – aceroid (*Acer*, *Liquidambar*), h – leguminosoid, i – quercoid (*Quercus*), l – populoid (*Populus*, *Platanus*), m – carpinoid (*Alnus*, *Betula*, *Carpinus*, *Sorbus*, *Ulmus*), o – rosoid (cf. *Rosa*, *Parrotia*), p – salicoid (*Salix*) and r – typhoid (Poaceae). Type m – carpinoid – occurs in the largest numbers (194 specimens), types d, g, i, o attain lower values (11–33 specimens) and types h, l, p, r 2–9 specimens. Based on the frequency of particular forms, the flora from Gnojna represents the "dgimo" type, which lies within a broad type of vegetation composed mainly of deciduous trees and shrubs with a low proportion of exotic elements and a significant role of coniferous plants, defined by Gregor (1982) as the "defgikm" type. Index Eg, representing the value of the ratio of evergreen elements to the total of elements represented in the given flora amounts to zero for the Gnojna flora, which additionally confirms that they were deciduous plants.

The "defgikm" – type floras occurred in the Late Miocene and Pliocene (Gregor 1982). This type of flora is represented by leaf floras from various sites in Germany: Mannersdorf, Achldorf, Panholz, Holzen, Thalham, Frechen, Bischofsheim etc. (Gregor op. cit.). Therefore, the application of this method does not provide any data for determining precisely the age of the Gnojna flora.

Neither does an analysis of the floristic composition make it possible to determine the age of the leaf flora from Gnojna exactly. The taxa distinguished in the flora are not in the nature of guiding forms and have no stratigraphic significance. Many species represented at Gnojna occur frequently in the Neogene floras of Central Europe; these are *Taxodium dubium*, *Parrotia pristina*, *Liquidambar europaea*, *Platanus leucophylla*, *Quercus gigas*, *Betula subpubescens*, *Carpinus grandis*, *Salix varians*, *Ulmus pyramidalis*, *Acer integrilobum* and *Phragmites oeningensis*.

The stratigraphic range of some taxa goes as far back as the Palaeogene. It is known that *Phragmites oeningensis* had occurred since the Late Eocene (Knobloch 1969), *Carpinus grandis*, *Liquidambar europaea* and *Salix varians* since the Middle Oligocene (Mai & Walther 1978, 1988), *Taxodium dubium* and *Acer integrilobum* since the Late Oligocene (Knobloch 1961, 1985). Such species as *Parrotia pristina*, *Ulmus pyramidalis*, *Salix varians* and *Carpinus grandis* were found present in the Late Pliocene floras (Mai & Walther 1978, 1988). Only one species from among those occurring at Gnojna – *Acer quercifolium* – is characterized by a relatively narrow stratigraphic range, as it is known to have existed in Europe over a period from the Middle Miocene to the Miocene/Pliocene boundary (Kovar-Eder et al. 1994).

A comparison of the taxonomic composition of the leaf flora from Gnojna with that of other Neogene floras from Poland (Tab. 3) shows its great similarity, above all, to the flora from the classic site at Sośnica near Wrocław (Goeppert

1855; Kräusel 1919, 1920; Łańcucka-Środoniowa et al. 1981; Walther & Zastawniak 1991). These have 17 taxa in common. It should, however, be emphasized that in comparison with the flora from Sośnica the flora of Gnojna is considerably poorer in species and less diversified; moreover, it is characterized by a distinctly higher proportion of the family Betulaceae. Remains belonging to two genera, *Salix* and *Ulmus*, are dominant in the flora of Sośnica. They constitute nearly half of all the specimens; important roles in this flora are also played by *Quercus*, *Liquidambar*, *Parrotia*, *Platanus*, *Populus*, *Taxodium*, Leguminosae-type leaves and species of the genera lacking at Gnojna: *Fagus*, *Pterocarya*, *Zelkova*, *Vitis* and *Salvinia*; the genera *Acer*, *Myrica*, *Celtis* etc. are also represented (Łańcucka-Środoniowa et al. 1981). The flora of Gnojna contains several taxa absent from Sośnica, e.g. *Carpinus parvifolia*, *Ulmus plurinervia*, *Acer integrilobum* and *Phragmites oeningensis*. A comparison of these two floras shows a fairly similar picture of their plant communities; the flora from Sośnica reflects a community of mesophytic deciduous forest, the forest of wet and swampy habitats with *Taxodium* (Łańcucka-Środoniowa et al. 1981). The marked similarity of the floras from Gnojna and Sośnica may provide evidence of their similar age, although they come from different geological formations. The flora from Sośnica has survived in the top part of the complex of clayey-sandy Poznań clays, in a horizon of flamy clays, below the Gozdnica series (Stachurska et al. 1973). In Sadowska's (1985) opinion, the sedimentation of the Gozdnica series started somewhat earlier in the Gnojna region than at Sośnica further to the north-west, where at that time the Poznań series was still being deposited. On the basis of palynological studies, the age of the deposits containing the fossil flora of Sośnica was initially estimated at Early Pliocene (Stachurska et al. 1973) but has recently been referred to the period of Miocene/Pliocene transition (Sadowska 1995) or the Late Pontian (Piwocki & Ziembińska-Tworzydło 1995).

Of the leaf floras from Central Europe outside Poland the Pannonian floras of the Viennese Basin are the most closely related to the flora of Gnojna in respect of their character and floristic composition: Brunn-Vösendorf, Laaerberg (Berger 1952, 1955a); those of Molassezone in Austria (Kovar-Eder 1988); Transcarpathia: Rika, Ignatovskii (Ilinskaya 1968); Czech Rep. (Knobloch 1969); Late Miocene floras of Germany: Achldorf, Aubenham, Sprendlingen (Gregor 1986; Knobloch 1986b, 1988; Meller 1989); the Pontian and Mio-Pliocene floras from Transcarpathia (Ilnica, Uzgorod, Berezinka; Ilinskaya 1968); Germany: Massenhausen (Jung 1963). They have from eight (at Nova Moravska Ves) to thirteen (at Laaerberg) taxa in common with the flora of Gnojna (Tab. 3). *Liquidambar europaea*, *Parrotia pristina*, *Platanus leucophylla*, *Quercus gigas*, *Carpinus grandis*, *Betula subpubescens* and *Ulmus pyramidalis* occur in all or nearly all of these floras, while *Taxodium dubium* and *Acer integrilobum* are also frequent. *Acer quercifolium* was reported, among other sites, from Aubenham (Knobloch 1988), Schneegattern (Kovar-Eder 1988) and Transcarpathia (Ilinskaya 1968). *Betula macrophylla*, *Alnus menzelii* and *Ulmus plurinervia* occur more rarely.

Elements of deciduous forest communities are dominant in the floras of the Late Miocene of Central Europe. The floristic composition and percentages of particular groups of plants are different at different sites and vary with age, geographical situation and biotopic conditions (Kovar-Eder 1986, 1988; Knobloch 1992). Unlike the flora from Gnojna, these floras contain evergreen elements, generally in small proportions, from, among others, the family Lauraceae.

The Early Pliocene floras from Poland – Ruszów (Hummel 1983, 1991) and Domański Wierch (Zastawniak 1972) – resemble the flora from Gnojna in being dominated by species of mesophytic trees and shrubs. The Gnojna flora has 8–9 species in common with Ruszów and 5–7 with Domański Wierch. The family Betulaceae plays an important role in the flora of Ruszów, just as it does in that of Gnojna, the leaves of different genera of this family forming about 35% of all the remains. *Betula subpubescens*, *Alnus menzelii* and *Carpinus grandis* (leaves and fruit involucres) are common to both floras. Ruszów is additionally characterized by an abundance of remains belonging to the Fagaceae, the leaves and cupules of *Quercus* being particularly numerous. *Parrotia*, *Liquidambar*, *Trapa* and *Taxodium* were also found present at Gnojna, as they were at Ruszów. The genera *Ulmus*, *Populus* and *Acer* are represented at Ruszów, but by different

Table 3. The occurrence of the taxa of the leaf flora from Gnojna in the Miocene and Pliocene of Central Europe. x – taxon given under another name

Taxa occurring in the leaf flora from Gnojna	Poland			Central Europe												
	Mio-Pl.	Pliocene		Upper Miocene							Mio-Pl.	Pliocene				
	Sośnica	Ruszów	Domański Wierch	Aubenham	Achldorf	Massenhausen	Shneegattern Lohnsburg	Laaerberg	Brunn Vosendorf	Moravska Nova ves	Transcarpathia	Frimmersdorf	Frankfurt	Drevenik	Berga	Willershausen
Taxodium dubium (Sternb.) Heer	+	+			+	+		x			+	x	x		+	?
Parrotia pristina (Ett.) Stur	+	+	+	+	+	x	+		x		+	x	x	x	+	?
Liquidambar europaea A. Br.	+	+	+	+	+	+	+	+	+	+	+	+	?	+	+	?
Platanus leucophylla (Ung.) Knobl.	+			+	?	x	+	x	x	x	x				?	
Quercus gigas Goepp.	+	x	x	x	x		x		x	x	x					?
Betula macrophylla (Goepp.) Heer	+							x			+					
Betula subpubescens Goepp.	+	+		?	+		+	+	?			?	+			
Betula cf. *subpubescens* Geopp.						x										x
Alnus menzelii Ran.-Bobr.		+		+	+											
Alnus rotundata Goepp.	+											?				
Alnus sp. 1	x					x										
Alnus sp. 2																
Carpinus grandis Ung. emend. Heer	+	+	+	?	?	?	+	x	+		+	?	?	+		?
Carpinus grandis Ung. sensu Berger	+	+			+	+	+			+		x				
Carpinus parvifolia (Ung.) Knobl.					x		x	x		x						
Populus cf. *balsamoides* Goepp.	?		?	?		?			?		?	?				
Salix varians Goepp.	+		+	+				+	+		+	?			+	
Ulmus plurinervia Ung.			?				?	+			+					
Ulmus pyramidalis Goepp.	+				+	x	x	x		+	+		x		+	
cf. *Rosa* sp.																
Sorbus proaria Pim.																
Trapa silesiaca Goepp.	+	?					x						?			
Acer integrilobum Weber					+		+	x	x	+		?				
Acer quercifolium (Goepp.) Kovar-Eder	x			x			+				x					
Leguminosae sensu Berger	+			+	+			+	?							?
Phragmites oeningensis A. Br.								+	+	+	+					?

species (*U. ruszovensis* Hummel, *P. populina* /Brongn./ Knobloch, *A. tricuspidatum* Bronn and *A. integerrimum* /Viv./ Massal.). Moreover, the flora from Ruszów is enriched by genera absent from Gnojna, such as *Myrica*, *Celtis*, *Fraxinus*, *Ostrya* and *Corylus* (Hummel 1983, 1991). Furthermore, several distinctly younger forms – species closely related to present-day taxa – have been described from Ruszów and Domański Wierch, namely, *Fagus* sp. aff. *F. ferruginea* Ait., *Castanea* cf. *sativa* Mill., *Acer* sp. aff. *A. palmatum* Thunb., *Ostrya carpinifolia* Scop. foss., *Corylus avellana* L. foss. (at Ruszów) and *Alnus* cf. *glutinosa* Gaertn., *Populus* cf. *nigra* L., *Acer platanoides* L. foss., *Cornus* cf. *mas* L. (at Domański Wierch).

The Pliocene floras of Central Europe are markedly different from that at Gnojna in by their clearly different species composition and the dominance of other taxa. The floras from

Frankfurt-am-Main (Mädler 1939), Frimmersdorf (Killpper 1959), Willershausen (Wilde et al. 1992) and Berga (Mai & Walther 1988) possess only a limited number of taxa in common with Gnojna, namely, above all, those commonly occurring in the Neogene of Europe: *Parrotia pristina*, *Liquidambar europaea*, *Carpinus grandis*, *Ulmus pyramidalis* and *Taxodium dubium*. These floras often have some forms which have not been found at Gnojna, namely *Aesculus* sp., *Quercus* cf. *pseudorobur* Kováts, *Sassafras ferretianum* Mass. etc. Unlike the flora from Gnojna, the Pliocene floras of Central Europe, like those from Ruszów and Domański Wierch, comprise some taxa very closely related to species growing at present; these are *Populus tremula* L. foss., *P. balsamifera* L. foss., *Carpinus betulus* L. foss., *Alnus incana* (L.) Moench foss., *Fagus silvatica* L. foss., *Quercus robur* L. foss. at Frimmersdorf (Kilpper 1959); *Quercus sessiliflora* Salisb. foss., *Fagus ferruginea* Ait. foss., *Buxus sempervirens* L. foss. in the flora of Frankfurt-am-Main (Mädler 1939); *Quercus castaneifolia* C. A. Mey. foss., *Ulmus carpinifolia* Gleditsch foss. and *Sorbus torminalis* (L.) Crantz foss. at Willershausen (Wilde et al. 1992).

The small number of taxa the Pliocene floras and that from Gnojna have in common, and the lack of taxa in the flora of Gnojna which are very closely related to present-day plants, may suggest its somewhat older age, although no traces of the presence of thermophilous plants have been found in the material. This lack can be accounted for by the fact that thermophilous plants are, in general, evergreen and so their leaves have a poorer chance of becoming part of the taphocoenosis, than have the leaves of deciduous plants. In the Late Miocene floras leaves of evergreen plants usually occur in very small numbers, forming only a small percentage of the total material; therefore, the quantity of material examined may also be of significance – the larger the number of specimens looked at the better is the chance of finding them.

It seems that, for the flora from Gnojna, we may assume a Miocene-Pliocene transition or Uppermost Miocene age, on account of its marked similarity to the floras of that age in Central Europe, notably to the flora from Sośnica.

FOREST COMMUNITIES IN THE LATE MIOCENE AND EARLY PLIOCENE IN SOUTH-WESTERN POLAND

Trees and shrubs of such genera as *Clethra*, *Eurya*, *Ilex*, *Magnolia*, *Mastixia*, *Styrax* and *Symplocos* grew in the forest communities of south-western Poland in the Late Miocene (Pannonian); coniferous trees also played an important role, particularly *Pinus* and *Sequoia* and, of the deciduous trees, *Fagus*. *Pinus*, *Sequoia* and *Fagus* accompanied by *Betula*, *Quercus*, *Gleditsia*, *Liquidambar* and *Carya* formed the canopy layer of the forest; *Tetraclinis*, *Carpinus*, *Ostrya*, *Eurya*, *Mastixia*, *Styrax*, *Magnolia*, *Symplocos*, *Tectocarya* etc. made up the understorey; the shrubby layer included, among other taxa, *Boehmeria*, *Ilex*, *Paliurus* and *Swida*; wet and swampy habitats were occupied by *Taxodium*, *Nyssa* and *Alnus*. The flora from Gozdnica belongs to the youngest floras of Poland, in which the palaeotropical element – components of the so-called mastixian flora – were still of great significance (Dyjor et al. 1992).

Towards the end of the Miocene and during the Miocene-Pliocene transition, these forests were replaced by somewhat cooler but also rich multicomponent mesophytic forests with a well-developed layer of shrubs and numerous creepers, as is documented by the flora from Sośnica (Goeppert 1855; Kräusel 1919, 1920; Łańcucka-Środoniowa et al. 1981) and also that from Gnojna. These forest communities included *Carpinus*, *Parrotia*, *Betula*, *Quercus*, *Fagus*, *Zelkova*, *Celtis*, *Acer*, *Liquidambar*, *Carya*, *Paliurus*, *Ulmus*, *Platanus* etc. Forests with *Taxodium*, *Nyssa*, *Alnus*, *Salix* etc. grew in wetter habitats, just as they did in the Pannonian.

Forests in which various species of *Quercus* dominated, accompanied by *Acer*, *Betula*, *Carpinus*, *Castanea*, *Celtis*, *Corylus*, *Fagus*, *Fraxinus*, *Magnolia*, *Parrotia*, *Phellodendron*, *Ostrya* etc., prevailed in the south-western part of Poland in the Early Pliocene; wetland forests with *Taxodium*, *Glyptostrobus*, *Nyssa*, *Myrica*, *Alnus* and *Populus* were no longer of major importance (Hummel 1983, 1991; Baranowska-Zarzycka 1988).

CONCLUSIONS

1. The floristic analysis of the orictocoenosis from Gnojna has made it possible to establish the nature of the plant communities of those times – they constituted deciduous forest. Taxa belonging to the arctotertiary element occur at Gnojna. No impressions of leaves of evergreen plants have been found in the material. The ratio of evergreen elements to the total number of flora elements (the so-called Eg index) equals zero. This confirms the existence of deciduous plant communities.

2. The types of forest that can be reconstructed on the basis of the material from Gnojna belong to the widespread plant communities of the Late Miocene and Pliocene of Central Europe. These were a mesophytic broad-leaved forest and a forest of moister and wet habitats in the nature of riparian forest; both these communities occurred in the immediate neighbourhood of or not far from water. It is mainly the canopy layer which is represented, the shrub layer to a smaller extent; few remains of herbs have persisted. *Carpinus* and *Parrotia* probably played a significant role in the mesophytic broad-leaved forest with *Quercus*, *Acer* and *Betula* also present, while *Ulmus*, "Leguminosae" and Rosaceae constituted an admixture. The riparian forest was characterized by a great proportion of *Ulmus* and *Alnus* accompanied by *Liquidambar*, *Betula* and *Salix*, while *Platanus* and *Populus* occurred in smaller numbers. *Taxodium* grew in the wettest habitats.

3. The taxa occurring at Gnojna are comparable with the trees and shrubs growing at present in deciduous forest in south-western and eastern Asia, eastern and south-eastern North America and southern and Central Europe. The deciduous forest of the Talysh Lowland approaches the mesophytic forest from Gnojna in its nature; many elements from Gnojna also have their present-day counterparts in the Mixed Mesophytic Forest (MMF) of China, the mixed deciduous forest of the eastern part of the United States of America and that of Europe. Forest resembling the riparian forest from Gnojna occurs now in fertile river valleys and on the banks of streams in the eastern and south-eastern parts of North America – it is composed of elm-maple forest and mixed multispecies forest containing *Taxodium*; some taxa from Gnojna are also comparable with the trees and shrubs growing in the riverside woodland and carr of Europe.

4. The modern taxa comparable with the fossil ones from Gnojna occur now in areas with a humid, warm-temperate to temperate climate, with an annual precipitation of 700–1500 mm. I assume the lowest annual temperature of today's range of *Liquidambar* (11°C) and *Taxodium* (13.3°C) as indicators that can throw some light on the temperature prevailing during the period of formation of the taphocoenosis.

5. The application of Gregor's (1982) method for comparing various leaf floras from the Neogene of Europe without taking taxonomic determinations into account does not permit any closer determination of the age of the flora from Gnojna. This flora represents the "defgikm" type, occurring over a broad time spane – from the Late Miocene throughout the Pliocene.

6. No taxa of stratigraphic significance occur in the orictocoenosis from Gnojna, many species being widespread in the Neogene floras of Central Europe.

7. The age of the flora from Gnojna can be determined only approximately on the basis of its comparison with other leaf floras. The small number of taxa shared with the Pliocene floras of Central Europe – mostly species common in the Neogene of Europe – and the absence of taxa very closely related to those growing at present, suggest the age of the flora to be somewhat older than Pliocene, namely, Miocene-Pliocene transition – like that estimated for the pollen flora of Gnojna (Sadowska 1995) – or Uppermost Miocene. One or other of these ages is assumed for the flora from Sośnica, with which that of Gnojna has the largest number of taxa in common. The flora of Gnojna to a great extent relates to the Late Miocene and Mio-Pliocene floras of Central Europe.

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STRESZCZENIE

Miejscowość Gnojna usytuowana jest w pd.-zach. Polsce, w województwie opolskim, we wschodniej części bloku przedsudeckiego, w obrębie wału metakarpackiego, stanowiącego strefę wododziałową, rozdzielającą w miocenie 2 prowincje paleogeograficzno-strukturalne: basen Niżu Polskiego i zapadlisko przedkarpackie (Fig. 1).

Flora została tutaj znaleziona w 1984 roku przez S. Dyjora w utworach młodszego trzeciorzędu w tzw. serii Gozdnicy. Gnojna jest jak dotąd czwartym, obok Gozdnicy, Ruszowa i Kłodzka, stanowiskiem z makroszczątkami roślinnymi pochodzącymi z osadów serii Gozdnicy.

Budowa geologiczna rejonu Gnojnej została opracowana przez Dyjora (Fig. 2). Oprócz spągowej części serii Gozdnicy w Gnojnej stwierdzono występowanie dwóch ogniw młodszego trzeciorzędu: fragmentarycznie zachowanego pokładu węgla brunatnego tzw. pokładu Henryk oraz utworów serii poznańskiej o miąższości ok. 70 m (poziom iłów zielonych i poziom iłów płomienistych). Utwory serii Gozdnicy znajdują się na zerodowanej powierzchni iłów płomienistych. Osadziły się w strefie stożka deltowego pra-Nysy Kłodzkiej, który powstał na brzegu wycofującego się w kierunku północnym zbiornika basenu serii poznańskiej. Seria Gozdnicy w rejonie Gnojnej osiąga miąższość ok. 7 m, składa się z różnoziarnistych piasków i żwirów przeławiconych warstwami piaszczystych glin kaolinitowych i mułków. W profilu serii A. K. Teisseyre wyróżnił 10 ławic osadów; badany materiał paleobotaniczny pochodził ze stropowej części profilu, ławicy 10, dolnej warstwy iłów szarych (Fig. 3). Górna część profilu o miąższości ok. 3,5 m została objęta badaniami palinologicznymi przez A. Sadowską, wiek osadów Sadowska oceniła początkowo na dolny pliocen, a ostatnio na przełom miocen/pliocen.

Badany materiał składał się z 328 okazów zawierających ok. 385 szczątków roślinnych; są to przede wszystkim odciski liści drzew lub krzewów, najczęściej fragmentów liści, nieliczne są odciski pędów roślin jednoliściennych, roślin szpilkowych i owoców.

W wyniku badań morfologicznych oznaczono 345 okazów. Flora charakteryzuje się niewielkim zróżnicowaniem taksonomicznym, wyróżniono w sumie 29 taksonów (Tab. 1).

Rośliny szpilkowe reprezentowane są przez 11 okazów – są to wszystko odciski pędów *Taxodium dubium*; pozostałe okazy należą do roślin okrytozalążkowych. W obrębie dwuliściennych wyróżniono 25 taksonów należących do 10 rodzin: Aceraceae, Altingiaceae, Betulaceae, Fagaceae, Hamamelidaceae, Platanaceae, Rosaceae, Salicaceae, Trapaceae, Ulmaceae, 24 okazy to odciski owoców (*Trapa*, *Carpinus*); w obrębie roślin jednoliściennych wyróżniono 1 gatunek *Phragmites oehningensis*.

Dominującym składnikiem w kopalnej florze Gnojnej są liście rodziny Betulaceae, stanowią one ok. 45% wszystkich okazów (140 szt.), najliczniejsze są fragmenty liści *Carpinus* (59 okazów), nieco mniejszy jest udział *Betula* i *Alnus*. Dużą rolę odgrywają też Ulmaceae (2 gatunki *Ulmus*, 52 okazy) i Hamamelidaceae (*Parrotia*, 33 okazy), mniej liczne są liście należące do Aceraceae (2 gatunki *Acer*, 20 okazów), Fagaceae (*Quercus*, 19 okazów), Altingiaceae (*Liquidambar*, 11 okazów) oraz Salicaceae (*Salix* i *Populus*, 10 okazów). Pozostałe taksony reprezentowane są przez 1 lub 2 okazy (Rosaceae, *Platanus*, Leguminosae).

Flora liściowa z Gnojnej, podobnie jak inne flory liściowe, stanowi tzw. oriktocenozę, która zawiera materiał w znacznym stopniu zubożony w stosunku do flory wyjściowej, jak również do pierwotnego kompleksu martwych szczątków organicznych. We florze liściowej reprezentowana jest głównie warstwa drzew, w znacznie mniejszym stopniu warstwa krzewów.

Skład florystyczny oriktocenozy z Gnojnej pozwala ustalić charakter ówczesnych zbiorowisk roślinnych, które występowały w pobliżu miejsca sedymentacji – były to lasy o opadających liściach. Wszystkie taksony drzew i krzewów wyróżnione w Gnojnej stanowią element arktyczno-trzeciorzędowy, brak jest elementu paleotropikalnego.

Porównanie wymagań współczesnych taksonów, które związane są z kopalnymi taksonami z Gnojnej pozwoliło na stwierdzenie obecności dwóch typów lasów: mezofilnego lasu liściastego oraz lasu łęgowego; lasy te należą do zbiorowisk szeroko rozprzestrzenionych w późnym miocenie i pliocenie środkowej Europy. Zbiorowiska te znajdowały się w bezpośrednim sąsiedztwie lub niedalekiej odległości od zbiornika wodnego, obecność zbiornika o spokojnych lub wolno płynących wodach potwierdzają odciski orzechów *Trapa* oraz pędów *Phragmites*. W mezofilnym lesie znaczącą rolę odgrywał prawdopodobnie *Carpinus* i *Parrotia*, rosły też drzewa *Quercus*, *Acer*, *Betula*, w domieszce występował *Ulmus*, Leguminosae, Rosaceae. Las łęgowy charakteryzował się dużym udziałem *Ulmus* i *Alnus*, towarzyszyły im *Liquidambar*, *Betula*, *Platanus*, *Salix*, *Populus*. W miejscach najbardziej podmokłych rosły drzewa *Taxodium*.

Wyniki badań odcisków liści oraz wyniki badań palinologicznych osadów serii Gozdnicy przeprowadzone przez Sadowską wykazują dużą zgodność; wyraża się ona podobnym charakterem zbiorowisk roślinnych i dużym udziałem tych samych arktyczno-trzeciorzędowych rodzajów: *Carpinus*, *Ulmus*, *Betula*, *Alnus*, *Quercus*; we florze pyłkowej dużą rolę odgrywa też *Fagus* i *Carya*. W górnej części profilu pokrywającej się częściowo z warstwą, zawierającą szczątki liściowe, przeważają składniki lasu mezofilnego, zwłaszcza *Carpinus*, *Quercus*, *Parrotia*, przy zmniejszonym udziale taksonów charakterystycznych dla zbiorowisk bagiennych.

Taksony występujące we florze liściowej Gnojnej można porównać z drzewami i krzewami rosnącymi obecnie na obszarach o klimacie dość wilgotnym, umiarkowanym ciepłym do umiarkowanego, w lasach pd.-zach. i wsch. Azji, wsch. i pd.-wsch. Ameryki Północnej oraz pd. i środkowej Europy (Tab. 2). Zbliżone w charakterze do lasu mezofilnego z Gnojnej są lasy liściaste Niziny Tałyskiej, gdzie dominującymi składnikami jest *Quercus*, *Parrotia*, dużą rolę odgrywa też *Carpinus*; wiele elementów z Gnojnej ma ponadto swe współczesne odpowiedniki w mieszanych lasach mezofilnych Chin, mieszanych lasach liściastych wsch. Stanów Zjednoczonych oraz w europejskich mieszanych lasach liściastych. Taksony występujące w lesie łęgowym z Gnojnej można porównać z drzewami i krzewami rosnącymi m.in. w dolinach rzek we wsch. i pd.-wsch. części Ameryki Północnej w lasach wiązowo-klonowych – są to lasy z *Ulmus*, *Platanus* i *Liquidambar*, a także w wielogatunkowych lasach mieszanych z *Taxodium*, czy łęgach brzozowo-olszowych.

Wiek flory liściowej z Gnojnej można w przybliżeniu określić jedynie na podstawie porównania z innymi florami kopalnymi (Tab. 3). Brak jest bowiem taksonów o znaczeniu stratygraficznym, wiele gatunków należy do powszechnie występujących w neogeńskich florach Europy (m.in. *Liquidambar europaea*, *Parrotia pristina*, *Ulmus pyramidalis*, *Platanus leucophylla*, *Salix varians*). Również zastosowanie metody porównywania różnych flor liściowych z neogenu Europy bez uwzględniania oznaczeń taksonomicznych, metody wprowadzonej przez Gregora w 1982 roku, nie pozwoliło na dokładniejsze datowanie flory; flora z Gnojnej reprezentuje bowiem typ flory, który występuje w szerokim odcinku czasowym – od późnego miocenu poprzez pliocen.

Na podstawie porównań z innymi florami liściowymi wiek flory z Gnojnej oceniono na przełom miocen/pliocen lub na najwyższy miocen. Flora z Gnojnej nawiązuje w znacznym stopniu do flor późnomioceńskich i mio-plioceńskich środk. Europy. Największe podobieństwo wykazuje do flory z klasycznego stanowiska w Sośnicy, ma z nią największą liczbę (17) wspólnych taksonów, przy czym należy podkreślić, że flora Gnojnej jest uboższa gatunkowo. Wiek flory Sośnicy szacowany jest przez różnych autorów na najwyższy miocen lub przełom miocen/pliocen. Wśród flor liściowych z obszaru środkowej Europy najbardziej zbliżone do flory Gnojnej są flory późnomioceńskie Basenu Wiedeńskiego, zony molasowej Austrii, Zakarpacia, Czech, Niemiec i mio-plioceńskie flory Zakarpacia i Niemiec. Zawierają one od 8 do 13 wspólnych z Gnojną taksonów. Wczesnoplioceńskie flory z obszaru Polski (Ruszowa i Domańskiego Wierchu) mają 5–9 wspólnych z Gnojną gatunków. We florze Ruszowa, podobnie jak w Gnojnej, dużą rolę odgrywa rodzina Betulaceae, szczątki liści Betulaceae stanowią ok. 35% wszystkich okazów. Natomiast flory plioceńskie środkowej Europy zawierają tylko kilka wspólnych z Gnojną taksonów, które należą przeważnie do szeroko rozpowszechnionych w neogeńskich florach jak np. *Liquidambar europaea*, *Ulmus pyramidalis*, *Carpinus grandis*. We florach tych występują ponadto taksony bardzo blisko związane ze współcześnie rosnącymi gatunkami, takich taksonów nie stwierdzono w Gnojnej.

PLATES

Plate 1

1. *Taxodium dubium* (Sternb.) Heer, specimen No MZ.VII/71/40, × 1
   1a. the same specimen, × 1.8
2. *Parrotia pristina* (Ett.) Stur, specimen No KRAM-P 199/152, × 1
3. *Parrotia pristina* (Ett.) Stur, specimen No KRAM-P 199/103, × 1
   3a. the same specimen, × 2
4. *Liquidambar europaea* A. Br., specimen No KRAM-P 199/216, × 1
   4a. the same specimen, × 2
5. *Liquidambar europaea* A. Br., specimen No KRAM-P 199/273, × 1
6. *Platanus leucophylla* (Ung.) Knobl., specimen No KRAM-P 199/240, × 1.7
7. *Quercus gigas* Goepp. emend. Walther & Zastawniak, specimen No KRAM-P 199/91, × 1
   7a. the same specimen, × 1.8
8. *Quercus gigas* Goepp. emend. Walther & Zastawniak, specimen No KRAM-P 199/197, × 1
   8a. the same specimen, × 2
9. *Quercus gigas* Goepp. emend. Walther & Zastawniak, specimen No KRAM-P 199/241, × 1
   9a. the same specimen, × 2

phot. L. Dwornik


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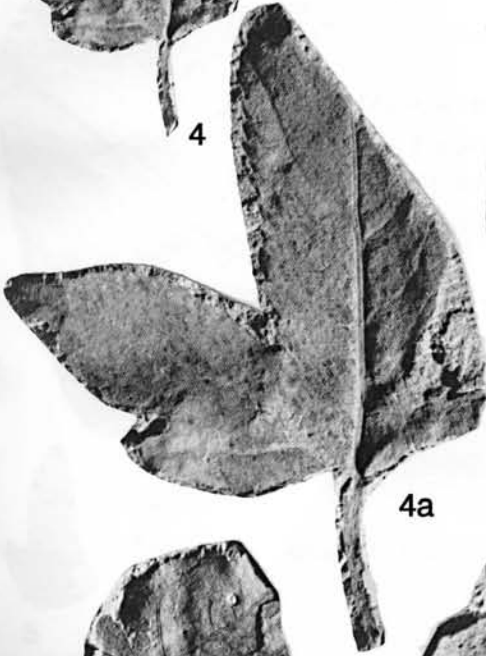
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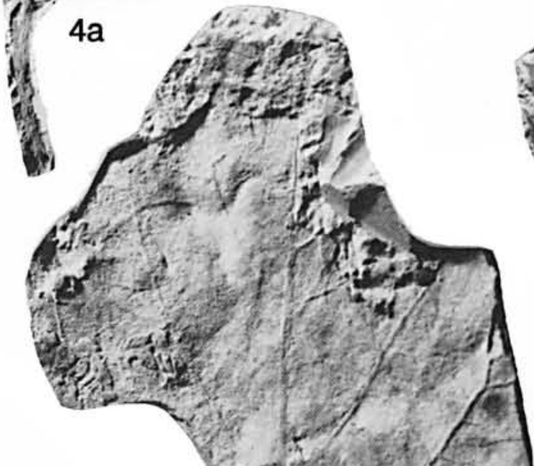
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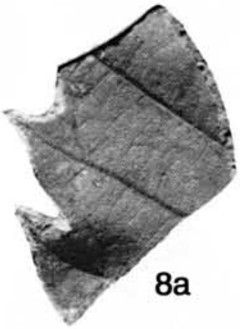
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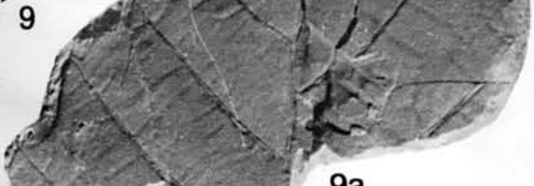
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Plate 2

1. *Quercus gigas* Goepp. emend. Walther & Zastawniak, specimen No MZ.VII/71/29, × 1
   1a. the same specimen, × 2
2. *Quercus gigas* Goepp. emend. Walther & Zastawniak, specimen No KRAM-P 199/240, × 1
3. *Carpinus grandis* Ung. emend. Heer, specimen No MZ.VII/71/34, × 1
4. *Carpinus grandis* Ung. emend. Heer, specimen No KRAM-P 199/110, × 1
5. *Carpinus grandis* Ung. sensu Berger, specimen No KRAM-P 199/275, × 1
   5a. the same specimen, × 2
6. *Betula macrophylla* (Goepp.) Heer, specimen No MZ.VII/71/35, × 1
   6a. the same specimen, × 1.8
7. *Betula subpubescens* Goepp., specimen No KRAM-P 199/250, × 1
   7a. the same specimen, × 1.8
8. *Alnus menzelii* Ran.-Bobr., specimen No MZ.VII/71/2, × 1
   8a. the same specimen, × 2

phot. L. Dwornik


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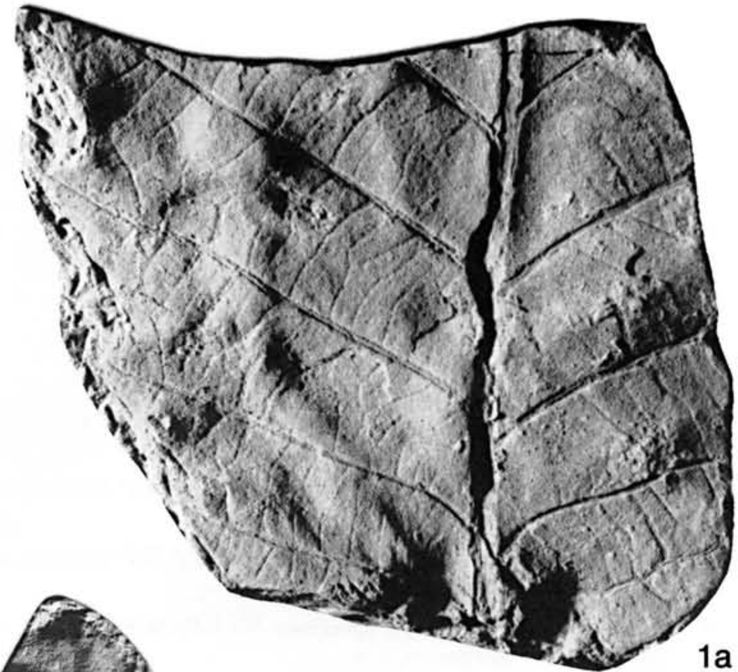
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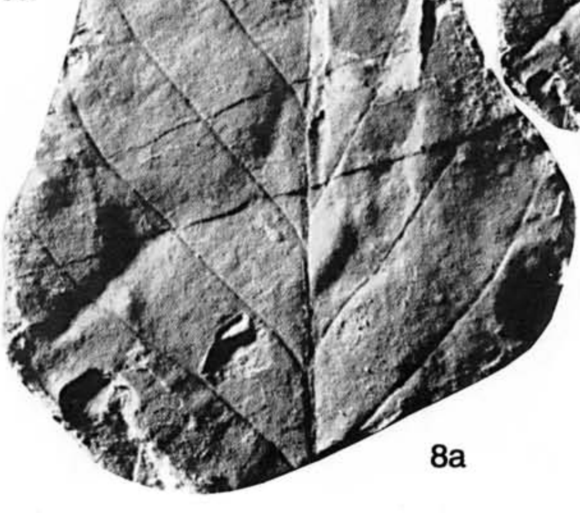
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K. Krajewska

Plate 3

1. *Alnus rotundata* Goepp., specimen No KRAM-P 199/257, × 1
   1a. the same specimen, × 2
2. *Alnus rotundata* Goepp., specimen No KRAM-P 199/139, × 1
   2a. the same specimen, × 2
3. *Alnus rotundata* Goepp., specimen No KRAM-P 199/258, × 1
   3a. the same specimen, × 2
4. *Alnus rugosa* (DuRoi) Spreng., specimen of herbarium, Royal Botanic Garden Kew, × 1.5
5. *Ulmus pyramidalis* Goepp., specimen No KRAM-P 199/25, × 1
   5a. the same specimen, fragment, × 2
   5b. the same specimen, fragment, × 2
6. *Ulmus pyramidalis* Goepp., specimen No KRAM-P 199/119, × 1
7. *Ulmus pyramidalis* Goepp., specimen No KRAM-P 199/189, × 1
   7a. the same specimen, × 1.8

phot. L. Dwornik

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Plate 4

1. *Ulmus pyramidalis* Goepp, specimen No MZ.VII/71/24, × 1
   1a. the same specimen, × 1.8
2. *Ulmus plurinervia* Ung., specimen No KRAM-P 199/202, × 1
   2a. the same specimen, × 2
3. *Ulmus plurinervia* Ung., specimen No KRAM-P 199/130, × 1
   3a. the same specimen, × 2
4. *Ulmus parvifolia* Jacq., specimen of herbarium, PAScs Inst. Dendr. in Kórnik, × 1.5
5. *Acer integrilobum* Weber, KRAM-P 199/193, × 1
   5a. the same specimen, × 1.8
6. *Acer quercifolium* (Goepp.) Kovar-Eder, specimen No KRAM-P 199/269, × 1
   6a. the same specimen, × 1.8
7. *Acer quercifolium* (Goepp.) Kovar-Eder, specimen No KRAM-P 199/282, × 1
   7a. the same specimen, × 2
8. *Acer quercifolium* (Goepp.) Kovar-Eder, specimen No KRAM-P 199/174, × 1

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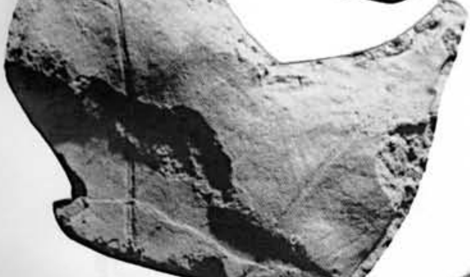
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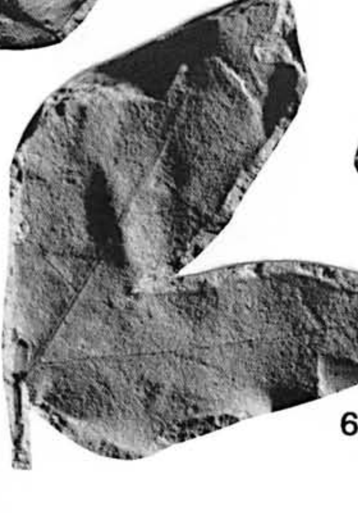
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Plate 5

1. *Salix varians* Goepp., specimen No KRAM-P 199/221, × 1
   1a. the same specimen, × 2
2. *Salix varians* Goepp., specimen No KRAM-P 199/144, × 1
   2a. the same specimen, × 2
3. *Populus* cf. *balsamoides* Goepp., specimen No KRAM-P 199/234, × 1
   3a. the same specimen, × 2
4. cf. *Rosa* sp., specimen No KRAM-P 199/71, × 1
   4a. the same specimen, × 2
5. cf. *Rosa* sp., specimen No KRAM-P 199/237, × 3
6. *Sorbus proaria* Pim., specimen No KRAM-P 199/174, × 1
7. Leguminosae sensu Berger, specimen No KRAM-P 199/161, × 1
   7a. the same specimen, × 1.8
8. *Phragmites oeningensis* A. Br., specimen No KRAM-P 199/41, × 1
   8a. the same specimen, × 2
9. *Phragmites oeningensis* A. Br., specimen No KRAM-P 199/181 and 199/182, × 2

phot. L. Dwornik


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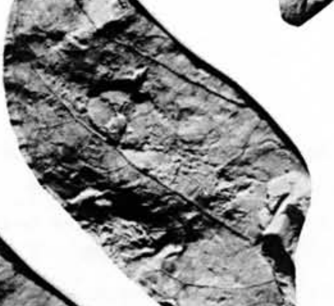
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Plate 6

1. Monocotyledones incertae sedis, specimen No KRAM-P 199/39, × 1
   1a. the same specimen, × 2
2. Monocotyledones incertae sedis, specimen No KRAM-P 199/40, × 1
   2a. the same specimen, × 2
3. *Trapa silesiaca* Goepp., specimen No MZ.VII/71/41, × 2.5
4. *Trapa silesiaca* Goepp., specimen No KRAM-P 199/44, × 2.5
5. *Trapa silesiaca* Goepp., specimen No KRAM-P 199/46, × 2.5
6. *Trapa silesiaca* Goepp., specimen No KRAM-P 199/49, × 1
   6a. the same specimen, × 2.5
7. *Trapa silesiaca* Goepp., specimen No KRAM-P 199/51, × 2.5
8. *Trapa silesiaca* Goepp., specimen No KRAM-P 199/73, × 2.5
9. *Trapa silesiaca* Goepp., specimen No KRAM-P 199/74, × 2.5
10. *Trapa silesiaca* Goepp., specimen No KRAM-P 199/211, × 2.5

phot. L. Dwornik


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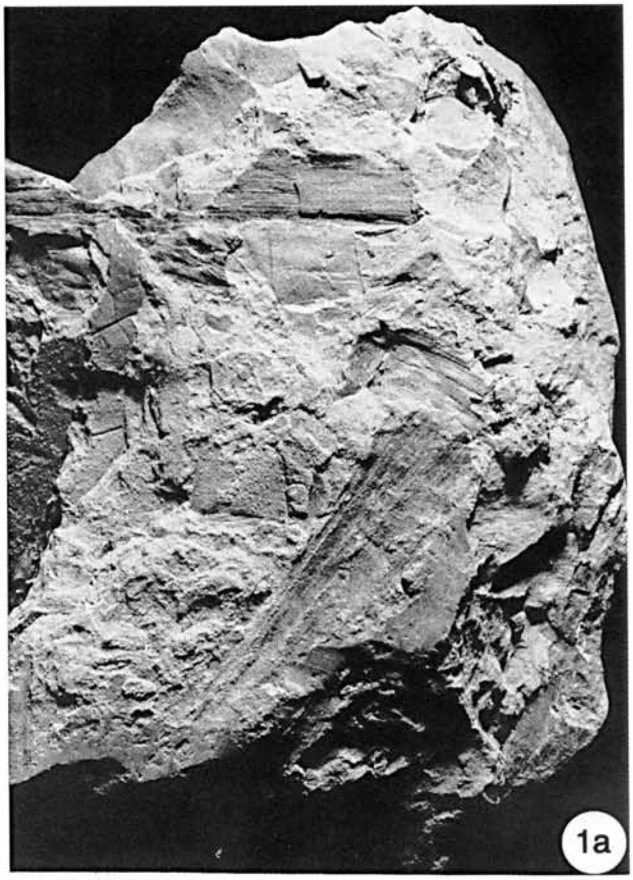
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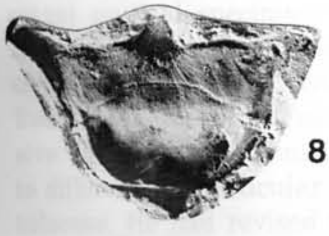
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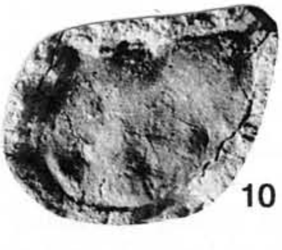
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