

# Miocene carpological floras of the Konin region (Central Poland)

RAFAŁ KOWALSKI

Polish Academy of Sciences Museum of the Earth in Warsaw, Al. Na Skarpie 27, 00-488 Warsaw, Poland;  
e-mail: rafal.kowalski@mz.pan.pl

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**ABSTRACT.** Carbonaceous, three-dimensionally preserved macroscopic plant remains from the Lubstów, Goślawice and Pałnów brown coal open-pit mines are described and illustrated, providing a comprehensive elaboration of the middle Miocene carpological floras of the Konin region. The diaspores represent the following families: Pinaceae, Sciadopityaceae, Cupressaceae, Annonaceae, Cabombaceae, Nymphaeaceae, Araceae, Typhaceae, Cyperaceae, Vitaceae, Rosaceae, Rhamnaceae, Fagaceae, Myricaceae, Cornaceae, Nyssaceae, Symlocaceae, Ericaceae, Araliaceae, and Adoxaceae. Forty-two species were recognised or documented for the first time in the Konin region. Two genera, three species and three morphotypes are described as new taxa.

Most of these plant remains represent azonal vegetation. Ericaceous bogs, pine bogs and mixed coniferous bogs, accompanied by *Gyptostrobis* swamp forests and various aquatic plant communities, are suggested as the most widespread vegetation types. Remains representing mesophytic, zonal vegetation, resembling extant evergreen broad-leaved and mixed mesophytic forests, are sparse. A *Sciadopitys* raised bog, a mixed coniferous bog subtype, was one of the important biomass sources forming the brown coal of the I-Middle Polish seam group. Other bog types recognised in Lubstów presumably also played a part in this process. Wildfire is suggested as an important factor controlling the Miocene vegetation of the Konin region.

The floristic composition and lithostratigraphy indicate the Badenian age (16.3–12.8 Ma) for the studied floras, but radiometric data suggest that two Lubstów floras are older and one is younger than 13.6 Ma. Biostratigraphically, Lubstów floras were correlated with the Klettwitz – Salzhausen floristic complex. Based on several climatic indicators and biostratigraphic correlation, the climate is estimated to have been humid, warm-temperate or subtropical.

The upper Miocene lower Rhenish Basin floras are the most comparable in floristic and plant communities' composition. Tropical – subtropical, Mediterranean and extinct genera represent approximately 40% of the genera identified in Lubstów.

**KEYWORDS:** fruits, seeds, cones, Lubstów, middle Miocene, Konin Basin, Poland

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## INTRODUCTION

Shallowly buried coal seams have been known for a long time in the Konin region of Poland. The earliest mention of coal and accompanying deposits of the Konin region can be found in Pusch (1836). The first methodological studies in geology of the Konin coal formations were conducted by Makowski (1926) and later by many others (Ciuk 1952, 1991, Hesemann 1944, Kasiński 2004, Kasiński et al. 1994, Malt & Wagner 1986, Widera 2007).

The sediments exposed during open-cast brown coal mining provided abundant material for the palaeobotanical studies. The earliest of these was the palynological analysis made by Kremp (1949) based on materials from the “Morzysław” lignite mine. His conclusion was that the brown coals exploited in Morzysław are middle to upper Miocene in age. Palynological studies in Konin’s surrounding region were continued later by many others (Ciuk & Grabowska 1991, Domagała 1982, Durska 2008, Mamczar 1960, Sadowska & Giża 1991).

Jadwiga Raniecka-Bobrowska (1954, 1959) carried out the earliest studies based on macroremains from clays of the Poznań Formation (middle Miocene) from the “Morzysław” lignite mine. Grabowska (1956) and Smólska (1959) investigated fossil wood from the Morzysław and Gosławice-Niesłusz lignite mines, consecutively, although with differing results.

The present paper documents and describes new materials collected in Lubstów’s open cast mine, plus specimens undetermined and omitted by Kowalski (2008), besides an unpublished collection gathered by Jadwiga Raniecka-Bobrowska in the Gosławice and Pątnów open cast mines near Konin. The identified remains provide the basis for the reconstruction of the local plant assemblages and palaeoclimate conditions. This monograph further complements knowledge on the vegetation and climate of the

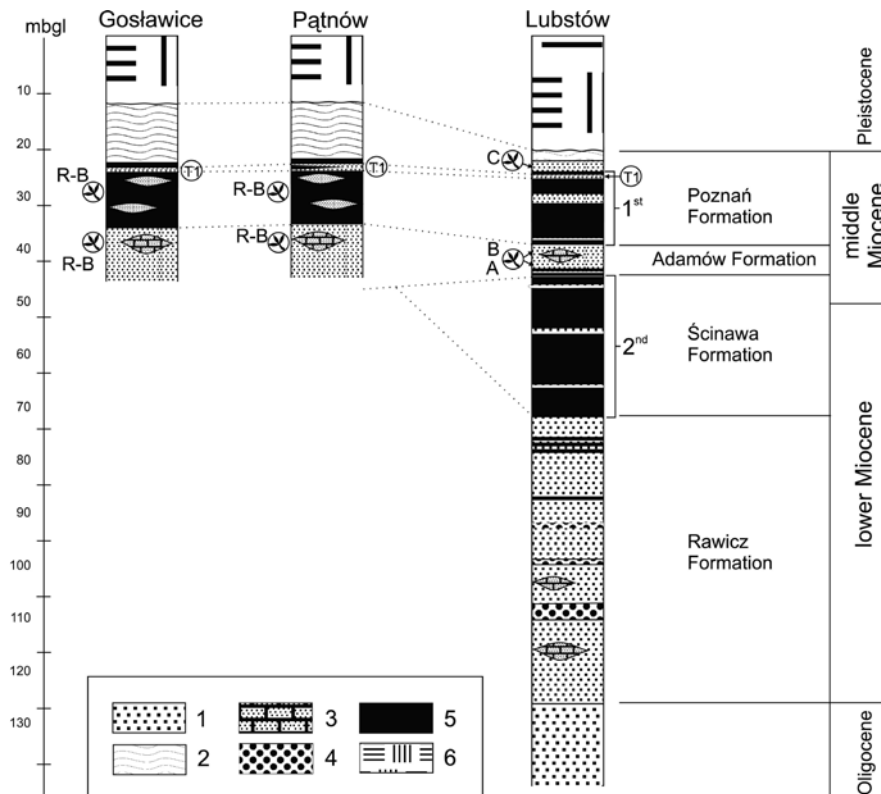
lesser known part of Central Europe during the middle Miocene. The Konin region floras are interesting to compare with other Neogene carpo-floras from Central Europe.

## GEOLOGICAL SETTINGS

Lubstów’s open cast mine was located about 20 km northeast of Konin (Fig. 1), in Central Poland. The brown coal beds exploited in Lubstów’s open cast mine occur within the deepest tectonic depression in the Wielkopolska region, known as Lubstów Graben (Widera 2007). This tectonic depression is filled with the most complete Cenozoic sequence in the Konin area (Widera 1998). According to Ciuk & Grabowska (1991), the lowermost part of the Cenozoic sediments in Lubstów Graben is represented by the upper Eocene quartz sands and quartz-glaucinitic sands of the Jerzmanowice Formation and lies unconformably upon



**Fig. 1.** Location of the Lubstów, Gosławice and Pątnów brown coal open-pit mines



**Fig. 2.** Lithostratigraphic profiles of the Lubstów, Gosławice and Pątnów brown coal open-pit mines (after Ciuk & Grabowska 1991, Kasiński 2004, Malt & Wagner 1986, Wagner 2007). 1 – sands, 2 – clays, 3 – sandstones, 4 – gravels, 5 – brown coals, 6 – glacial tills; T1 – tonstein layer; 1<sup>st</sup>, 2<sup>nd</sup> – coal of the 1<sup>st</sup> (Middle Polish) Group of Seams and 2<sup>nd</sup> (Lusatian) Group of Seams; R-B – possible location of the Raniecka-Bobrowska materials; A, B, C – location of the Lubstów floras

the Mesozoic marls and limestones. Quartz-glaucconitic sands intercalated with gravels and clays of the Lower Mosina Formation represent the lower part of the Oligocene. The Czempień Formation represents the upper part of the Oligocene; consisting of quartz sands, silts and clays with the lignite seam of the 5<sup>th</sup> (Czempień) Group of Seams (Kasiński 2004).

The Miocene sequence (Fig. 2), with an average thickness of 100 m, mainly consists of quartz sands and brown coals grouped into four formations (Kasiński 2004). The lower Miocene and lower middle Miocene deposits are represented consecutively by quartz sands of the Rawicz Formation and large, being up to 90 m thick, homogeneous detrital coal of the 2<sup>nd</sup> (Lusatian) Group of Seams, representing the Ścinawa Formation (Kasiński 2004, Durska 2008). According to Durska (2008), the enormous plant biomass that formed Ścinawa Formation brown coal in Lubstów Graben may have been created within shrub swamps with tree islands comparable to the present-day Okefenokee and Everglades wetlands in Georgia and Florida, USA.

The middle Miocene deposits are represented from the bottom by quartz sands of the

Adamów Formation and a brown coal seam intercalated with and overlain by quartz sands and clays of the Poznań Formation. The brown coal of the Poznań Formation, represents the 1<sup>st</sup> (Middle Polish) Group of Seams (Kasiński 2004, Piwocki & Ziemińska-Tworzydło 1997) and in its upper part the tonstein layer have been (Malt & Wagner 1986, Wagner 2007). This brown coal generally represents xylitic and detroxylitic macrolithotypes, and contains numerous logs and the base of tree trunks, frequently preserved in *growth position* (Kasiński 2004). According to Kasiński (2004), the biomass that formed the coals of the 1<sup>st</sup> Group may have been created within peat bogs and swamp forests. The uppermost Miocene is represented by clays, which are unconformably overlain by Pleistocene deposits (Ciuk & Grabowska 1991, Kasiński 2004).

The former Gosławice (52°15'4"N – 18°15'27"E) and Pątnów (52°20'31"N – 18°16'27"E) open cast mines are located, consecutively, ca 3 km and 12 km north of Konin (Fig. 1). The sediments exposed in both sites (Fig. 2) represent the middle Miocene (Mamczar 1960, Sadowska & Giza 1991), which unconformably overlies the Upper Cretaceous

rocks. The sands in the lower part of the Miocene sequence were assigned to the Adamów Formation. Above are brown coals (1<sup>st</sup> (Middle Polish) Group of Seams) with sand intercalations, overlain by clays assigned to the Poznań Formation. The tonstein layer, analogous to that identified from Lubstów, was observed also in Pątnów and Gosławice (Matl & Wagner 1986). Pleistocene deposits unconformably overlie the uppermost part of Poznań Formation clays.

Based on the lithostratigraphy and palinostratigraphy, the deposits of the Adamów Formation and lower part of the Poznań Formation have been correlated with Badenian (Piwocki & Ziemińska-Tworzydło 1997, Piwocki et al. 2004), thus represent the interval between 16.3–12.8 Ma (Hohenegger et al. 2014). The tonstein layers found in the 1<sup>st</sup> (Middle Polish) group of seams of the Konin region correspond with the youngest tuffaceous intercalation (T1), known from Bełchatów's brown coal open pit mine and Badenian tuffites of the Carpathian Foredeep (Matl & Wagner 1986). Some of the Carpathian Foredeep tuffites, the "Bochnia Tuffite" have been lately radiometrically dated to be  $13.62 \pm 0.10$  Ma (Bukowski et al. 2010). Hence, we can estimate that the Lubstów A and B floras are younger than 16.3 Ma, but not younger than 13.6 Ma, while Lubstów C flora is probably slightly younger than 13.6 Ma.

#### PALAEOGEOMORPHOLOGY AND DEPOSITIONAL ENVIRONMENT

The Konin region in Neogene was a part of the extensive coastal plains related to the North Sea Basin (Piwocki & Kasiński 2008). Palaeogeographic studies in the Konin and Turek area revealed a well-developed drainage system within the pre-Cenozoic bedrock. The river valleys' development was controlled by tectonics and erosion (Czarnik 1972, Kasiński et al. 1994, Widera 2007). Sedimentological studies of the Adamów Formation sands (Kasiński et al. 1994, Osjuk 1979) have shown that the general transport direction of the sediment was probably from south to north. Rivers that existed in the Miocene in the Konin area generally had a slow current, but some types of bedding indicate a high-energy flow (Osjuk 1979), suggesting periodic or episodic floods. The result of these floods is the sequences

of fluviatile sands where the fossil disseminules were found. Tree trunks, abraded wood fragments, diaspores of various sizes, small branches and leaves, and charcoals chaotically intermingled with medium- to coarse-grained sand, were observed personally by the author in site A. This characteristic resembles "bed-load carpo deposits" described by (Gee 2005) from the Neogene of the Lower Rhine Basin. According to Gee (2005) this type of sedimentation represents an accumulation related with catastrophic flood.

Kasiński (2004) defined three sedimentary units within deposits from Lubstów Graben, with the lower to middle Miocene sedimentary unit (corresponding to Rawicz and Ścinawa Formation) being characterised consecutively by fluviatile-lacustrine clastic sedimentation, peat-fen and peat bog sedimentation (Kasiński et al. 1994). During this time, there was significant tectonic activity of the Lubstów Graben and Konin area (Kasiński 2004). Basement subsidence that would have reached up to 100 m (Widera 2007) was crucial for the formation of the large (90 m thick) lignite seam of the 2<sup>nd</sup> (Lusatian) Group.

The middle Miocene sedimentary unit (corresponding to Adamów and the lowermost part of the Poznań Formation) is characterised by a generally similar succession to the first unit, although the coal sedimentation was shorter, much more unstable and the plant biomass originates from different peat-forming plant communities. Therefore, the coal of the 1<sup>st</sup> (Middle Polish) Group reached up to 20 m (Piwocki et al. 2004).

The third, middle to upper Miocene sedimentary unit (corresponding to the upper part of the Poznań Formation) in its lowest part is characterised by fluviatile clastic sediments, but changes into clay in the upper part (Kasiński 2004). The environment of the deposition for the uppermost clay complex was vast alluvial plains close to the mouth of the river (Piwocki et al. 2004).

#### MATERIAL AND METHODS

The basis for this paper are fossil plant remains, mainly fruits and seeds (ca 3000 specimens) collected by the author himself from the Lubstów open cast mine, near Konin. Plant remains from Lubstów were collected during field works between 2002–2006. Within the slopes of Lubstów's open cast mine, three

different sites with plant fossils were discovered. The sites were named A, B and C. The distance from site A to B is ca 1600 m north, from site A to C it is ca 1300 m north-northwest, and from site B to C it is ca 300 m south-southwest. Plant remains from sites A and B were collected from different horizons of the Adamów Formation sands. Plant remains from site C occurred in the sands of the Poznań Formation.

The remains were extracted in three different ways: 1) picked directly from the outcrop wall, 2) sediment samples were sieved in the field, or 3) sediment samples collected in bulk and sieved later in the laboratory. Separated specimens were dried in the laboratory. The most delicate specimens were soaked with glycerol.

The collection of the fossil plants from Lubstów (including the specimens described by Kowalski 2008 – UWPalaeo/mag.2004/1-26) is stored at the Polish Academy of Sciences, Museum of the Earth in Warsaw, Poland. The specimens were numbered consecutively; site A – MZ VII/122/1-58, site B – MZ VII/116/1-27, and site C – MZ VII/121/1-46.

This paper also takes into account the unpublished materials from the Gosławice and Pątnów open cast mines collected by Jadwiga Raniecka-Bobrowska, which were collected probably between 1957 and 1970. There was no information about whether the specimens came from one location and horizon or multiple levels, and instead only brief information was provided on the type of sediment where the specimens were found. Because the lithostratigraphic sequence exposed in Gosławice and Pątnów is uncomplicated, the author therefore assumed that they corresponded with Lubstów floras in age and lithostratigraphic location. The specimens from Gosławice and Pątnów are numbered MuzPIG Warszawa 78.III.1 – 29. and stored at the Geological Museum of the State Geological Institute, Warsaw, Poland.

The comparative studies were based on the fossil collections and carpological collection of the recent plants of the Museum of the Earth in Warsaw, Museum für Naturkunde in Berlin, and W. Szafer Institute of Botany Polish Academy of Sciences in Kraków.

Taxa described in the systematic chapter and Tab. 1 were organised according to APG III (Angiosperm Phylogeny Group, 2009) classification.

## SYSTEMATIC DESCRIPTIONS

Pinales Gorozh.

Pinaceae Spreng. et F. Rudolphi

*Pinus* L.

*Pinus brevis* Ludwig

Pl. 2, figs 1–3, 4a, 4b, 5

1857 *Pinus brevis* Ludwig; p. 89, Pl. 19, fig. 1.

1887 *Pinus askenasyi* Geyl. & Kink.; Geyler and Kinkelin, p. 12, Pl. 1, fig. 5.

1939 *Pinus brevis* Ludwig; Mädler, p. 29.

1960 *Pinus brevis* Ludwig; Schloemer-Jäger, p. 233–237, Pl. 1, figs 10–12.

2004 *Pinus brevis* Ludwig; Mai, p. 16–17, Pl. 2, figs 14–16.

**Material.** Lubstów A – 2 seed cones (MZ VII/122/25); Lubstów B – 7 seed cones, 4 seeds (MZ VII/116/4); Lubstów C – 6 seed cones (MZ VII/121/3); Pątnów, “sands in apical part of coal bed” – 1 seed cone (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.1a).

**Description.** Seed cones broadly elliptic to elliptic, 2.3–3.8 cm long and 1.6–3.5 cm wide, symmetrical, and the base is sometimes distorted. Apophyses less than 100 per cone, small, almost flat to raised (erect) (Tab. 1, fig. 8a, b), on one side of the basal area of cones somewhat curved down apophyses can be observed (basaluncinate). Umbo dorsal, sunken in apophysis, vallate type. Mucro represents excentromucronate type.

Seeds obovate, 4.0–4.5 mm long and 3.5 mm wide, pointed at the micropylar end, surrounded on 3 sides by wing. Seed wing about 14.0 mm long and 5.0 mm wide, asymmetrical.

**Remarks.** Morphology terms used herein follow those of Klaus (1980).

According to Klaus (1980), the dorsal excentromucronate umbo is typical of the extant pines of the section *Parrya* and subsection *Pineae* and *Silvestres*. However, among the European fossil pines, such small cones, whose scales number less than 100, slightly basaluncinate apophyses can be observed in *Pinus brevis*. Cones from Lubstów and Pątnów clearly correspond with *P. brevis* from Pliocene of Dornassenheim (Mai 1973, 1986) and Rüterberg (Mai 1986).

Cones from the Konin region are the oldest evidence of *Pinus brevis*, and this species has been reported so far from sediments not older than the upper Miocene, but mostly from the Pliocene (Mai 1986).

According to Mai (op. cit.), among modern pines, the cones of *Pinus mugo* Turra and *P. uncinata* Ramond ex DC. are morphologically closest to the fossil. *Pinus mugo* occurs in the Alps and Pyrenees above 2300 m a.s.l., in the Carpathians above 1000 m a.s.l., and the second noted species occurs in the Alps and Pyrenees above 600–1600 m a.s.l. (Farjon 2005a).

**Occurrence in the fossil floras of Poland.** Middle Miocene: Wieliczka (Kolasa

**Table 1.** List of species and families from Lubstów, Gosławice and Pątnów indicating number of specimens (+ – extinct taxon)

Family/Species	Lubstów					Gosławice	Pątnów	Total
	A – Kowalski (2008)	A	B	C	Total			
	Specimens quantity							
Pinaceae					72			
<i>Pinus brevis</i> Ludwig		2	7	6	15		1	1
<i>Pinus cf. leitzii</i> Kirchheimer							1	1
<i>Pinus ornata</i> (Sternberg) Brongniart				1	1			
<i>Pinus cf. spinosa</i> Herbst							3	3
<i>Pinus thomasi</i> (Goepf.) Reichenbach		1	22	2	25			
<i>Pinus urani</i> (Unger) Schimper	20	1	2	8	31		1	1
Sciadopityaceae								
<i>Sciadopitys tertiaria</i> Menzel						20<		20<
Cupressaceae					33			
<i>Cunninghamia miocenica</i> Ettingshausen		1			1			
<i>Glyptostrobus europaeus</i> (Brongniart) Unger		1	4	5	10	3		3
<i>Cupressus rhenana</i> (Kilpper) Mai et E. Velitzelos	3	1	1		5			
<i>Sequoia abietina</i> (Brongniart) Knobloch						49		49
<i>Chamaecyparis salinarum</i> Zabłocki	17				17			
Geinitziaceae								
<i>Cupressospermum saxonicum</i> Mai emend. Kunzmann +	2	1	4	1	8			
Cabombaceae								
<i>Brasenia victoria</i> (Caspary) Weberbauer			100	33	133	12	6	18
Nymphaeaceae								
<i>Nymphaea szaferi</i> Knobloch		1			1	27	9	36
<i>Nuphar canaliculata</i> C. & E.M. Reid	21				21			
Magnoliaceae								
<i>Magnolia ludwigii</i> Ettingshausen	1		7	54	61		27	27
Annonaceae								
<i>Asimina brownii</i> Thomson						4	1	5
Araceae					160			
<i>Epipremnites reniculus</i> (Ludwig) Mai +			1	158	159	36	2	38
<i>Urospathites dalgasii</i> (Hartz) Gregor et Bogner +				1	1			
Typhaceae								
<i>Sparganium bessarabicum</i> Negru				1	1			
Cyperaceae					76			
<i>Scirpus lusaticus</i> Mai		1	1	56	58		23	23
<i>Kownasia lubstovensis</i> gen. et sp. nov. +		10			10			
<i>Cladiocarya europaea</i> (Dorofeev) Mai +		3			3	12		12
<i>Cladium cf. europaeum</i> Dorofeev	1	4			5			
Hamamelidaceae					109			
<i>Fothergilla europaea</i> Szafer	9		100		109	12	18	30
Vitaceae					86			
<i>Ampelocissus aff. lobatum</i> (Chandler) Chen et Manchester			43	43	86	5	5	10
Rosaceae								
<i>Prunus spinosa</i> L. foss.						1		1
Rhamnaceae					10			
<i>Frangula solitaria</i> Gregor				10				
Fagaceae					2			
<i>Castanopsis cf. pyramidata</i> (Menzel) Kirchheimer		1			1			
<i>Castanopsis aff. salinarum</i> (Unger) Kirchheimer	1				1			
Myricaceae					31			
<i>Myrica suppanii</i> Kirchheimer	9		3	11	23			
<i>Myrica cf. ceriferiformis</i> Kownas		3		3	6	13		13
<i>Myrica burghii</i> Gregor		2			2			
Cornaceae					1			
<i>Cornus aff. discimontana</i> (Mai) Martinetto				1	1			
Nyssaceae								
<i>Mastixia thomsonii</i> Mai	1				17			

Table 1. Continued

Family/Species	Lubstów					Gosławice	Pałnów	Total
	A – Kowalski (2008)	A	B	C	Total			
	Specimens quantity							
<i>Nyssa disseminata</i> (Ludwig) Kirchheimer		3	4	4	11	26		26
<i>Nyssa ornithobroma</i> Unger		4		1	5			
Pentaphylacaceae					1			
<i>Ternstroemia sequoioides</i> (Engel.) Bůžek & Holý	1				1			
Symplocaceae					7			
<i>Symplocos minutula</i> (Sternberg) Kirchheimer		4			4			
<i>Symplocos incurva</i> (Kirchh.) Manchester & Fritsch	2				3			
<i>Symplocos casparyi</i> Ludwig	1				1			
Cyrillaceae					26			
<i>Piroparella aquisgranensis</i> Mai +	7	19				71		71
Ericaceae					1635			
<i>Enkianthus maii</i> n. sp.				5	5	6		6
<i>Comarostaphylis globula</i> (Menzel) Mai	332		49	ca 500	ca 881		22	22
<i>Maiella miocaenica</i> Kowalski & Fagúndez (2017)		1	4	11	16			
<i>Kalmiocarpus dorofeevi</i> gen. et sp. nov.		6			6			
<i>Rhododendron polonicum</i> n. sp.		6	1		7			
<i>Lyonia polonica</i> n. sp.		1	15	150<	166<	9		9
<i>Lyonia danica</i> Friis		3			3			
<i>Zenobia fasterholtensis</i> Friis				2	2			
<i>Zenobia microcarpa</i> Mai				4	4			
<i>Leucotrys europea</i> n. sp. +		3	7	ca 500	ca 510			
Gaultherieae gen. et sp. indet.				35	35			
Araliaceae					6			
<i>Aralia</i> aff. <i>dorofeevii</i> Mai		1		3	4			
<i>Aralia</i> aff. <i>lusatica</i> Mai				2	2			
Adoxaceae					30			
<i>Viburnum</i> aff. <i>hercynicum</i> Mai et Walther			1	29				
Incertae sedis					164			
<i>Carpolites lubstovensis</i> n. sp.		63	1		64			
<i>Carpolites drupifera</i> n. sp.		100<			100<			
SUM					2686<			405

1982, Łańcucka-Środoniowa & Zastawniak 1997); upper Miocene: Gozdnicza (Łańcucka-Środoniowa et al. 1992).

### *Pinus* cf. *leitzii* Kirchheimer

Pl. 3, figs 1–3

1936b *Pinus* Kirchheimer; p. 215–216, Pl. 13, fig. 1a–d.

1960 *Pinus leitzii* Kirchheimer; Schloemer-Jäger, p. 222–224.

1968a *Pinus leitzii* Kirchheimer; Kilpper, p. 214–215, Pl. 41, figs 1–5.

**Material.** Pałnów, “in the apical part of the coal bed” – 1 seed cone (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.1).

**Description.** The seed cone is narrowly oblong, curved, 10.5 cm long and 3.0 cm wide on average. The cone scales are more or less

rectangular in shape, ca 1.2 cm wide, delicate, thin, striated on the external surface, with undulated, sharp lateral edges.

**Remarks.** Poorly preserved cone, with both apical and basal parts broken, incompletely preserved scales and abraded apophyses. Despite poor preservation, the size and shape of the cone and the scales prove most certainly that this cone represented the *Pinus* sect. *Strobos*. According to Mai (1986), four species of *Pinus* are known in the Neogene of Europe within this section, *P. echinostrobos* Saporta, *P. grossana* Ludwig, *P. leitzii* and *P. peuce* Grisebach foss. Sordelli. The cone from Pałnów differs from *P. echinostrobos* in the shape of the scales, which are short, and rhomb-shaped with triangular apophysis. *Pinus grossana* cones are about twice as large as *P. leitzii*. Morphological

differences between *P. leitzii* and *P. peuce* foss. are not clear, but *P. peuce* foss. is known mostly from the Pliocene and Pleistocene (Mai 1986) sediments and there is only one report from the upper Miocene (Reichenbach 1919), while *Pinus leitzii* was reported only in the upper Miocene (Kirchheimer 1936, Schloemer-Jäger 1960, Kilpper 1968a). Based on age, attribution of the Pałnów cone to the *P. leitzii* seems most likely.

According to Mai (1986), *P. leitzii* cones are morphologically close to extant *P. dalatensis* Y. de Ferre, from southern and central Vietnam. They grow in mountains at elevations of 1400–2300 m a.s.l. (Farjon 2005a).

Occurrence in the fossil floras of Poland. Upper Miocene: Gozdnicza (Łańcucka-Środoniowa et al. 1992, Stachurska et al. 1971), Bełchatów (Stuchlik et al. 1990).

### *Pinus ornata* (Sternberg) Brongniart

Pl. 3, figs 4a, 4b, 5

- 1825 *Conites ornatus* Sternberg; p. 39, Pl. 55, figs 1, 2.  
 1828 *Pinus ornata* (Sternberg) Brongniart; p. 107.  
 1994 *Pinus ornata* (Sternberg) Brongniart; Mai, p. 213–214, Pl. 3, figs 1–3.

Material. Lubstów C – 1 seed cone (MZ VII/121/4).

Description. Seed cone ovate, slightly curved at the base, 6.8 cm long and 4.2 cm wide. Apophyses, pentagonal and hexagonal, almost flat, only close to the cone base convex, up to 12.0 mm wide, with a clearly visible sharp transverse keel and minor single longitudinal keel along with a few radial keels on the surface. Umbo sunken in apophyse, mucro relatively small, convex, excentromucronate.

Remarks. Despite the incompleteness and small differences in shape with that of the type material (slightly curved base v. symmetrical), it is rather clear that the specimen from Lubstów represents *Pinus ornata*. *Pinus ornata* is known from the Oligocene to Miocene of Central and Western Europe (Mai 1994).

According to Mai (1994), *P. ornata* is morphologically related to modern *Pinus merkusii* Jungh. et de Vriese. Farjon (2005a) described *Pinus merkusii* under *P. latteri* Mason, as being a wider distributed, closely related species. Despite the close relation those species are geographically separated, with *P. merkusii* being restricted to northern Sumatra and

the Philippines and *P. latteri* occurring much more often in almost all Indochina (except the southern Malay Peninsula) and southernmost provinces of China (Farjon 2005a).

Occurrence in the fossil floras of Poland. New species for Polish fossil floras.

### *Pinus* cf. *spinosa* Herbst

Pl. 3, figs 7a, 7b

- 1844 *Pinus spinosa* Herbst, p. 567–568.  
 1960 *Pinus spinosa* Herbst; Schloemer-Jäger, p. 224–227, Pl. 1, fig. 7.  
 2004 *Pinus spinosa* Herbst; Mai, p. 19–20, Pl. 3, figs 1–20.

Material. Pałnów, “sands in the apical part of the coal bed” – 3 cones fragments (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.1a).

Description. The best-preserved cone fragment is 6.9 cm long and 3.0 cm wide. Apophyses up to 1.0 cm wide, short, rhombic in shape, elevated. Umbo convex, centroerectomucronate.

Remarks. Apophyses morphology corresponds with *Pinus spinosa*, which is characterised by an extensive, convex umbo with a mucro protruding upwards (Mai 1986).

In Europe *P. spinosa* is known from the lower Miocene to Pliocene (Mai 1986), although the oldest known remains come from the Oligocene of Western Siberia (Dorofeev 1963). Based on Siberian finds, Mai (1986) suggested that *P. spinosa* may have spread to Europe from Asia, which probably coincides with the final closing of the Turgai strait.

The morphological interrelationships of extant pines and *P. spinosa* are not clear and left open. *Pinus spinosa* have much in common with both *P. maritima* Lam. sect. *Pinaster* from the western Mediterranean, and pines of the same section from North America (Mai 1986).

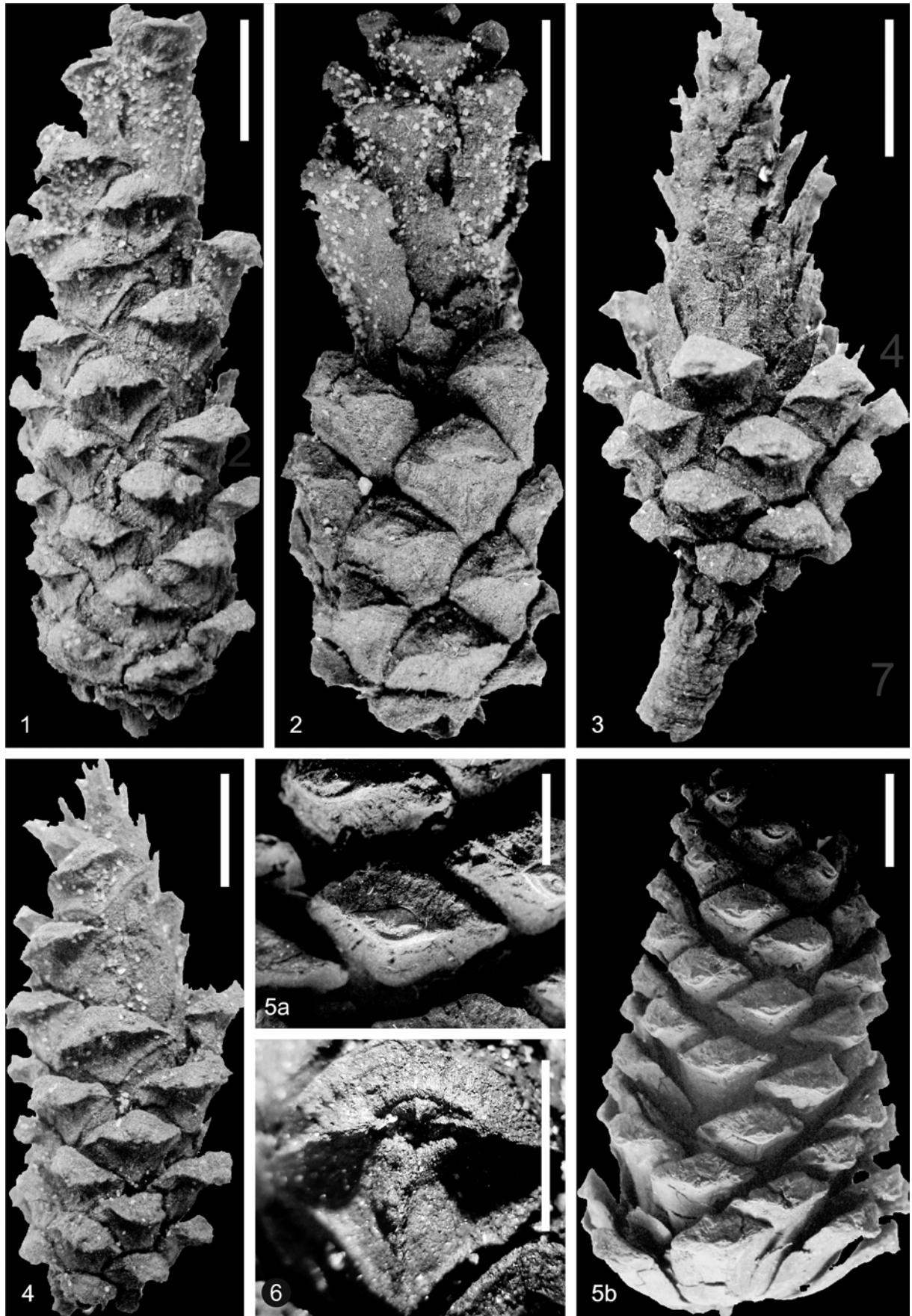
Occurrence in the fossil floras of Poland. Middle Miocene: Bełchatów (Stuchlik et al. 1990), Stare Gliwice (Szafer 1961), Wieliczka (Zabłocki 1928); Miocene: Zaręba (Lichtenau) near Jelenia Góra (Krausel 1920).

### *Pinus thomasiana* (Goepf.) Reichenbach

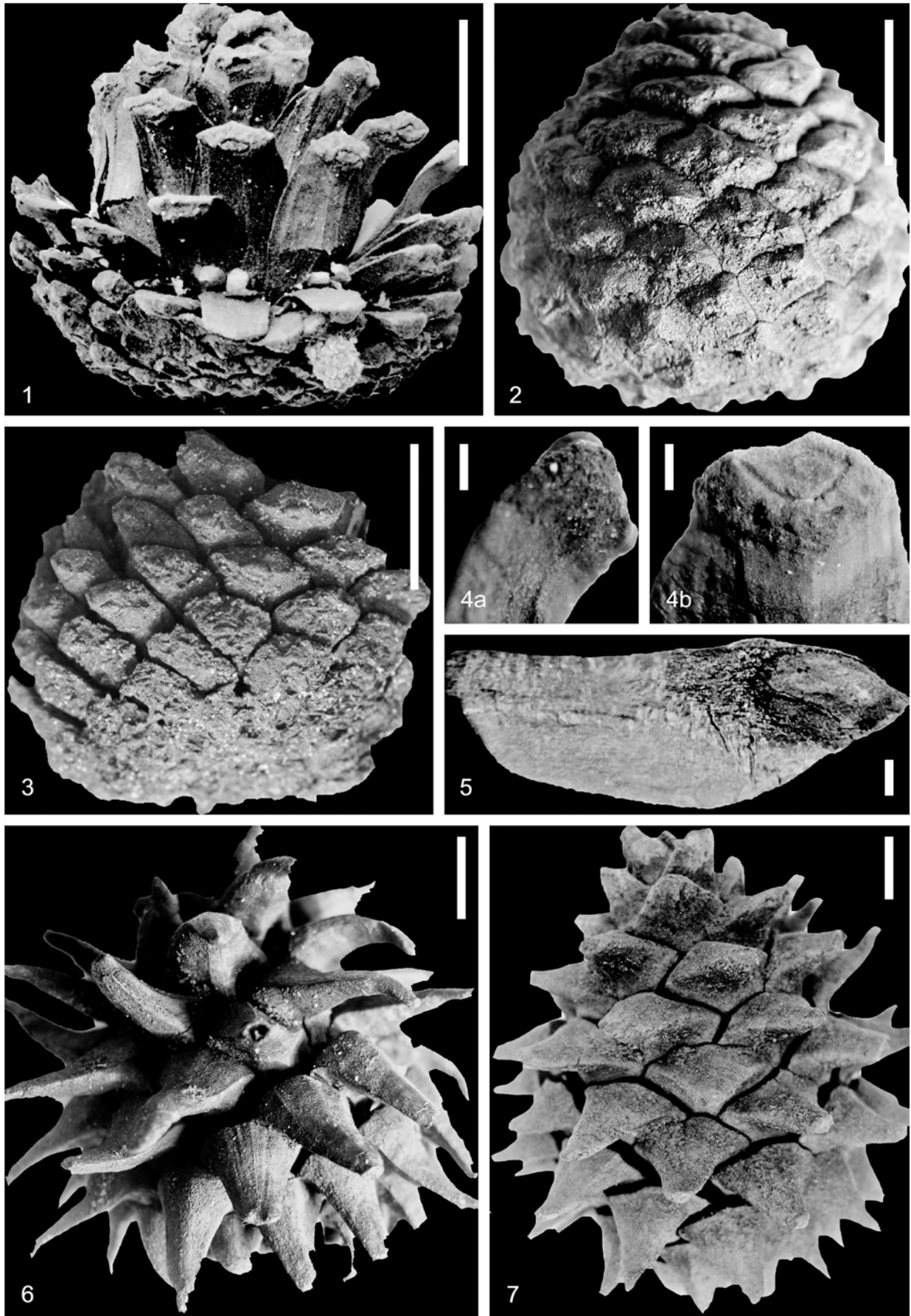
Pl. 1, figs 1–6

- 1869 *Pinus larico-thomasiana* Heer, p. 22–25, Tab. 1, figs 1–18  
 1919 *Pinus thomasiana* (Goepf.) Reichenbach, p. 115, Pl. 10, figs 29, 30.





**Plate 1.** 1–4. *Pinus thomasiana* (Goep.) Reichenbach, cones; scale bar = 1 cm; MZ VII/116/3; 5a. *Pinus thomasiana* (Goep.) Reichenbach, enlargement of 5b showing apophyses morphology; scale bar = 5 mm; MZ VII/121/1; 5b. *Pinus thomasiana* (Goep.) Reichenbach, cone; scale bar = 1 cm; MZ VII/121/1; 6. *Pinus thomasiana* (Goep.) Reichenbach, apophyse morphology; scale bar = 5 mm; MZ VII/116/3



**Plate 2.** 1–3. *Pinus brevis* Ludwig, cones; scale bar = 1 cm; MZ VII/116/4; 4a, b. *Pinus brevis* Ludwig, apophyse: a – profile view, b – abaxial side view; scale bar = 1 mm; MZ VII/116/4; 5. *Pinus brevis* Ludwig, seed; scale bar = 1 mm; MZ VII/116/4; 6–7. *Pinus urani* (Unger) Schimper, cones; scale bar = 1 cm; MZ VII/116/2

**Material.** Lubstów A – 1 seed cone (MZ VII/122/26); Lubstów B – 22 seed cones (MZ VII/116/3); Lubstów C – 2 seed cones (MZ VII/121/1).

**Description.** Seed cones ovate to narrowly ovate, slightly curved at the base, 3.0–6.0 cm long and 1.5–3.3 cm wide. Apophyses in the median belt of the cones broadly rhombic, up to 10.0 mm long and 5.0 mm wide, and convex in the upper and concave in the lower area, separated by a clearly visible transverse keel. Umbo articulate, convex, mucro small, excentromucronate. The cones are set on robust peduncles, up to 0.5 cm in diameter.

**Remarks.** Shapes, size of cones and apophyses' morphology clearly correspond with *Pinus thomasiana*, which is a relatively common fossil pine, well known from the upper Eocene (Dölau, Lieskau/Halle, Gaumnitz/Zeitz, Espenhain/Leipzig – Mai 1986), to Miocene (Chłapowo – Heer 1869, Mai 1986; Sjøby – Christensen 1975).

According to Mai (1986), comparable to *Pinus thomasiana* are extant *Pinus nigra* Arnold and *Pinus heldreichii* Christ., widespread consecutively in southern Europe, Asia Minor and northern Africa (Algeria and Morocco) at elevations of 250–1800 m a.s.l., and limited to the Balkans and Apennine Peninsula at elevations of 1000–2500 m a.s.l. (Farjon 2005a).

**Occurrence in the fossil floras of Poland.** Lower Miocene: Osieczów (Raniecka-Bobrowska 1962); Miocene: Chłapowo (Heer 1869).

### *Pinus urani* (Unger) Schimper

Pl. 2, figs 6, 7, Pl. 3, fig. 6

1960 *Pinus urani* (Unger) Schimper; Schloemer-Jäger, p. 227–231, Pl. 1, figs 8, 9.

1968a *Pinus urani* (Unger) Schimper; Kilpper, p. 213–220, Pl. 41, figs 12–14, Pl. 42, figs 4, 5, Pl. 44, figs 1–6.

**Material.** Lubstów A – 21 seed cones, 4 seeds (UWPalaeo/mag.2004/5-7; MZ VII/122/5-7); Lubstów B – 2 seed cones (MZ VII/116/2); Lubstów C – 8 seed cones (MZ VII/121/2); Pątnów, “sands in apical part of coal bed” – 1 seed cone (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.1a).

**Description.** Seed cones ovate, mostly open then broadly ovate, asymmetrical, 3.0–12.0 cm

long and 3.0–6.0 cm wide. Apophyses are variable in shape, broadly rhombic or pentagonal, predominantly on one side of the cone and extremely elongated (uncinate), up to 10.0 mm long, curved downward or protruding. The umbo is almost flat to elevated, conical, excentromucronate. Mucro small, denticulate.

Seeds obovate, winged, 12.0–14.0 mm long and 4.0 mm wide.

**Remarks.** Fossil pine species related to sect. *Sylvestres*, with highly variable cones. Very distinctive, considering the cones asymmetry and remarkably elongated apophyses. Cones of this species are the most common fossil pine and fossil remains in Lubstów.

This species is known from the Miocene to Pliocene of Central Europe (Berger 1951, Mädler 1939, Mai 1994), but is especially well studied in the Lower Rhenish Basin (Schloemer-Jäger 1960, Kilpper 1968a, Van der Burgh 1987).

According to Mai (1994), extant *Pinus uncinata* Ramond et DC. is most closely related to *Pinus urani*. *Pinus uncinata* grows on moors at elevations of 600–1600 m a.s.l. in the Pyrenees, Ore Mountains, Massif Central, Jura, Vosges and Bohemian Forest, (Farjon 2005a).

It is likely that the elongated apophyses in *Pinus urani* provided protection for seeds against squirrel predation and fire. A similar adaptation was reported in extant *Pinus muricata* D. Don (Linhart 1978).

**Occurrence in the fossil floras of Poland.** Middle Miocene: Lubstów, (Kowalski 2008, Zastawniak et al. 1996); Miocene: Pątnów (Mai 1986).

### Sciadopityaceae Luer. & Sacc.

#### *Sciadopitys* Siebold et Zucc.

#### *Sciadopitys tertiaria* Menzel

Pl. 4, figs 3, 4

1913 *Sciadopitys tertiaria* Menzel, p. 23, Pl. 3, figs 15–18.

2004 *Sciadopitys tertiaria* Menzel; Mai, p. 27–28, Pl. 6, figs 1–6.

**Material.** Gosławice, “bedded coal” – numerous needles on the surface and within a brown coal sample (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.5).

**Description.** Cladodes (“needles”) straight, 2.0–3.0 mm wide, the longest fully preserved

is ca 4.0 cm long, slightly tapering close to the base, predominantly apically retuse. Longitudinal groove running all along the abaxial and adaxial side of the “needle”, but on the adaxial side groove is only delicately marked and on the abaxial side, the groove is relatively broad.

**Remarks.** The needle fragments documented here were determined by Raniecka-Bobrowska using cuticular analysis. Careful re-examination of the photos prepared by Raniecka-Bobrowska confirmed the previous attribution. Raniecka-Bobrowska also found *Marcoduria inopinata* Weyland rootlets (Raniecka-Bobrowska 1970). According to Dolezych and Schneider (2007) *M. inopinata* can be assigned to *Sciadopitys*.

**Occurrence in the fossil floras of Poland.** Middle Miocene: Stare Gliwice (questionable, Szafer 1961), Turów (Zalewska 1961); Miocene: Cybinka, Górzycza, Ośno Lubuskie, Sieniawa, Smogóry, Spudłów (Gothan 1936).

#### Cupressaceae Gray

### *Cunninghamia* R. Br.

#### *Cunninghamia miocenica* Ettingshausen

Pl. 4, figs 1, 2a, 2b

- 1872 *Cunninghamia miocenica* Ettingshausen, p. 32: 167, Pl. 1, figs 30a, 30b.  
 1961 *Cunninghamia europaea* Szafer, p. 22–26, Pl. 6, figs 11–18.  
 1968b *Cunninghamia rhenana* Kilpper, p. 107–109, Pl. 35, fig. 13, Pl. 36, figs 1–5.  
 1989 *Cunninghamia miocenica* Ettingshausen; Walther, p. 287–311, Pl. 1–7.

**Material.** Lubstów A – 1 fragment of the apical part of stem (MZ VII/122/27).

**Description.** Apical part of stem, 3.1 cm long. Needles spirally arranged around the twig, straight or sigmoid, up to 8.0 mm long and up to 2 mm wide, gradually tapering toward the pointed apex, quadrangular or flattened in cross-section, serrulate at margin, ad- and abaxially keeled. Central resin duct clearly visible in cross-section. Stomata arranged in two bands on the adaxial side.

**Remarks.** Determination based only on morphology (general shape and serrulate margin). Preservation condition is similar to fossils from the lower Rhine Basin (Kilpper 1968b).

*Cunninghamia* is well known in Europe, from the Oligocene to Miocene (Mai & Walther 1991, Mai 1999a, 2000a, 2004, Szafer 1958).

According to Walther (1989), extant *Cunninghamia konishii* Hayata is closer to the fossil species than *C. lanceolata* (Lamb.) Hook. *Cunninghamia konishii* is distributed in Taiwan, China, Laos and Vietnam (Farjon 2005b, Nguyen et al. 2004).

**Occurrence in the fossil floras of Poland.** Middle Miocene: Stare Gliwice (Szafer 1958, 1961), Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997, Łańcucka-Środoniowa 1984).

### *Glyptostrobus* Endl.

#### *Glyptostrobus europaeus*

(Brongniart) Unger

Pl. 4, figs 6, 8

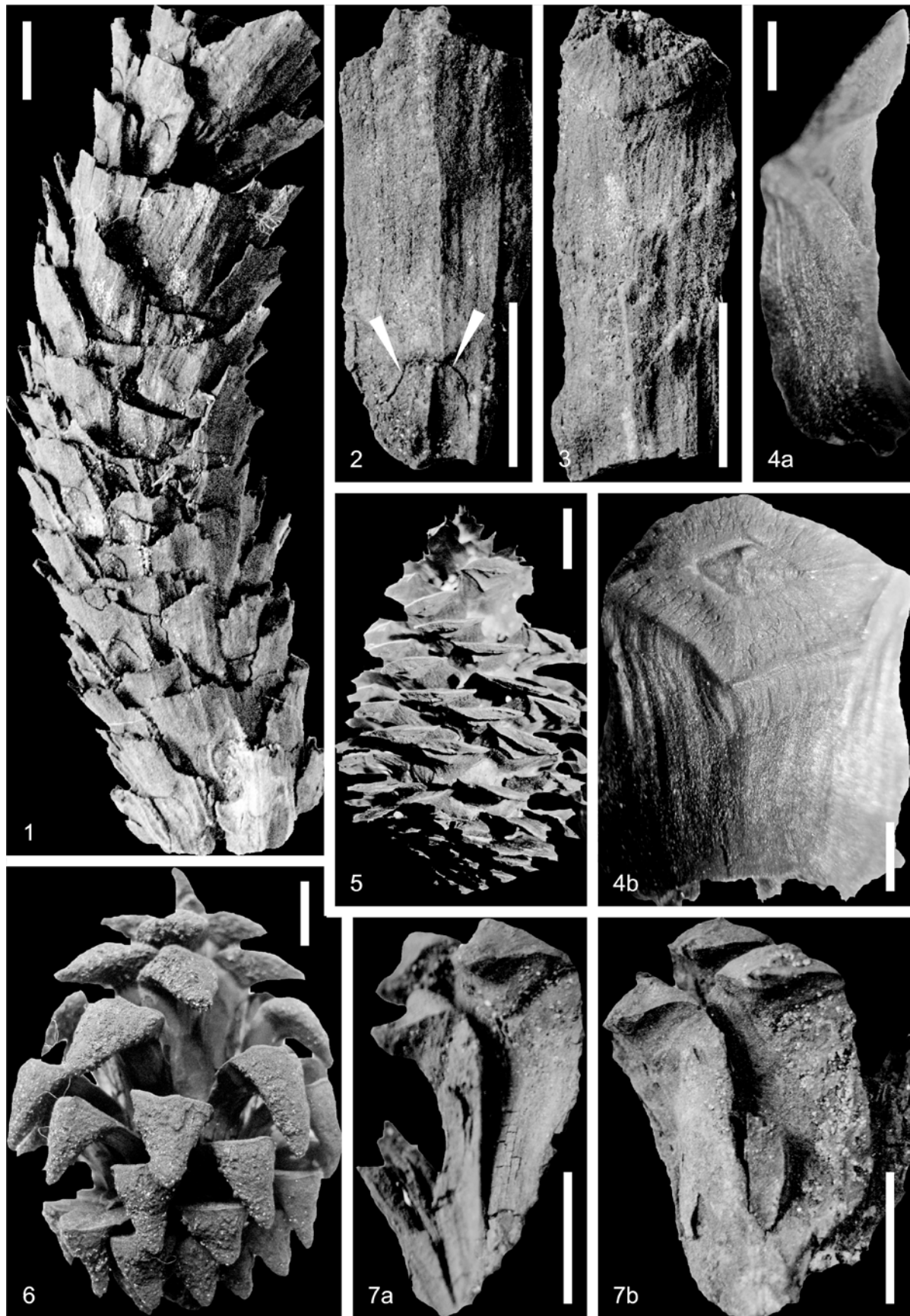
- 1833 *Taxodium europaeum* Brongniart, p. 168, Pl. 3, Pl. 12.  
 1850 *Glyptostrobus europaeus* (Brongniart) Unger, p. 434–435  
 2000a *Glyptostrobus brevisiliquatus* (Ludwig) Mai, p. 18, Tab. 9, fig. 1–3.

**Material.** Lubstów A – 1 ovuliferous scale fragment (MZ VII/122/4); Lubstów B – 3 seed cones (2 almost complete, 1 only partially preserved) and 1 ovuliferous scale (MZ VII/116/8); Lubstów C – 2 incomplete seed cones, 3 seeds (MZ VII/121/5, 6); Gosławice, “sands in apical part of coal bed” – 2 ovuliferous scales and 1 seed (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.2).

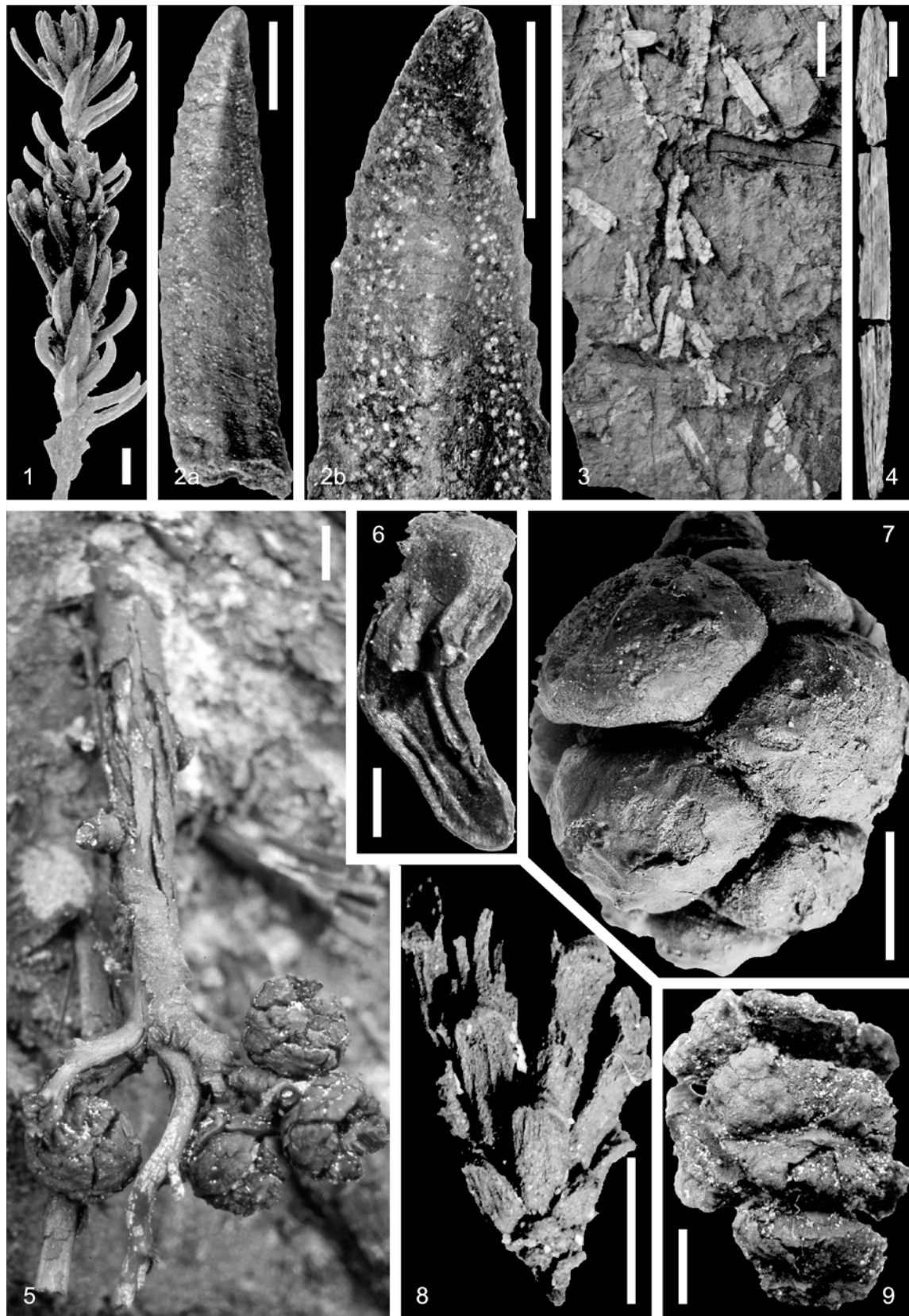
**Description.** Cones obovate, 2.0–3.0 cm long and 1.0–1.1 cm wide. Dorsal surface of the long and narrow ovuliferous scales with tooth-like bract, also pointed lobes on the margin of some of the scales. Seeds are sigmoid or curved, 5.0 mm long and 2.0 mm wide.

**Remarks.** Shape and size of cones, ovuliferous scales and seeds clearly represent *Glyptostrobus europaeus* (Brongniart) Unger. Loose fossil seeds were formerly included to separate species *G. brevisiliquatus* (Ludwig) Mai, but Mai (2004) synonymised *G. brevisiliquatus* within *G. europaeus* based on Czaja (2003) reports on finding seeds included in cone.

*Glyptostrobus europaeus* is a common element of the Cenozoic fossil floras in Central Europe, reported from the lower Eocene to



**Plate 3.** 1. *Pinus cf. leitzii* Kirchheimer, cone; scale bar = 1 cm; MuzPIG Warszawa 78.III.1; 2–3. *Pinus cf. leitzii* Kirchheimer, ovuliferous scales, arrow indicates: 2 – seeds imprint, 3 – apophyse remains; scale bar = 1 cm; MuzPIG Warszawa 78.III.1; 4a, b. *Pinus ornata* (Sternberg) Brongniart, ovuliferous scale: a – profile view, b – abaxial side view; scale bar = 2 mm; MZ VII/121/4; 5. *Pinus ornata* (Sternberg) Brongniart, cone; scale bar = 1 cm; MZ VII/121/4; 6. *Pinus urani* (Unger) Schimper, cone; scale bar = 1 cm; MZ VII/122/7; 7a, b. *Pinus cf. spinosa* Herbst, cone fragment; scale bar = 1 cm; MuzPIG Warszawa 78.III.1a



**Plate 4.** 1. *Cunninghamia miocenica* Ettingshausen, shoot; scale bar = 5 mm; MZ VII/122/27; 2a, b. *Cunninghamia miocenica* Ettingshausen, needle; scale bar = 1 mm; MZ VII/122/27; 3. *Sciadopitys tertiaria* Menzel, coal fragment with cladodes; scale bar = 1 cm; MuzPIG Warszawa 78.III.5; 4. *Sciadopitys tertiaria* Menzel, cladode; scale bar = 5 mm; MuzPIG Warszawa 78.III.5; 5. *Cupressus rhenana* (Kilpper) Mai et E. Velitzelos, branch with seed cones exposed within the outcrop wall; scale bar = 1 cm (photo courtesy K. Dembicz); 6. *Glyptostrobus europaeus* (Brongniart) Unger, seed; scale bar = 1 mm; MZ VII/121/6; 7. *Cupressus rhenana* (Kilpper) Mai et E. Velitzelos, seed cone, scale bar = 5 mm; MZ VII/122/2; 8. *Glyptostrobus europaeus* (Brongniart) Unger, seed cone; scale bar = 1 cm; MZ VII/116/8; 9. *Cupressus rhenana* (Kilpper) Mai et E. Velitzelos, seed cone, scale bar = 5 mm; MZ VII/122/2

Pliocene (Mai 2004). The genus *Glyptostrobus* consist of a single extant species, *G. pensilis* (Staunton et D. Don) K. Koch, distributed in swamp areas of southern Vietnam and south-eastern China (Farjon 2005b, LePage 2007). Its distribution is connected with a subtropical climate, with a mean annual temperature (MAT) of about 20–23°C and mean annual precipitation (MAP) of 1300–1800 mm (Luu & Thomas 2004).

Occurrence in the fossil floras of Poland. Middle Miocene: Lipnica Mała (Lesiak 1994), Morzysław (Raniecka-Bobrowska 1954, 1959), Rypin (Łańcucka-Środoniowa 1957), Stare Gliwice (Szafer 1961), Turów (Kowalski 2010, Zalewska 1959), “Zatoka Gdowska” (Łańcucka-Środoniowa 1966); Pliocene: Ruszów (Baranowska-Zarzycka 1988).

### *Cupressus* L.

#### *Cupressus rhenana* (Kilpper)

Mai et E. Velitzelos

Pl. 4, figs 5, 7, 9

- 1968b *Cupressoconus rhenanus* Kilpper, p. 102–103, Pl. 34, fig. 4–17  
 1985 *Cupressoconus rhenanus* Kilpper; Mai and Walther, p. 30, Pl. 5, fig. 21, 22.  
 1987 *Cupressoconus rhenanus* Kilpper; Van der Burgh, p. 304, Pl. 1, fig. 1, 5, 6, 8, 9.  
 1997 *Cupressus rhenana* (Kilpper) Mai and Velitzelos, p. 511, Pl. 2, figs 1–10.  
 2008 *Cupressoconus rhenanus* Kilpper; Kowalski, p. 279–280, Pl. 1, figs 3–6.

Material. Lubstów A – 2 seed cones, 10 scales and 9 seeds removed from one cone (MZ VII/122/2; UWPalaeo/mag.2004/2 – Kowalski 2008); Lubstów B – 1 seed cone (MZ VII/116/9).

Description. Seed cones solitary on short, robust branchlets, grouped in clusters, ellipsoid in shape, 1.6–2.1 cm long and 1.9–2.0 cm wide. Scales decussate, robust, peltate, 11–12 per cone, quadrangular or hexagonal, 5–10 mm long and 7–15 mm wide, with a rounded margin, abaxial face convex, with a central, knobby bract tip or with a transverse groove, with numerous, wide resin ducts. Seeds elliptic, 3.0–4.0 mm long and 1.5–2.8 mm wide, winged, covered with resinous verrucae and delicately striped longitudinally.

Remarks. In respect of the preservation and morphology, the seed cones from Lubstów

correspond exactly with those from the locality, Zukunft-West (Kilpper 1968b). According to Mai (Mai & Velitzelos 1997) the size of the cones (>15 mm) and number of seeds per scale (>4) clearly relate to the remains from the upper Miocene of Vegora and Lower Rhine Basin to *Cupressus*. Generally, these characteristics are relatively good for distinguishing most *Cupressus* species from *Chamaecyparis*, but there are some exceptions, like *Cupressus funebris* (seed cones >15 mm in diameter, 3–5 seeds per scale) (Farjon 2005b).

*Cupressus rhenana* was compared by Mai (Mai & Velitzelos 1997) with extant *C. sempervirens* L., *C. macrocarpa* Hartw. and *C. arizonica* Greene.

Occurrence in the fossil floras of Poland. Middle Miocene: Lubstów (Kowalski 2008).

### *Sequoia* Endl.

#### *Sequoia abietina* (Brongniart) Knobloch

Pl 5, figs 1, 2, 4–6

- 1822 *Phyllites abietina* Brongniart; Cuvier and Brongniart, p. 362, Pl. 11, fig. 13.  
 1855 *Sequoia langsdorfii* Heer, p. 54–55, Tab. 20, fig. 2, Pl. 21, fig. 4.  
 1964 *Sequoia abietina* (Brongniart) Knobloch, p. 601.

Material. Gosławice – 2 seed cone fragments within a sandstone sample, 19 scales, 15 seeds, and 13 fragments of foliage shoots (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.4).

Description. Seed cones broadly ellipsoid, 1.6 cm long and 8.5 mm wide, set on branchlet up to 9.0 mm long. Scales relatively loosely arranged perpendicular to the cone rachis, much broader than long, 3.0–5.0 mm long and 4.0–6.0 mm wide, with a transverse groove and small bract in the centre of the abaxial face. Seeds irregularly oval, 2.0–3.0 mm long and 1.8–2.5 mm wide, winged, pointed, slightly bent at the base, hilar area obtuse, concave, and locule more or less orthotropous.

Remarks. Cones, seeds and foliage shoots were identified by Raniecka-Bobrowska.

*Sequoia abietina* is known in Europe from the upper Eocene to the Pliocene epoch. *Sequoia* has a single species today, a relict *S. sempervirens* (D. Don) Endl, native to western USA, occurring mostly in mixed coniferous

forests along the Pacific coast of California and (Farjon 2005b). According to Mai (1997) fossil and extant species are almost indistinguishable, thus perhaps *S. abietina* is the ancestor to *S. sempervirens*.

The seeds cone preserved in sandstone also contains spherical structures, each with a relatively wide, round, single aperture. Comparable structures from the Miocene of Düren in Germany were identified by Möhn (1960) as galls. Based on larva and pupa remains preserved inside they were described as a new fossil genus *Sequoiomyia* Möhn of the family Itonididae (Möhn 1960). The shape and size suggest that the structures from Gosławice represent *Sequoiomyia*.

Occurrence in the fossil floras of Poland. The species is known from many Neogene sites (i.e.: middle Miocene: Dobrzyń (Kownas 1956), Rypin (Łańcucka-Środoniowa 1957), Turów (Zalewska 1959), Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997); upper Miocene: Bełchatów (Stuchlik et al. 1990).

#### Geinitziaceae Kunzmann

#### *Cupressospermum* Mai

#### *Cupressospermum saxonicum* Mai emend. Kunzmann

Pl. 5, fig. 3

1960 *Cupressospermum saxonicum* Mai, p. 74–75, Pl. 3, figs 1–5.

1999 *Cupressospermum saxonicum* Mai; Kunzmann, p. 91–98, Pl. 21–23.

2004 *Cupressospermum saxonicum* Mai, p. 26–27.

Material. Lubstów A – 5 seeds removed from 2 seed cones (MZ VII/122/3; UWPalaeo/mag.2004/3, 33) and 1 loose seed (MZ VII/122/43); Lubstów B – 4 seed cones (MZ VII/116/10); Lubstów C – 1 seed cone (MZ VII/121/7).

Description. Seed cones ellipsoidal, 15.0–16.0 mm long and 11.0–13.0 mm wide. Scales 19–30, spirally arranged, peltate, 2.0–5.0 mm in diameter, rounded at the margin, quadrangular, pentagonal or hexagonal, the abaxial face uniformly domed, with a small knobby bract tip. Seeds reniform, flat, 5.0–2.0 mm long and 1.25–1.50 mm wide, wing narrow, asymmetric winged, locule amphitropous.

Remarks. Remains found in Lubstów, B and C, clearly correspond with the cone and seeds

of the *Cupressospermum saxonicum*, previously described from Lubstów A (Kowalski 2008).

Occurrence in the fossil floras of Poland. Miocene: Lubstów (Kowalski 2008).

#### Nymphaeales Dumortier

#### Cabombaceae Rich. et A. Rich.

#### *Brasenia* Schreb.

#### *Brasenia victoria* (Caspary) Weberbauer

Pl. 6, figs 11a, 11b

1935b *Brasenia teumeri* Kirchheimer, p. 26–28, figs 1–4.

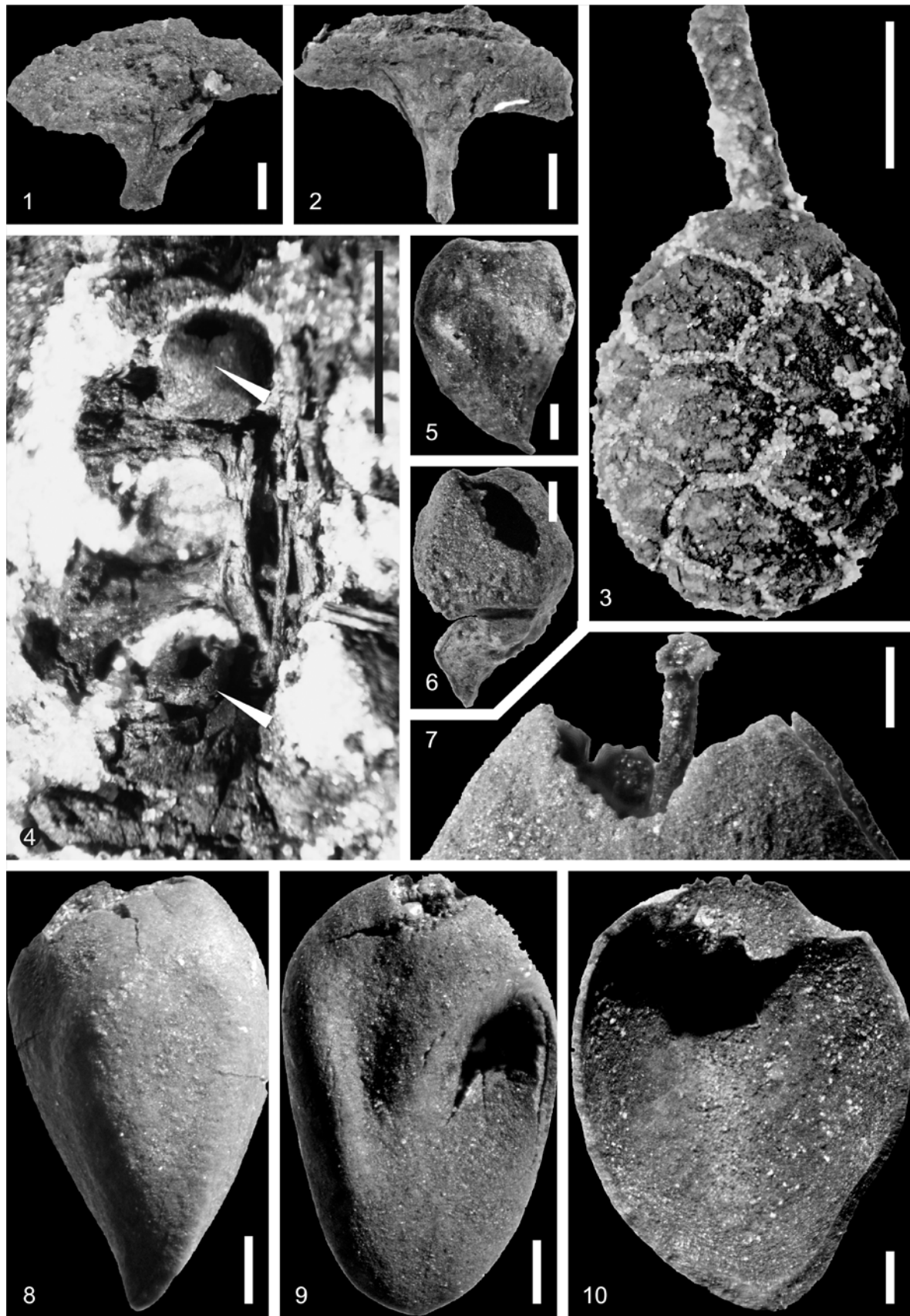
1999b *Brasenia victoria* (Caspary) Weberbauer; Mai, p. 13, Pl. 4, figs 1–12, Pl. 5, figs 1–5.

Material. Gosławice, “sands in the bottom part of the coal bed” – 6 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.10), Gosławice, “sandstone” – 6 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.9), Pałtów, “sandstone” – 6 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.9); Lubstów B – ca 100 seeds (MZ VII/116/14); Lubstów C – 33 seeds (MZ VII/121/11).

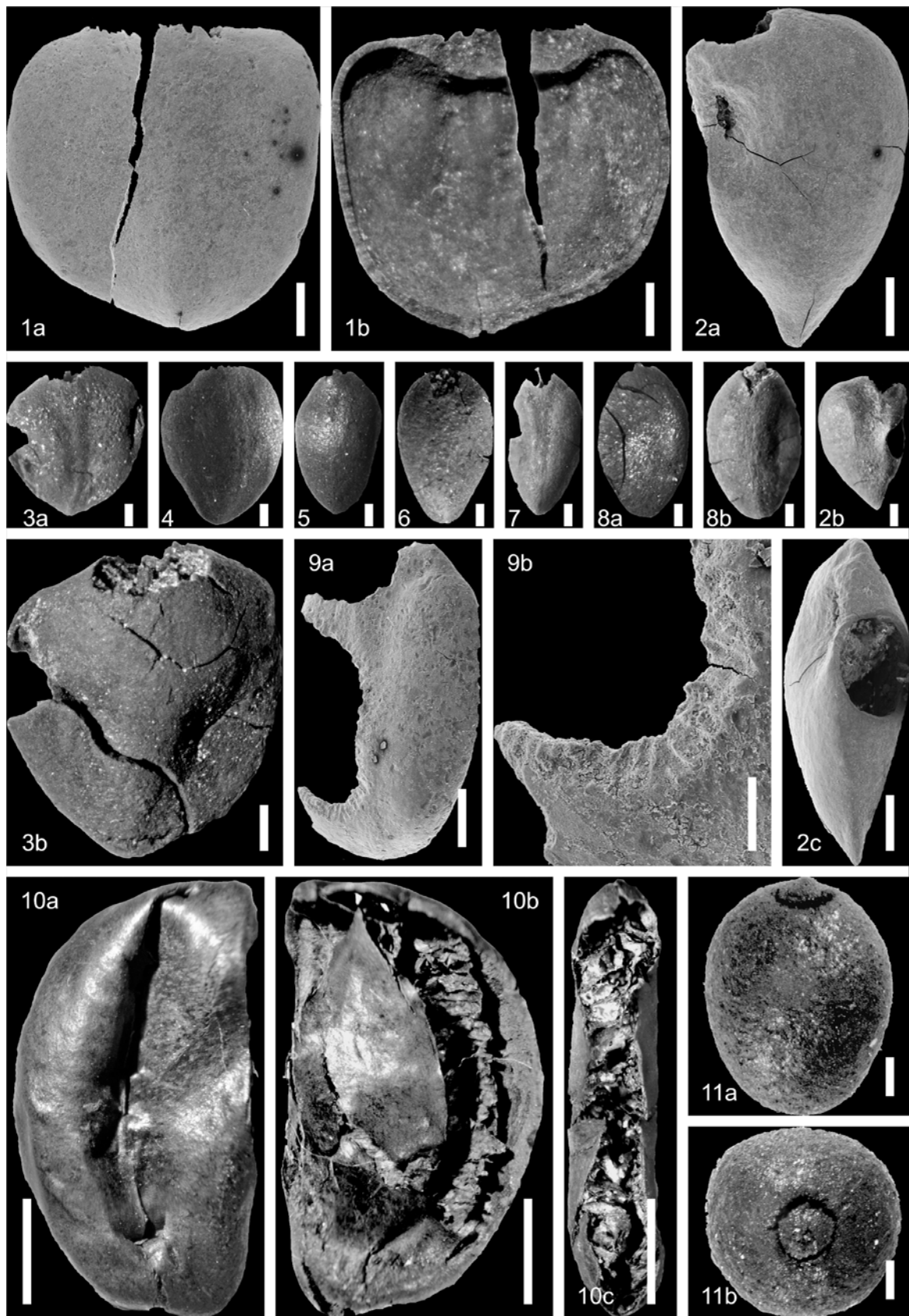
Description. Seeds ellipsoidal, barrel-like or occasionally subcircular, 1.7–3.0 mm long (2.0 mm on average) and 1.0–1.9 mm wide (1.6 mm on average). A truncated cone-shaped operculum is present at the apex of the seeds, serrated at the base margin, with a skewed pit or a depression at the apical surface; the cells of the operculum are rectangular. Seeds' surface smooth, matt or shiny, black, and composed of barely perceptible irregularly digitate cells. On the surface of some of the best-preserved seeds, small, oblong verrucae are present. Sclerotesta is ca 0.2 mm thick, consisting of perpendicular, thick walled cells and inner, much thinner, parenchymatous cells that are parallel to the surface.

Remarks. *Brasenia* has an excellent fossil record; more than 30 fossil species have been described in the Cenozoic of Eurasia so far (Mai 2008). Considering only the Miocene floras of the former Soviet Union territory, more than 10 species have been distinguished based on the size, morphology and anatomy of the seed wall (Dorofeev 1974, 1984, Nikitin 1976). The number of described species might suggest





**Plate 5.** 1, 2. *Sequoia abietina* (Brongniart) Knobloch, scales; scale bar = 1 mm; MuzPIG Warszawa 78.III.4; 3. *Cupressospermum saxonicum* Mai emend. Kunzmann, seed cone; scale bar = 1 cm; MZ VII/116/10; 4. *Sequoia abietina* (Brongniart) Knobloch, seed cone with *Sequoiomyia* Möhn galls (arrows); scale bar = 5 mm; MuzPIG Warszawa 78.III.4; 5–6. *Sequoia abietina* (Brongniart) Knobloch, seeds; scale bar = 0.5 mm; MuzPIG Warszawa 78.III.4; 7. *Magnolia ludwigii* Ettingshausen, detail of seed, chalazal end; scale bar = 0.5 mm; MZ VII/121/46; 8–10. *Magnolia ludwigii* Ettingshausen, seeds, 8–9 – external view, 10 – internal view; scale bar = 1 mm; MZ VII/121/46



**Plate 6.** 1a, b. *Magnolia ludwigii* Ettingshausen, external and internal view of the seed; scale bar = 1 mm; MZ VII/121/8; 2a, b, c. *Magnolia ludwigii* Ettingshausen, seed with rodent-gnawed? hole; scale bar = 1 mm; MZ VII/121/9; 3a, b, 4–8b. *Magnolia ludwigii* Ettingshausen, seeds, variability of shape; scale bar = 1 mm; MZ VII/121/8; 9a, b. *Magnolia ludwigii* Ettingshausen, a – seed with rodent gnawing, b – enlargement of a, showing teeth marks; scale bar: a = 1 mm, b = 0.5 mm; MZ VII/121/45; 10a–c. *Asimina brownii* Thomson, seed from Goslawice: a – lateral view, b – other side with partially exposed rumination, c – view of the ventral side with exposed rumination; scale bar = 5 mm; MuzPIG Warszawa 78.III.8; 11a, b. *Brasenia victoria* (Caspary) Weberbauer, seed: a – lateral view, b – apical view; scale bar = 0.5 mm; MZ VII/116/14

that *Brasenia* was remarkably diverse in the past. On the other hand, considering European fossil record, even the oldest seeds of *B. spinosa* Chandler known from upper Eocene of Hordle (Chandler 1925), are remarkable similar to the extant *B. schreberi* Gmel. According to Collinson (1980) European species differ only in size. This observation has prompted Collinson (1980) to suggest that the evolution in *Brasenia* may have proceeded towards the increasing size of the seeds.

Koch (1931) provided evidence that the presence of the verrucae on the seeds may be related with climatic conditions, as the *B. schreberi* that grows in the tropics possesses verrucae on the surface, unlike temperate climate populations. Therefore, the verrucate surface may not have any diagnostic value to discriminate between species. In view of this, Mai (2008) suggested that some authors may not have properly considered polymorphism and the dispersal ability of the *Brasenia* seeds whilst establishing new species. Therefore, many species distinguished in the European and Russian Cenozoic era may be closely related or even represent the same single species.

At present, the single species, *Brasenia schreberi* Gmel., is widely distributed in temperate and tropical (Williamson & Schneider 1993) of the North and Central America, Eastern Himalaya, East Asia, Australia, and Africa (Cook et al. 1974, Hutchinson 1959a, Takhtajan 1997). *Brasenia* prefers oligotrophic, low pH value water (Muenscher 1944, Srivastava et al. 1995) and fossil *B. victoria* possibly had similar ecological preferences, as the seeds are commonly accompanied with brown coals (Mai 1999b).

Occurrence in the fossil floras of Poland. Middle Miocene: Rypin (Łańcucka-Środoniowa 1957); upper Miocene: Stara Wieś (Łańcucka-Środoniowa 1981); Pliocene: Mizerna (Szafer 1954).

Nymphaeaceae Salisb.

*Nymphaea* L.

*Nymphaea szaferi* Knobloch

Pl. 7, figs 1–4

1957 *Nymphaea alba* L. foss. Łańcucka-Środoniowa; p. 25–27, Pl. 4, figs 1–7.

1961 *Nymphaea lotus* L. foss. Szafer; p. 51, Pl. 14, figs 13–15.

1964 *Carpolithus* sp. 4; Mai, p. 63–64, Pl. 7, figs 21–22.

1978 *Carpolithus* sp. 4; Mai and Walther, p. 150, Pl. 25, figs 17–21.

1978 *Nymphaea szaferi* Knobloch, p. 155–156, Pl. 2, figs 1–4, 7.

1999b *Nymphaea szaferi* Knobloch; Mai, p. 15–16, Pl. 4, figs 21–28, Pl. 5, figs 14–16.

Material. Lubstów A – 1 seed, (MZ VII/122/42) Gosławice, “intra-coal sands” – 18 seeds, “sands in apical part of coal bed” – 9 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.12); Pątnów, “sandstones under coal bed” – 9 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.11).

Description. Seeds ellipsoidal or ovate, 2.0–3.0 mm long and 1.0–2.0 mm wide, and ovate in the cross-section. At the apex of the seeds a circular operculum with a micropyle in the centre and hilum laterally on a small ridge are visible. A raphe runs along the longitudinal ridge, on one side of the seed. Seed surface glossy, dark brown or black, longitudinally ridged, and the sclerotesta cells are digitate.

Remarks. *Nymphaea szaferi* seeds have long been reported in Central Europe from the Oligocene to Pliocene (Mai 1999b). It is believed that the extant *N. lotus* L. is morphologically closest to *Nymphaea szaferi* (Szafer 1961, Knobloch 1978, Mai 1999b). *Nymphaea lotus* is distributed in Africa (Wiersema 1982) and in the only European locality in Oradea/Romania (Conard 1905). Morphologically close to the specimens documented here are the *N. borysthenica* Dorofeev seeds from the Pliocene of Kholmech. They are only slightly bigger and covered with hairs (Dorofeev 1971, Velichkevich & Zastawniak 2003), which probably are not preserved in our materials. According to Dorofeev (1974) *N. borysthenica* resembles *N. alba* L. foss. from the Miocene of Rypin (Łańcucka-Środoniowa 1957) and *N. lotus* L. from the Miocene of Stare Gliwice (Szafer 1961). These may suggest that *N. borysthenica* and *N. szaferi* represent a single species closely related with recent *N. lotus* (see also Mai 1999b).

Occurrence in the fossil floras of Poland. Middle Miocene: Stare Gliwice (Szafer 1961), Rypin (Łańcucka-Środoniowa 1957).

## Magnoliales Bromhead

## Magnoliaceae Juss.

**Magnolia** L.**Magnolia ludwigii** Ettingshausen

Pl. 5, figs 7–10, Pl. 6, figs 1a–9b

1868 *Magnolia ludwigii* Ettingshausen, p. 8711999b *Magnolia ludwigii* Ettingshausen; Mai, p. 3–4,  
Pl. 1, figs 13–17

**Material.** Pałnów, “sandstone in the basal part of the coal bed” – 27 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.7); Lubstów A – 1 seed (MZ VII/122/9; UWPalaeo/mag.2004/10 – Kowalski 2008); Lubstów B – 7 seeds (MZ VII/116/13); Lubstów C – 18 seeds, 30 seed fragments (MZ VII/121/8, 9, 45, 46).

**Description.** Seeds variable in shape, mostly ovate, 8.3–4.3 mm (6.6 mm on average) long and 6.3–2.5 mm (4.5 mm on average) wide, the average length to width ratio (L/W) is 1.5. Nucellar end rounded, but many seeds have a micropylar beak. The heteropyle is of the moat-and-stalk type, or slightly constricted at the chalazal end, moat round or v-shaped, or round on the dorsal side and v-shaped on the ventral side, terminal or sometimes sublateral, moat edge frayed, and the stalk (if preserved) long and narrow. The raphal sinus is clearly expressed with a slightly raised or faint raphal trace. Sclerotesta 0.2–0.5 mm wide.

**Remarks.** The seeds from Pałnów were identified by Raniecka-Bobrowska as the *Magnolia burseracea* (Menzel) Mai.

The studied seeds were differentiated into two morphological types. A prevailing morphotype has a >1.4 in average long to wide (L/W) ratio, which corresponds to *Magnolia ludwigii* Ettingshausen (average L/W ratio 1.3) from Salzhausen (Mai 1975, 1999b), but they are approximately 2 mm smaller in each dimension with ca 0.2 mm thinner sclerotesta. Another morphotype represented only by four specimens has a L/W ratio (1.0–1.25), similar to the subcircular (average L/W ratio 1.1) seeds of the *Magnolia burseracea* from Sandförstgen (Mai 1975). However, the other characteristics, especially the morphology of the micropylar and heteropylar area in both types, are similar. Hence, they are included in a single

species, provisionally assigned to *M. ludwigii*, with a broad range of shape variation.

The morphological variability of the *M. burseracea* and *M. ludwigii* has been discussed several times. Both morphotypes were originally described by Kirchheimer (1935a) as a single species *M. sinuata* Kirchw. Mai (1975) divided this species into *M. burseracea* and *M. ludwigii* based on L/W ratio and thickness of sclerotesta. However, Tiffney (1977) suggested they are very close to each other. Lubstów and Pałnów materials indicate that the size and L/W ratio are inadequate criteria for distinguishing between *M. burseracea* and *M. ludwigii*. Further studies are necessary to ascertain whether the two species have been appropriately identified.

Mai (1975) suggested the possible relationship of *Magnolia ludwigii* to the extant North American magnolias of the sections *Theorodon* and *Rytidospermum*, especially with *M. ashei* Weatherby. Tiffney (1977), and also later Mai (1999b), noted that *M. ludwigii* and *M. burseracea*, are morphologically comparable to *M. waltonii* Tiffney, a fossil species from North America, and that they show a close morphological resemblance to the extant magnolias of the sections *Tulipastrum* (*M. acuminata*, *M. cordata*, *M. liliflora*) and *Theorodon* (*M. schiedeana*, *M. sororum*, *M. grandiflora*). The key to magnoliaceous genera proposed by Xu (2003) suggests that seeds from Lubstów and Pałnów, especially those with a slightly constricted chalazal end, correspond with North American magnolias.

The holes (ca 1.5 mm in diameter) which can be seen on two seeds from Lubstów C have been interpreted as the result of rodent gnawing.

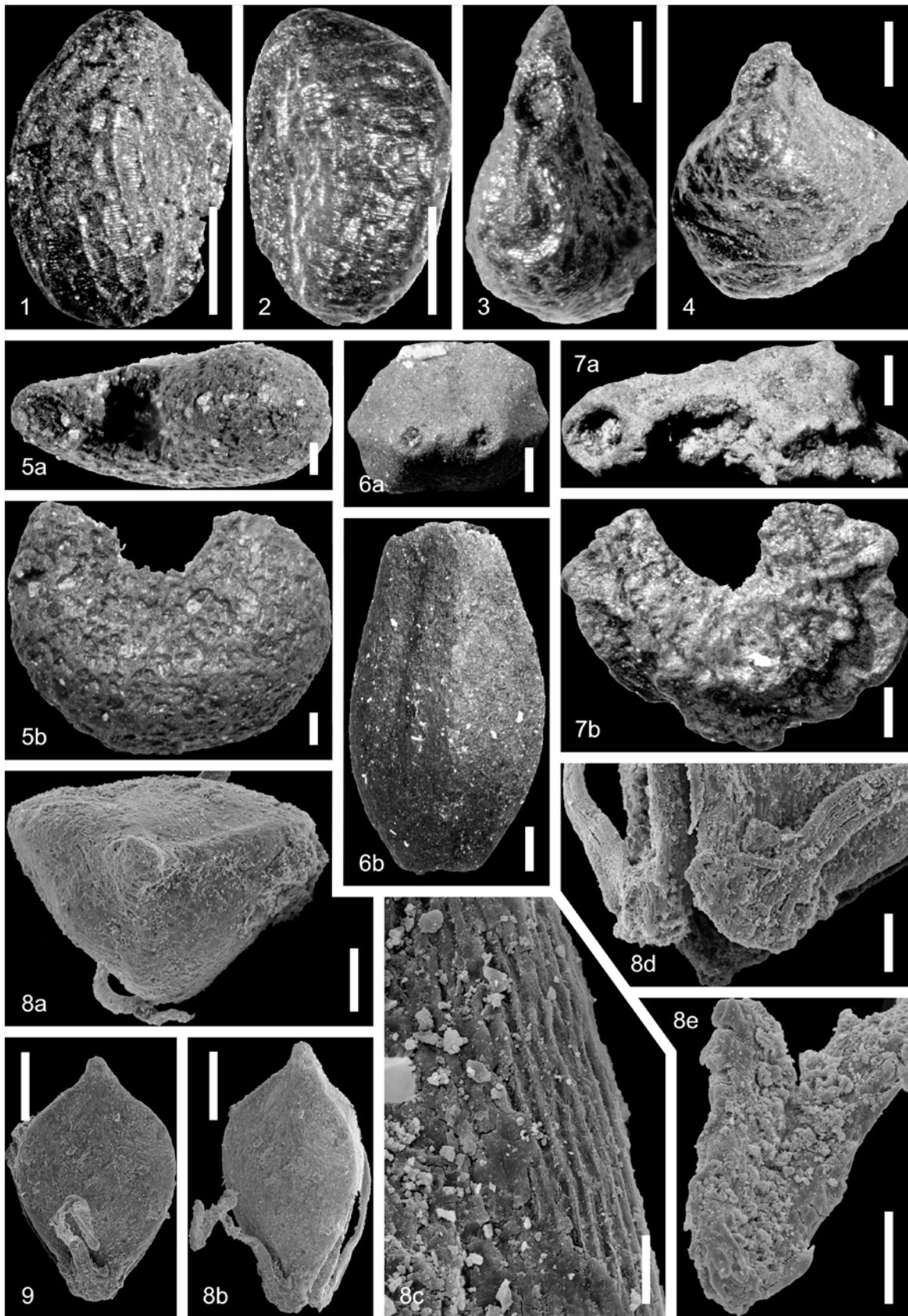
**Occurrence in the fossil floras of Poland.** Middle Miocene: Adamów (Mai 1975) upper Miocene: Nowogród Bobrzański, Jordanów (Kräusel 1920); Pliocene: Krościenko (Szafer 1947).

## Annonaceae Juss.

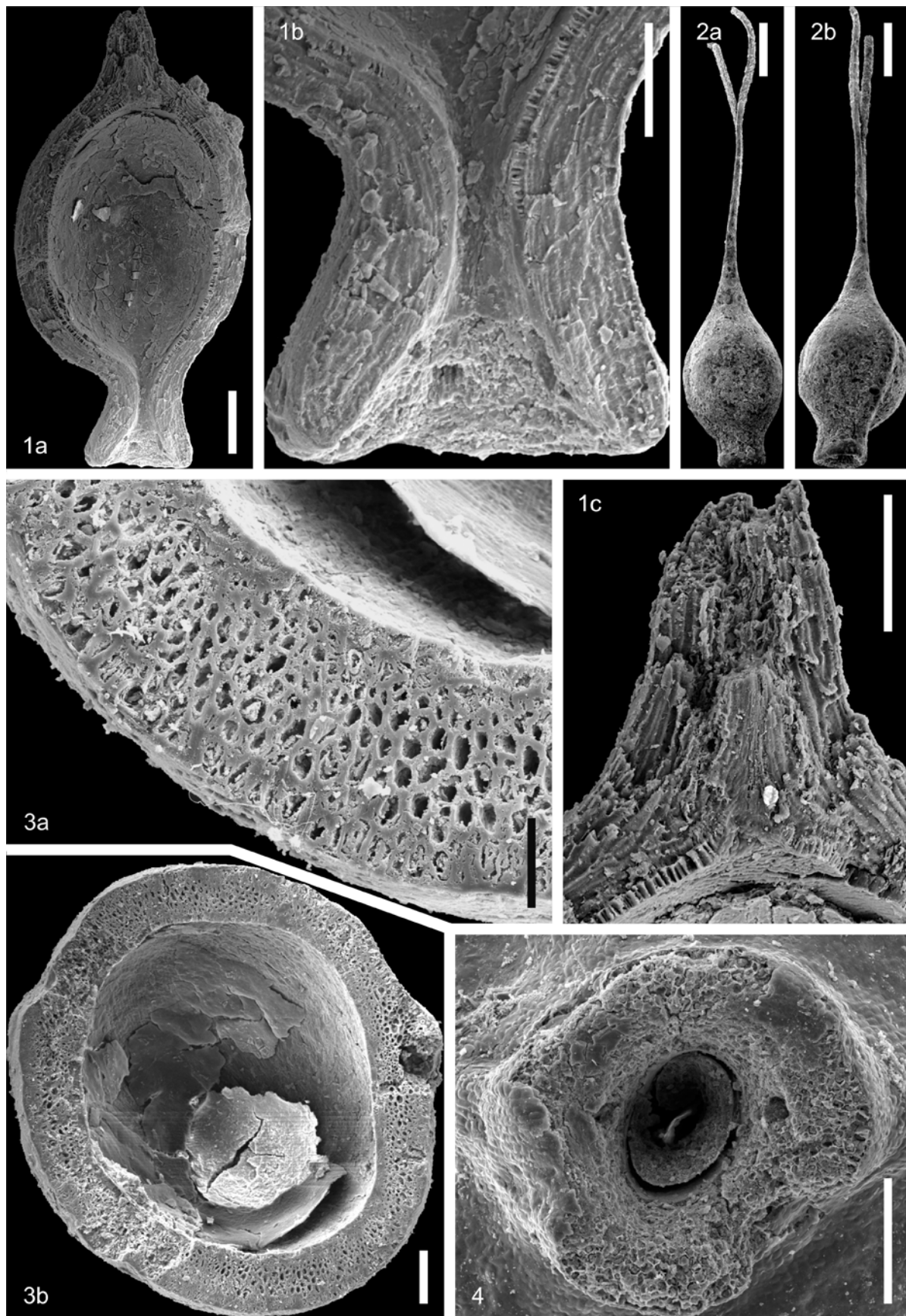
**Asimina** Adans.**Asimina brownii** Thomson

Pl. 6, figs 10a–10c

1954 *Asimina brownii* Thomson, p. 314–315, Pl. 1–5.1990 *Asimina brownii* Thomson; Geissert et al., p. 18,  
Pl. 16, fig. 29.



**Plate 7.** 1–4. *Nymphaea szaferi* Knobloch, seeds: 1, 2 – lateral view, 3, 4 – apical view; scale bar: 1, 2 = 1 mm, 3, 4 = 0.5 mm; MuzPIG Warszawa 78.III.12; 5a, b. *Epipremnites reniculus* (Ludwig) Mai, seed: a – ventral side, b – lateral view; scale bar = 0.5 mm; MZ VII/121/21; 6a, b. *Sparganium bessarabicum* Negru, endocarp: a – apical view, b – lateral view; scale bar = 0.5 mm; MZ VII/121/23; 7a, b. *Urospathites dalgasii* (Hartz) Gregor et Bogner, seed: a – ventral side, b – lateral view; scale bar = 0.5 mm; MZ VII/121/22; 8a–e. *Scirpus lusaticus* Mai, achene: a – style end view, b – lateral view, c – epidermal cells enlargement, d – base end view, e – bristle enlargement; scale bar: a = 250  $\mu$ m, b = 0.5 mm, c = 25  $\mu$ m, d, e – 100  $\mu$ m; MZ VII/121/20; 9. *Scirpus lusaticus* Mai, achene; scale bar = 0.5 mm; MZ VII/121/43



**Plate 8. 1a–c.** *Kownasia lubstovensis* Kowalski, fruit: **a** – internal view, **b** – enlargement of **a**, base, **c** – enlargement of **a**, apex; scale bar: **a** = 0.5 mm, **b**, **c** = 250  $\mu$ m; MZ VII/122/46; **2a, b.** *Kownasia lubstovensis* Kowalski (Holotype), general view of the fruit with preserved style and stigma; scale bar = 1 mm; MZ VII/122/36; **3a, b.** *Kownasia lubstovensis* Kowalski, **a** – enlargement of **b**, **b** – fruit in cross-section; scale bar: **a** = 100  $\mu$ m, **b** = 250  $\mu$ m; MZ VII/122/55; **4.** *Kownasia lubstovensis* Kowalski, polar view, showing the base with central channel closed by a plug; scale bar = 250  $\mu$ m; MZ VII/122/56

**Material.** Pątnów, “sandstone” – 1 seed (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.8); Gosławice, “sandstone” – 4 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.8).

**Description.** Large, elliptic seeds, fully preserved specimen 2.1 cm long and 1.2 cm wide (seed fragments 1.4–2.6 cm long and 0.85–1.4 cm wide). Seed surface smooth, matt. Inside the seeds lamellar structures, indicating endosperm rumination, can be observed.

**Remarks.** The seeds were reported by Raniecka-Bobrowska (1970), but without a description and photographs.

*Asimina brownii* is a rare species known so far from a few localities in Europe, mainly from the upper Miocene of the Lower Rhine Basin, like Düren (Thomson 1954), Eschweiler, Fortuna and Hambach (Van der Burgh 1987). Furthermore, this species is also known from the upper Miocene of Chiuzbaia/Romania (Mai & Givulescu 1976), Pliocene of Sessenheim/France and Valdarno/Italy (Geissert et al. 1990). A second fossil *Asimina* species, *A. germanica*, Mai and Givulescu was described from the upper Eocene of Geiseltal (Mai & Givulescu 1976). *A. germanica* seeds are smaller, more circular and have a thicker seed coat.

According to Mai and Givulescu (1976), among recent *Asimina* particularly comparable to the Neogene species is *A. triloba* (L.) Dunal, widely distributed throughout the eastern United States, from New York to northern Florida, and the southernmost Ontario, Canada (Kral 1960). However, according to Steven Manchester (personal communication), it is questionable to distinguish the genera of Annonaceae using the seed morphology and patterns of rumination as a basis.

**Occurrence in the fossil floras of Poland.** Miocene: Gosławice (Raniecka-Bobrowska 1970).

## Alismatales Dumortier

### Araceae Juss.

#### *Epipremnites* H.-J. Gregor et J. Bogner

##### *Epipremnites reniculus* (Ludwig) Mai

Pl. 7, figs 5a, 5b

1913 *Carpolithus reniculus* Menzel, p. 19, Pl. 1, fig. 37.

1979 *Epipremnum crassum* C. & E.M. Reid; Łańcucka-Środoniowa, p. 92–94, Pl. 15, figs 1, 2.

1989a *Epipremnites reniculus* Mai, s. 40, Tab. 8, fig. 21, 22.

**Material.** Gosławice, “intra-coal sands” – 26 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.29) and 10 seeds (coll. Raniecka-Bobrowska – MuzPIG Warszawa 78.III.25); Pątnów, “sands under coal bed” – 2 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.25); Lubstów B – 1 seed (MZ VII/116/12); Lubstów C – 158 seeds (MZ VII/121/21).

**Description.** The seeds are hook like, flat, 3.0–5.0 mm long and 1.0–2.2 mm wide. Micropylar end extruded, with a broad aperture. Hilum within depression, bordered by thin ridges. The seed surface is smooth, matt.

**Remarks.** According to Dorofeev (1963) and Gregor and Bogner (1984) these distinctive seeds represent an extinct genus of the subfamily Monsteroideae. The most morphologically similar seeds are those of extant *Epipremnum* Schott (Gregor & Bogner 1984). At present, Monsteroideae are distributed in both Neotropical and Palaeotropical floral kingdoms (Hutchinson 1959b).

**Occurrence in the fossil floras of Poland.** Lower Miocene: Nowy Sącz (Łańcucka-Środoniowa 1979); middle Miocene: Lipnica Mała (Lesiak 1994); Miocene: Bełchatów (Stuchlik et al. 1990); Pliocene: Ruszów (Baranowska-Zarzycka 1988).

#### *Urospathites* H.-J. Gregor et J. Bogner

##### *Urospathites dalgasii* (Hartz)

Gregor et Bogner

Pl. 7, figs 7a, 7b

1909 *Carpolithus dalgasii* Hartz, p. 58, Pl. 3, fig. 10

1964 *Carpolithus cristatus* Mai, p. 53–54, Pl. 4, figs 24, 25.

1984 *Urospathites dalgasii* (Hartz) Gregor and Bogner, p. 6, Pl. 3

**Material.** Lubstów C – 1 seed (MZ VII/121/22).

**Description.** The seed is hook like, flat, 3.5 mm long and 2.7 mm wide. Uneven, knobby crest runs along the dorsal side of the seed, and small knobs are grouped in a row on both sides of the seed. A micropylar end with a broad funnel-shaped aperture. Hilum ventrally, within depression. Seed surface rugged.

Remarks. According to Gregor & Bogner (1984), the seeds of extant *Urospatha* Schott resemble *Urospathites dalgasii*. *Urospatha* is an aquatic plant from Central and South American (Mayo et al. 1998, Stevens et al. 2001).

Occurrence in the fossil floras of Poland. Lower Miocene: Nowy Sącz (Łańcucka-Środoniowa 1979); middle Miocene: Stare Gliwice (Szafer 1961).

## Poales Small

### Typhaceae Jussieu

#### *Sparganium* L.

##### *Sparganium bessarabicum* Negru

Pl. 7, figs 6a, 6b

1979 *Sparganium bessarabicum* Negru, p. 44, Pl. 4, fig. 6.

1999a *Sparganium bessarabicum* Negru; Mai, p. 54, Pl. 27, figs 6–10.

Material. Lubstów C – 1 endocarp (MZ VII/121/23).

Description. Endocarp ellipsoidal, 4 mm long and 2 mm wide, lenticular in cross-section, base and apex truncate, and small longitudinal ribs on both sides. Two locules inside.

Remarks. This endocarp is very similar to the specimen from Kaltwasser (Tab. 27, fig. 7, Mai 1999a), which is only slightly longer. This is not a common species, reported so far only from a few lower Miocene sites in Lusatia (Mai 1999a) and from the upper Miocene of Moldova (Negru 1979).

Occurrence in the fossil floras of Poland. The taxon has not been reported from Poland.

### Cyperaceae Juss.

#### *Scirpus* L. s. lat.

##### *Scirpus lusaticus* Mai

Pl. 7, figs 8a–8e, 9

1999a *Scirpus lusaticus* Mai; s. 48, Tab. 24, fig. 1–4.

Material. Pałnów, “sands in the bottom part of the coal bed” – 23 fruits (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.28);

Lubstów A – 1 fruit (MZ VII/122/31); Lubstów B – 1 fruit (MZ VII/116/11); Lubstów C – 56 fruits (MZ VII/121/20, 43–44).

Description. Achenes fusiform or broadly obovate, 1.5–2.0 mm long and 0.8–1.3 mm wide, 3-sided, with ± sharp angles, sides convex or flat, with one side always broader than the others. Fruit apex with persistent, slender style base. The surface is smooth, shiny, black, surface cells distinct, fine, and longitudinally elongated. Bristles rarely preserved, mostly 3, tape like, longer than the fruit, barbellate.

Remarks. In respect to the shape, size and general morphology, these fruits closely resemble *Scirpus lusaticus* from the lower Miocene of Hartau/Germany described by Mai (1999a), as well as the middle Miocene of Nochten and upper Miocene of Wischgrund (Mai 2000a). More than 10 species of *Scirpus* have been described from the Miocene of Central Europe (Mai 1997, 1999a, 2000a), but many of them are difficult to identify, due to the insufficient, shallow descriptions.

In seeking the generic affinity of these fossils' interactive key (IntKey): Sedge genera of the world (Bruhl 1995, Watson & Dallwitz 2015) have also been used. Based on the following characters: i) longitudinally elongated epidermal cells, ii) triangular shape in cross-section, iii) style-base “not enlarged”, iv) fruit wingless, without ribs, v) perianth present, the fossil fruits have been attributed to *Schoenoplectus*. Despite this the classification proposed by Bruhl (1995) has been criticised (Goetghebeur 1998), this identification is in accordance with the affiliation suggested by Mai (1999a). Mai's opinion is that there are close morphological relations between *Scirpus lusaticus* and the extant *Scirpus etuberculatus* (Steud.) Kuntze from eastern and southern North America (Whittemore & Schuyler 2002), which is now considered as belonging to *Schoenoplectus etuberculatus* (Steud.) Soják (Govaerts et al. 2007).

*Scirpus* s. lat. has been split into many separate genera (Goetghebeur 1998, Govaerts et al. 2007), but distinguishing between *Scirpus* s. strict. and other *Scirpaea* based on general morphology of fossil fruits is difficult (Mai & Walther 1988). On the other hand, recent studies of the pericarp diversity (Lye 2016) have suggested that clarification of the taxonomic diversity and the mutual relationship



between the fossil *Scirpaea* is possible, based on the fruit wall anatomy.

Occurrence in the fossil floras of Poland. Middle Miocene: Stare Gliwice (Szafer 1961)

***Kownasia*** Kowalski n. gen.

Pl. 8, figs 1a–4

Type species. ***Kownasia lubstovensis*** Kowalski n. sp.

Holotype. Pl. 8, figs 2a, b (MZ VII/122/36), collection of the Museum of the Earth PAS.

Locus typicus. “Lubstów” open cast mine near Konin.

Stratum typicum. Middle Miocene.

Derivatio nominis. The genus *Kownasia* is named in honour of Stefan Kownas for his contribution to Polish palaeobotany. The epithet refers to the Lubstów open cast mine.

Combined generic and specific diagnosis. Fruits with a long conical apex, base stipitate (stipe conical, 1/5 fruit length). Pericarp composed of epicarp, relatively thick mesocarp (broader than endocarp), and a thin endocarp, which are inseparable.

Material. Lubstów A – 10 fruits (MZ VII/122/36, 46, 55–57).

Description. Fruits ellipsoid, ovoid to globose, ± circular in cross-section, 2.2–3.0 mm long (from fruit base to style base) and 1.6–2.0 mm wide, with a pair of longitudinal ribs opposite on both sides of the pericarp wall. Apex gradually tapering into long, up to 6 mm, style and stigma remnants, style ± as long as fruit, with two, long (± as long as style) stigma branches. The base is expanded (stipitate), conical, with the central channel closed by a plug. Pericarp surface shiny black, with fine rectangular cells, parallel to the long axis of the fruit. The pericarp wall is three layered, 254 µm thick in cross-section, but 333 µm thick in the vascular bundle area. The epicarp is thin, ca 63 µm thick, and composed of a single cell layer. The mesocarp is ca 156 µm thick, composed of cells with only a slightly thickened wall, isodiametric in the cross-section and rectangular in the longitudinal section. The endocarp is ca 40 µm thick, composed of a single layer of sclerenchymatous cells, short and rectangular in shape, plus oriented perpendicular to the surface.

Remarks. *Kownasia* fruits resemble to some extent the fossil genus *Cladiocarya* Reid & Chandler; both have a comparable size (especially: *C. colwellensis* (Chandler) Mai, *C. hispanica* (Reid & Chandler) Mai, *C. lusatica* Mai), shape in the cross-section and two longitudinal ribs on sides. However, the fruits of *Cladiocarya*, unlike *Kownasia*, do not possess a distinct, articulated basal stipe and have a much thicker (ca 6 times thicker) and more easily separable mesocarp.

According to Chandler (1962, 1963) and Mai & Walther (1978) *Cladiocarya* resembles some modern genera, especially *Mapania* (subfamily Mapanioideae, tribe Hypolytreae), *Diplacrum* (subfamily Cyperoideae, tribe Bisboeckeler-eae) and *Cladium* (subfamily Cyperoideae, tribe Schoeneae).

An attempt was made to determine the modern Cyperaceae genus using the computer key IntKey: Sedge genera of the world (Bruhl 1995, Watson & Dallwitz 2015). Based on the following characters: two carpelate, circular in cross-section fruits, the fossil has been attributed to the multiple genera of different subfamilies, including: *Capitularina*, *Exocarya*, *Mapania*, *Chorizandra*, *Chrysitrix* (Mapanioideae), *Kyllingiella*, *Lipocarpha*, *Fimbristylis*, *Schoenus* (Cyperoideae), and *Calyptracarya* (Sclerioideae). Some of them can be eliminated when using epicarp morphology as the basis, and the style and style base characters; however, linking *Kownasia* with one of these genera has not been successful. These observations lead to the conclusion that *Kownasia* represents an extinct genus, but the plug-like structure in the conical base suggests an affinity with Mapanioideae (Smith et al. 2009).

***Cladiocarya*** E.M. Reid & Chandler

***Cladiocarya europaea*** (Dorofeev) Mai

Pl. 9, figs 1a–1c, 2, 3

1978 *Cladiocarya europaea* Mai; Mai & Walther, p. 143–144, Pl. 1, fig. 9, Pl. 48, figs 37, 38.

1997 *Cladiocarya europaea* Mai; p. 82–83, Pl. 12, figs 11–13.

Material. Lubstów A – 3 fruits (MZ VII/122/43); Gosławice, “sands in the bottom part of the coal bed” – 4 fruits (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.27), and “sandstones from the spoil tip” – 8 fruits (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.26).

**Description.** Fruits ovoid, 0.8–1.2 mm long and 0.7–1.1 mm wide, and round to slightly elliptic in cross-section. Truncated or slightly expanded at the base. Two types of preservation can be observed: more or less complete pericarps with gradually tapering style remnants, a pair of longitudinal ribs on both sides of the fruit and minor vascular bundles scattered on the surface and isolated endocarps, with a smooth surface and round or occasionally with a small apex at the top.

**Remarks.** These remains were attributed by Raniecka-Bobrowska to *Sparganium* sp. or to *Sparganium chomutovense* Bůžek. Based on the shape, size, clearly elongated apex, truncated base and the symmetric ribs, these fruits definitely correspond with *Cladiocarya europaea*. The fruits of *Sparganium chomutovense*, from the Miocene of Havraň/Chomutov (Bůžek & Holý 1964) were assigned by Mai & Walther (1978) to *Caricoidea jugata* (Nikitin) Mai, another fossil European Cyperaceae. According to Mai (1997), morphologically related to *Cladiocarya europaea* are fruits of the extant *Diplacrum* R. Br., the tribe Sclerieae (Goetghebeur 1998). *Cladiocarya europaea* is well known in Central Europe from the middle Eocene to the Pliocene (Mai 2000a).

**Occurrence in the fossil floras of Poland.** The taxon has not been reported from Poland so far.

Saxifragales Berchtold et J. Presl

Hamamelidaceae R. Br.

***Fothergilla*** L. in J.A. Murray

***Fothergilla europaea*** Szafer

Pl. 9, figs 6–8

1947 *Fothergilla europaea* Szafer, p. 247–251, Pl. 7, figs 33–35.

1990 *Fothergilla europaea* Szafer; Geissert et al., p. 24, Pl. 19, fig. 16.

**Material.** Goślawice, “sands in the bottom part of the coal bed” – 12 seeds; Pątnów, “sandstone under coal bed” – 18 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.13); Lubstów A – single endocarp with seed, 4 incomplete endocarps, 4 seeds (MZ VII/122/11; UWPalaeo/

mag.2004/12); Lubstów B – 34 endocarp fragments, 66 seeds (MZ VII/116/15).

**Description.** Fruit broadly ovoid, 7 mm long and 6 mm wide. Endocarps lyre-shaped, planoconvex, 5.5–7.0 mm long and 4.5–6.0 mm wide. Seeds ovoid, 4.0–4.3 mm long and 2.4–2.8 mm wide, with an oblique base, gradually tapering upwards, and the apex not clearly articulated. Hilum broad, almost circular, shallow, symmetric on both sides of the seed, up to 1/3 of seed length. Seed coat smooth, semilustrous.

**Remarks.** It is rather clear that these remains represent the *Fothergilla europaea* type, but it is uncertain whether their generic affinity is correct. Distinguishing between Hamamelidaceae seeds is difficult and researchers (Endress 1989, Manchester et al. 2009, Zhao & Li 2008) have raised this problem many times.

**Occurrence in the fossil floras of Poland.** Middle Miocene: Lubstów A (Kowalski 2008); Pliocene: Krościenko (Szafer 1947).

Vitales Reveal

Vitaceae Juss.

***Ampelocissus*** J.E. Planchon

***Ampelocissus* aff. *lobatum***  
(Chandler) Chen et Manchester

Pl. 9, figs 4a–4e, 5a–5e

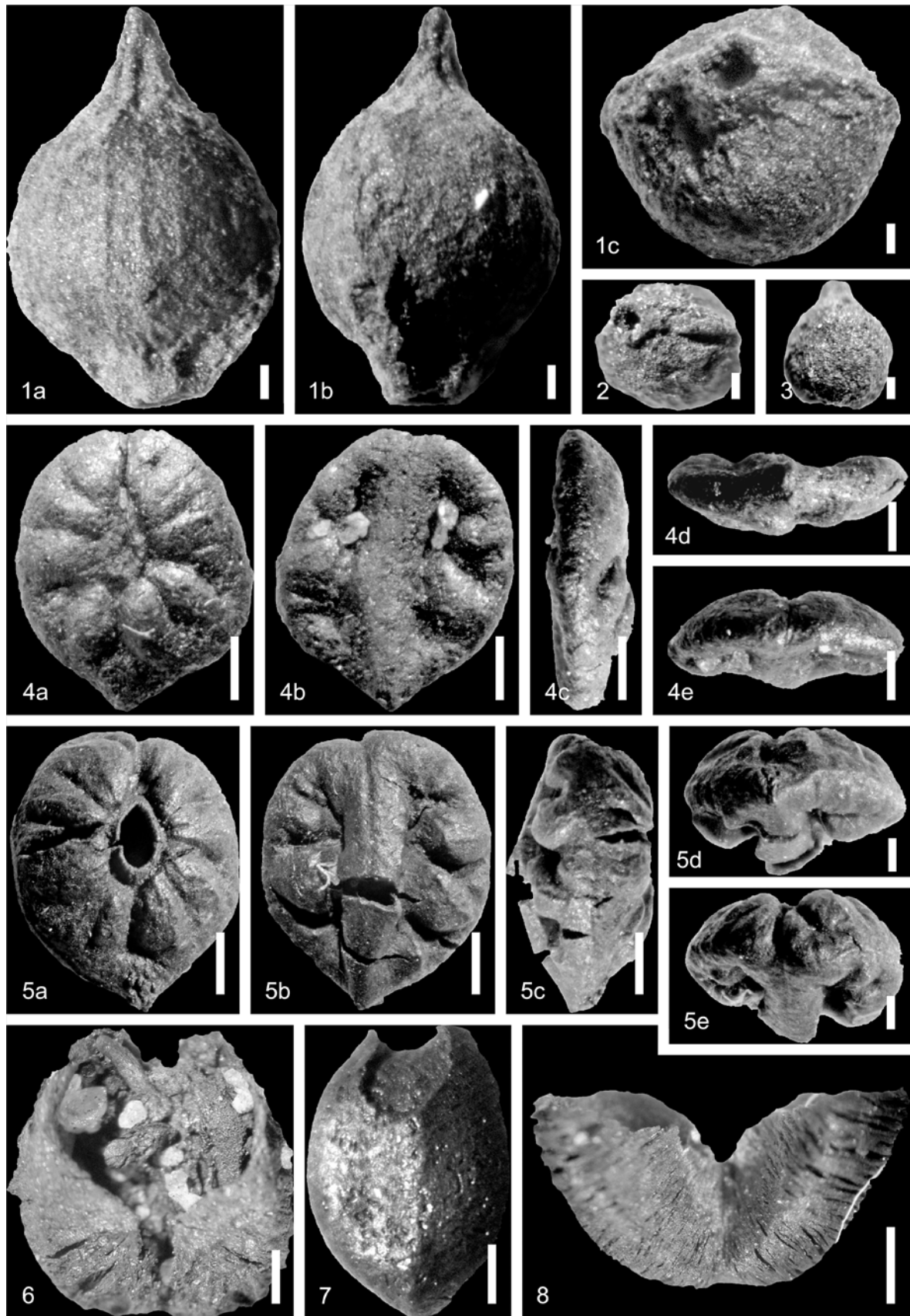
1925 *Tetrastigma lobata* Chandler, p. 32, Pl. 5, figs 3a–c.

2000b *Tetrastigma lobata* Chandler; Mai, p. 24.

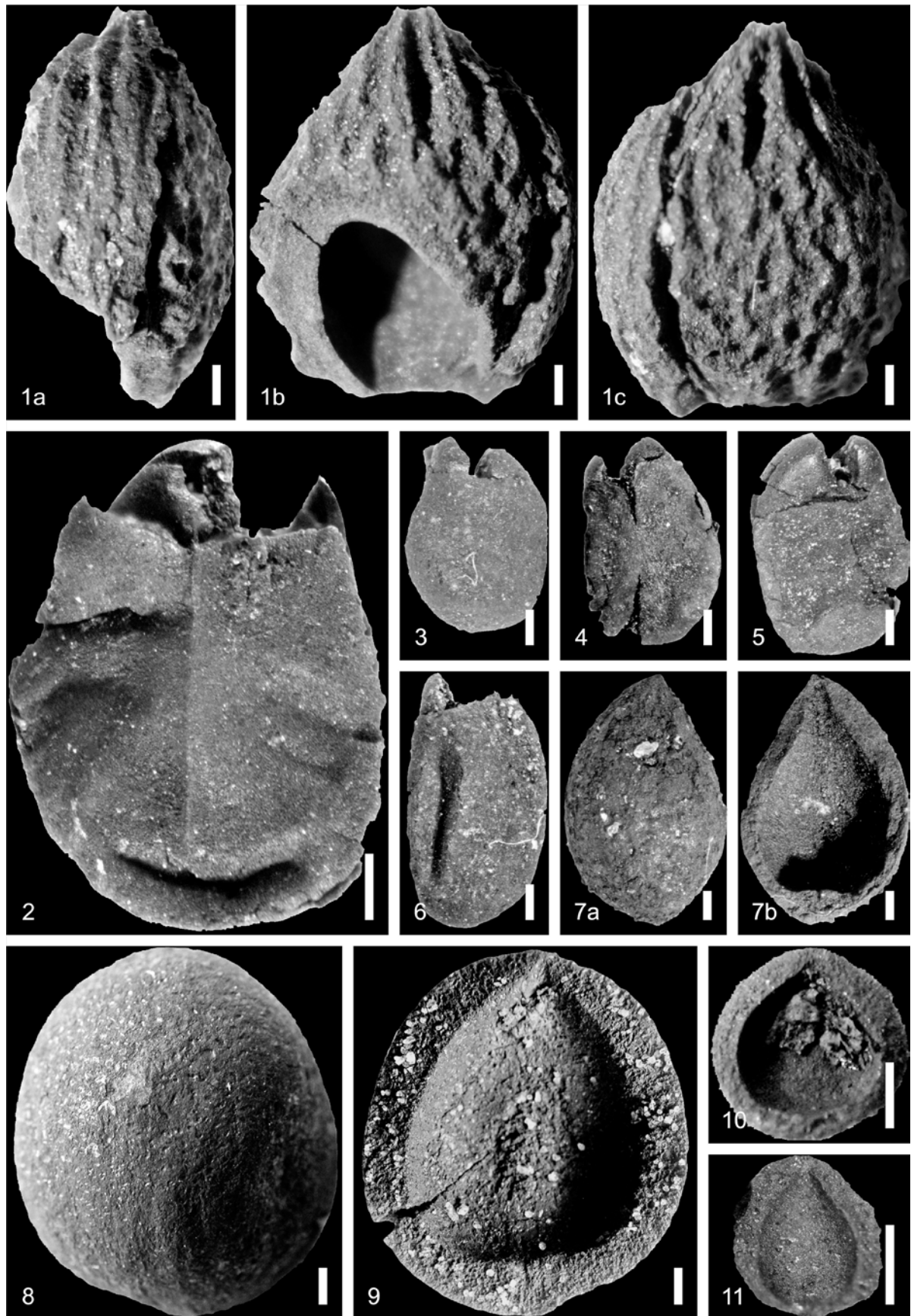
2007 *Ampelocissus lobatum* (Chandler) Chen & Manchester, p. 1546, fig. 8m.

**Material.** Goślawice, “sands in the bottom part of the coal bed” – 3 seeds, “sandstone under coal bed” – 2 seeds (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.15 and MuzPIG Warszawa 78.III.16); Pątnów, “sandstone in the lower part of the coal bed” – 1 seed, “sandstone under the coal bed” – 4 seeds, (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.15 and MuzPIG Warszawa 78.III.16); Lubstów B – 43 seeds (MZ VII/116/23); Lubstów C – 43 seeds (MZ VII/121/24).

**Description.** Seeds broadly elliptic to circular, 3.5–4.5 mm long and 1.8–3.5 mm wide, and 1.1–2 mm thickness in the transverse section. Apical notch present, small, or absent,



**Plate 9.** **1a–b.** *Cladiocarya europaea* (Dorofeev) Mai, fruit: **a, b** – lateral view, **c** – polar view, showing the base; scale bar = 100  $\mu$ m; MuzPIG Warszawa 78.III.27; **2–3.** *Cladiocarya europaea* (Dorofeev) Mai, fruit: **2** – polar view, showing the base, **3** – lateral view; scale bar = 200  $\mu$ m; MuzPIG Warszawa 78.III.27; **4a–e.** *Ampelocissus* aff. *lobatum* (Chandler) Chen et Manchester, seed: **a** – dorsal view, **b** – ventral view, **c** – lateral view, **d** – basal view, **e** – apical view; scale bar: a–c = 1 mm, d, e = 0.5 mm; MZ VII/116/23; **6, 8.** *Fothergilla europaea* Szafer, endocarp; scale bar = 1 mm; MZ VII/116/15; **7.** *Fothergilla europaea* Szafer, seed; scale bar = 1 mm; MZ VII/116/15



**Plate 10.** 1a-b. *Prunus spinosa* L. foss, drupe: **a** – ventral view, **b**, **c** – lateral view; scale bar = 1 mm; MuzPIG Warszawa 78.III.14; 2-6. *Frangula solitaria* Gregor, drupes, variability of shape; scale bar = 0.5 mm; MZ VII/121/18; 7a, b. *Myrica* cf. *ceriferiformis* Kownas, endocarp: **a** – external view, **b** – internal view; scale bar = 0.5 mm; MZ VII/121/13; 8, 9. *Myrica burghii* Gregor, endocarps: **8** – external view, **9** – internal view; scale bar = 2 mm; MZ VII/122/30; 10, 11. *Myrica suppanii* Kirchheimer, endocarps, internal view; scale bar = 1 mm; MZ VII/121/12

beak short and broad. Ventral infolds deep, and narrow, rarely shallow and broad, almost as long as the ventral surface. Two or sometimes three rounded, thick ridges radiating (rarely  $\pm$  parallel) from each side of the raphal ridge. The raphal ridge is thick, evenly broad or gradually tapering toward the seed base, elevated above the adjoining ridges. The chalaza is elliptic, or rarely circular, and sunken more or less in the centre of the dorsal side. There are 8–10 rounded ridges radiating from the chalaza, which predominantly do not reach the seed margin. Both the chalaza-apex and base grooves are relatively deep.

**Remarks.** The morphology and overall shape of the above described seeds correspond with recent *Ampelocissus* (type 2 and 3 sensu Chen and Manchester 2007), but also with some *Vitis* (subg. *Muscadinia*). According to Chen and Manchester (2011) it is difficult to distinguish the seeds of some of the extant *Ampelocissus* species from *Ampelopsis* and *Vitis*. Three *Ampelocissus* species have been described from the Cenozoic of Europe, *A. lobatum*, *A. chandleri* (Kirchheimer) Chen et Manchester and *A. wildei* Chen et Manchester. Among these, only *A. lobatum* seeds are comparable in shape and morphology, but they are larger (4.5–9.0 mm long and 3.5–10.0 mm wide) than specimens from the Konin region. Among European fossil *Vitis*, only *V. palaeomuscadinia* Mai seeds represent type 3, but their morphology is discrete, with especially the dorsal ridges being much less distinct.

Determination of the seeds described here is difficult and their attribution is only provisional. Morphologically, they clearly correspond to *Ampelocissus*, but their small size suggests a relationship to *Vitis*. They may represent a small seeded *Ampelocissus* as well as strongly sculptured *Vitis*. More detailed studies are needed, especially morphometric comparisons and seed coat anatomical observations, to clarify their generic affinity.

The extant *Ampelocissus tomentosa* (Roth in Schult.) Planch is morphologically close to the seeds from the Konin region. This modern species is distributed in Coromandel Coast/south-eastern India (Gamble 1915) in a tropical dry evergreen forests (Parthasarathy et al. 2008, Sridhar & Parthasarathy 2003).

Seeds from Gosławice and Pątnów were labelled by Raniecka-Bobrowska as *Ampelopsis ludwigii* (A. Braun) Dorof. This determination

is incorrect, because the *A. ludwigii* seeds differ in shape, morphology and, especially, in that their pyriform chalaza is closely placed to the apical notch.

Occurrence in the fossil floras of Poland. Middle Miocene: Turów (Czeczott & Skirgiełło 1959); upper Miocene: Gozdnicza (Łańcucka-Środoniowa & Zastawniak 1993, Łańcucka-Środoniowa et al. 1992).

Rosales Perleb

Rosaceae Juss.

***Prunus* L.**

***Prunus spinosa* L. foss.**

Pl. 10, figs 1a–1c

**Material.** Gosławice, “sandstone” – 1 drupe (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.14).

**Description.** Drupe ovate, 10.0 mm long and 5.5 mm wide, broad elliptic in cross-section, and pitted and ridged on the surface. Gradually tapering towards the top into the elongated micropylar apex. The ventral suture is well articulated, swollen, rounded, and with two sharp ridges. Drupe wall about 1 mm thick.

**Remarks.** Regarding shape, size and morphology, this drupe from Gosławice clearly represents sect. *Prunus* (Rehder 1940). There is no significant difference in the morphology between the studied fossil and the extant *Prunus spinosa* L. and *P. ramburii* Boiss. The fossil drupe seems to be longer, more robust, with a more ridged micropylar apex and strongly highlighted sculpture (more sharp and more elevated) than the extant drupes compared by the author, but the differences observed are probably the result of fossilisation and most likely do not exceed the morphological variability of the extant *P. spinosa* and *P. ramburii*.

There are several reports about fossil drupes of the *P. spinosa* type from the Pliocene and Pleistocene (Mai 1984), also from Miocene (Dorofeev 1964, Łańcucka-Środoniowa & Zastawniak 1997). However, affiliation of the Pre-Pliocene drupes with *P. spinosa* does not corroborate the hypotheses arising from molecular studies. According to Reales et al.

(2010) *P. spinosa* is the youngest lineage of the *P. brigantina*, *P. ramburii* and *P. spinosa* clade, diverged from ancestor of the *P. ramburii*. In addition, Chin et al. (2014) suggest that the ancestor of the *P. brigantina*-*P. spinosa* clade emerged probably in the early-middle Miocene, but in their opinion the divergence of the *P. spinosa* takes place much later, probably in the Pliocene or Pliocene/Pleistocene. Although it is legitimate to distinguish the Pre-Pliocene drupes as a separate fossil species, this requires more than one incomplete specimen.

Occurrence in the fossil floras of Poland. Drupe determined as *P. aff. spinosa* – middle Miocene: Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997).

Rhamnaceae Juss.

*Frangula* P. Miller

*Frangula solitaria* Gregor

Pl. 10, figs 2–6

1977 *Frangula solitaria* Gregor, p. 212, Pl. 19, figs 8, 9.  
2000b *Frangula solitaria* Gregor; Mai, p. 21, Pl. 6, fig. 9.

Material. Lubstów C – 10 drupes (MZ VII/121/18).

Description. Drupes elliptic or ovate, 2.0–3.7 mm long and 1.4–2.5 mm wide, flat, and rounded at the apex. At the base the characteristic pincer-like, glossy part of the seed protrudes beyond the drupe. The ventral site is marked by a faint longitudinal ridge. Drupes surface matt.

Remarks. Drupes clearly correspond with *Frangula*. Two fossil species of *Frangula* drupes have been described so far from Europe, *F. hordwellensis* Chandler, from the Eocene of the Hordle (Chandler 1961), England and *F. solitaria* from the Neogene of Germany and Poland. An emarginated base distinguishes the Eocene species from the younger Neogene species. Specimens from Lubstów are very close to the *F. solitaria* drupes from Germany (Gregor 1977, Mai 2000b), except they are smaller and more elongated. There is a wide spectrum of size and overall shape in extant *F. alnus* Mill. drupes (Staszkievicz & Białobrzaska 1997) which suggests that those characters may not be sufficient for distinguishing between *Frangula* species.

According to Gregor (1977) *F. solitaria* is morphologically comparable to the extant *F. rupestris* (Scop.) Schur and *F. alnus* Mill, which are both distributed in Europe. Mai (2000b) suggested, however, a close resemblance to the Asiatic *F. crenata* (Sieb. & Zucc.) Miq. (EFloras 2011, Ohwi 1965).

Occurrence in the fossil floras of Poland. Pliocene: Mizerna (Mai 2000b).

Fagales Engler

Fagaceae Dumortier

*Castanopsis* (D. Don) Spach

*Castanopsis cf. pyramidata*  
(Menzel) Kirchheimer

Pl. 11, fig. 1

1913 *Carpolithus pyramidatus* Menzel; p. 66–67, Pl. 6, figs 1–4.  
1957 *Castanopsis pyramidata* Kirchheimer, p. 126, Pl. 28, fig. 120.

Material. Lubstów A – 1 fruit (MZ VII/122/28).

Description. Fruit triangular, 7.0 mm long and 7.0 mm wide, clearly three-cornered in cross-section, with one side wider than the other. Pericarp surface semimatt, with longitudinal striae. Pericarp wall thin. Base of the fruit enveloped in the remains of knobby cupula, 6.0 × 6.0 mm.

Remarks. Triangular, three-cornered fruit corresponds with *Castanopsis* nuts (Mai 1989b). Regarding overall shape, the specimen from Lubstów closely resembles the fossil, *Castanopsis pyramidata*, except that typical *C. pyramidata* fruits are larger. It is probable that the specimen described here may represent a fruit that was not fully developed.

Mai (1989b) compared *C. pyramidata* with the extant *C. cuspidata* Schottsky and *C. caudata* Franch. The first-mentioned is distributed in China, Taiwan and Japan (Ohwi 1965). Dominating in temperate in Japan are Evergreen-Broadleaved forests up to 500 m a.s.l. (Numata 1974). *C. caudata* is an element of Mixed Mesophytic forests and Evergreen-Broadleaved forests in China and Taiwan (eFloras 2011).

Occurrence in the fossil floras of Poland. Middle Miocene: Stare Gliwice (Szafer 1961).

## Myricaceae Rich. et Kunth

*Myrica* L.*Myrica suppanii* Kirchheimer

Pl. 10, figs 10, 11

- 1938a *Myrica suppanii* Kirchheimer, p. 326–328, Pl. 3, figs 13–15, 17.  
 1961 *Myrica suppanii* Kirchheimer; Szafer, p. 33–34, Pl. 9, fig. 8.  
 1999b *Myrica suppanii* Kirchheimer; Mai, p. 42–43, Pl. 15, figs 24–31.  
 2008 *Myrica* cf. *suppanii* Kirchheimer; Kowalski, p. 283, Pl. 1, fig. 9.

Material. Lubstów A – 9 endocarps (MZ VII/122/13; UWPalaeo/mag.2004/15); B – 3 endocarps (MZ VII/116/16); Lubstów C – 11 endocarps (MZ VII/121/12).

Description. Endocarps more or less spherical, 1.2–2.9 mm long and 1.5–2.4 mm wide, Exocarp surface uneven, matt, with no or a few widely spaced papillae. The endocarp splits into two or sometimes three parts, with the endocarp wall being ca 0.5 mm thick. Locule single, pyriform.

Remarks. Pericarp sphericity and exocarp barely covered with papillae distinguish *Myrica suppanii* from other fossil species (Kirchheimer 1957, Mai 1999b). This fossil species is especially common in the Miocene climatic optimum (Mai 1999b). According to Mai (1999b), the morphologically closest to *M. suppanii* is the extant *M. cordifolia* L. from South Africa.

Occurrence in the fossil floras of Poland. Middle Miocene: Stare Gliwice (Szafer 1961).

*Myrica* cf. *ceriferiformis* Kownas

Pl. 10, figs 7a, 7b

- 1956 *Myrica ceriferiformis* Kownas, p. 459–461, fig. 8.  
 2004 *Myrica ceriferiformis* Kownas; Mai, p. 54, Pl. 11, figs 22–24.

Material. Gosławice, “sandstone in the bottom part of the coal bed” – 2 endocarps, “sandstone in upper part of the coal bed” – 8 endocarps, “lower sandstones” – 3 endocarps (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.6); Lubstów A – 3 endocarps (MZ VII/122/29); Lubstów C – 3 endocarps (MZ VII/121/13).

Description. Endocarps ovoid, 2.2–2.8 mm long and 1.5–2.1 mm wide, round at the base, and gradually tapering toward the pointed apex. Surface uneven. Locule single, drop-shaped, elongated. The endocarp wall is relatively thin, ca 0.2 mm thick.

Remarks. The shape and size of the specimens from Gosławice and Lubstów suggests they can be related to both *Myrica ceriferiformis* and *M. ceriferiformoides* Bůžek & Holý. More precise determination is problematic due to a poorly preserved exocarp. According to Mai (1999b), an exocarp with widely spaced, fine papillae is the most important characteristic distinguishing *M. ceriferiformis* from *M. ceriferiformoides*. The studied specimens are smaller and have a thinner endocarps' wall than *M. ceriferiformoides*, although these characteristics are of secondary importance.

Mai (1999b) suggested the morphological resemblance between *Myrica ceriferiformis* and the extant *Myrica pensylvanica* Mirb and *Myrica cerifera* L. The first-mentioned is distributed along the Atlantic coast of North America from New Scotland to North Carolina (Hauser 2006). The second extant species occurs in South-eastern USA, from New Jersey to Florida, westward to Texas, Central America, and the Caribbean (Bornstein 1997). Both *Myrica pensylvanica* and *M. cerifera* occupy dry (i.e. Xeric Longleaf Pine Woodlands) as well as wet habitats (i.e. Atlantic white cedar swamp forest) (Van Deelen 1991).

Occurrence in the fossil floras of Poland. Middle Miocene: Wieliczka (Zastawniak et al. 1996), Dobrzyń (Kownas 1956); upper Miocene: Gozdnicza (Łańcucka-Środoniowa et al. 1992).

*Myrica burghii* Gregor

Pl. 10, figs 8, 9

- 1983 *Myrica burghii* Gregor, p. 32–40, Pl. 1, figs 1–7.

Material. Lubstów A – two halves belonging to the separate endocarps (MZ VII/122/30).

Description. Endocarps halves, broad ovoid, 10.0–11.0 mm long and 8.0–9.0 mm wide, endocarp wall ca 1.25 mm thick, and the surface is more or less smooth. Locule single, drop-shaped, with median, longitudinal swelling.

Remarks. These are characteristic myricaceous endocarps distinguished by their size. There are two fossil *Myrica* species in the

Neogene characterised by endocarps of that size, *M. stoppii* Kirchh. (Gregor 1978, Kirchheimer 1942, Mai 1964) and *M. burghii* Gregor (Gregor 1983). The specimens from Lubstów are closer to *M. burghii* regarding especially their smooth surface, which is clearly ribbed in *Myrica stoppii* (Gregor 1983).

According to Gregor (1983), at least two extant *Myrica*, *M. rubra* Sieb. et Zucc. and *M. esculenta* Buch.-Ham. et D. Don (synonym *M. sapida* Wall.) are comparable to *M. burghii*. The first-mentioned species is an element of the mixed mesophytic and broad-leaved evergreen forests (Wang 1961) of Eastern and South-eastern Asia, and the second is an element of the subtropical coniferous and semi-evergreen forests (Khan et al. 1986) of the Southeast Asia (Lu & Bornstein 1999).

*Myrica burghii* is a rare species known so far from the middle Miocene of Garsdorf/ Lower Rhenish Basin, Germany (Gregor 1983).

Occurrence in the fossil floras of Poland. This taxon has not been reported from Poland so far.

#### Cornales Dumortier

#### Cornaceae Bercht. et J. Presl

#### *Cornus* L.

#### *Cornus* aff. *discimontana* (Mai) Martinetto

Pl. 11, figs 3a–3c

1982 *Swida discimontana* Mai; Mai and Gregor, p. 413–414, Pl. 19, figs 1–8.

1997 *Swida discimontana* Mai, p. 67, Pl. 10, fig. 9.

Material. Lubstów C – 1 incomplete endocarp (MZ VII/121/28).

Description. Endocarp oblate spheroid, distorted, 4.2 mm long and 3.7 mm wide. Surface even, with a distinct, meridional belt, emphasised by two furrows, and the vascular bundles invisible. The endocarp wall is 0.4–0.8 mm thick. Inside, two locules are separated by a relatively thin septum. Remarks. This endocarp has been attributed to *Cornus discimontana* due to the relatively smooth endocarp surface, which has no vascular bundles, but this specimen is about twice the size of the typical endocarps of *C. discimontana* from the middle Miocene of Salzhausen described

by Mai & Gregor (1982). According to Mai (1997), the extant *Cornus asperifolia* Michx. and *C. rugosa* Lam are morphologically closest to the *C. discimontana*, but only the first-mentioned is comparable in size (Mai 1997, Schneider 1912). *Cornus asperifolia* occupies wetland areas in South-eastern USA (Godfrey 1988). *Cornus discimontana* is known from the upper Oligocene to the upper Miocene of Austria, Germany and Italy (Kovar-Eder & Meller 2001, Kovar-Eder et al. 2006, Mai & Gregor 1982, Mai 1997, Martinetto 2015).

Occurrence in the fossil floras of Poland. This taxon has not been reported from Poland so far.

#### Nyssaceae Dumortier

#### *Nyssa* L.

#### *Nyssa disseminata* (Ludwig) Kirchheimer

Pl. 11, figs 2a, 2b

1937 *Nyssa disseminata* (Ludwig) Kirchheimer, s. 916

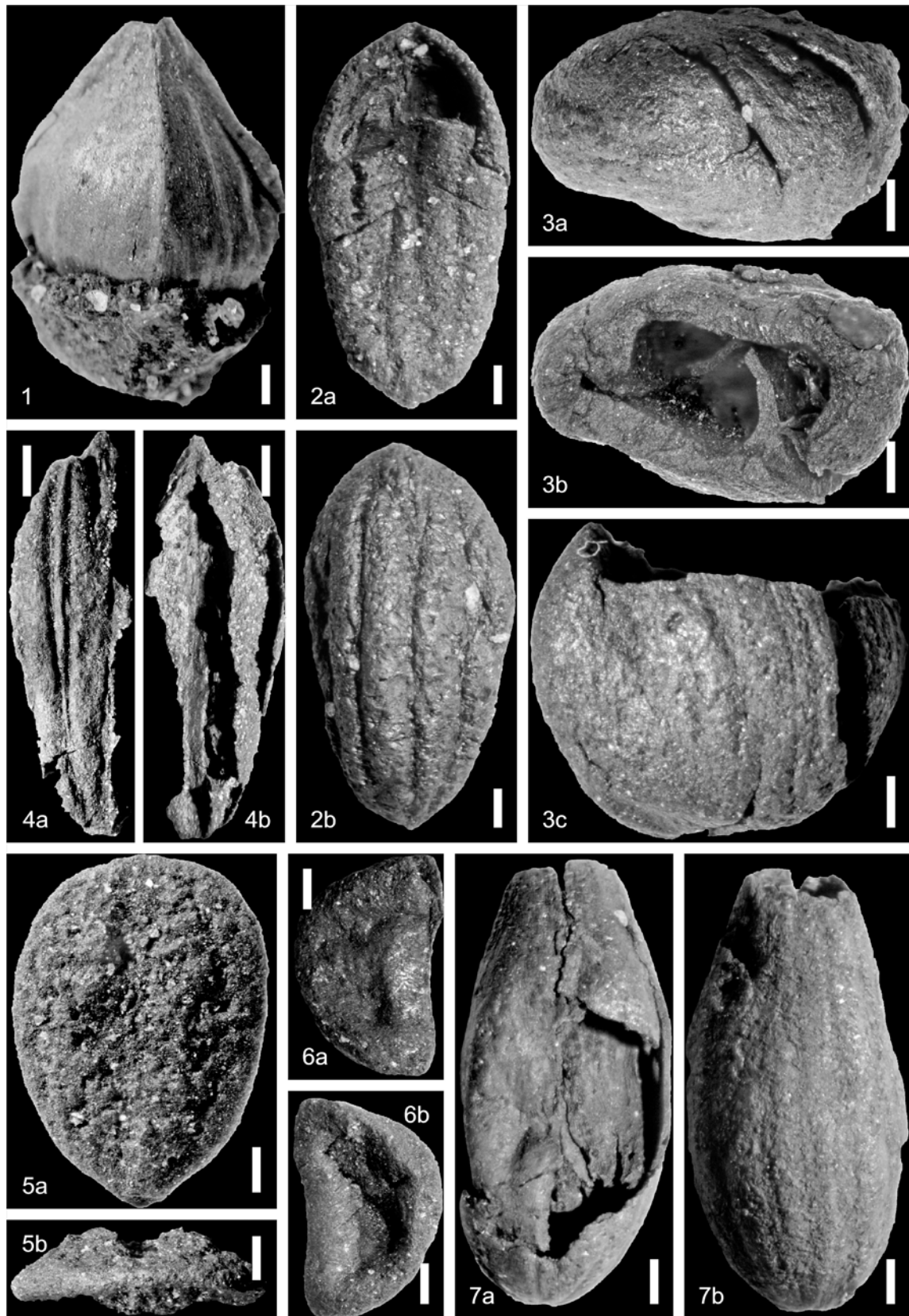
2004 *Nyssa disseminata* (Ludwig) Kirchheimer; Mai, p. 72–73, Pl. 17, fig. 3.

Material. Gosławice, “sandstone in lower and upper part of the coal bed” – 15 endocarps, „sandstone in lower part of the coal bed” – 11 endocarps (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.18); Lubstów A – 3 endocarps (MZ VII/122/ 8); Lubstów B – 4 endocarps (MZ VII/116/22); Lubstów C – 4 endocarps (MZ VII/121/25).

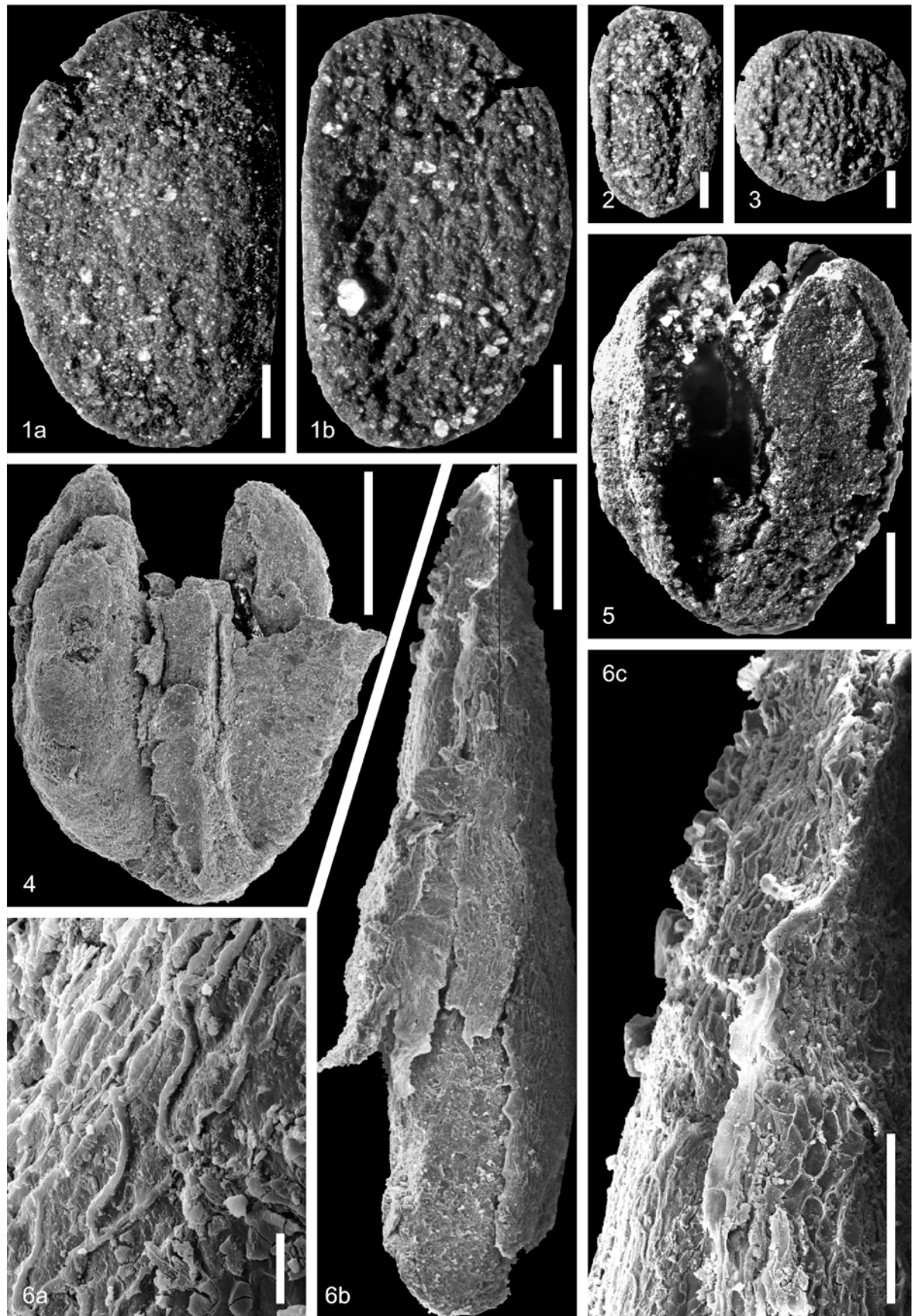
Description. Endocarps more or less elliptic, flat, 7.0–8.0 mm long and 3.5–4.0 mm wide, rounded at both ends, widest usually at half their length. Surface with distinct, longitudinal, broad, rounded ribs separated by narrow grooves, and very often with a triangular germination aperture in the subapical region. Single loculed.

Remarks. These endocarps certainly represent *Nyssa disseminata* (Mai 1973, 2000b). This assignment based on more or less regular, elliptic shape, relatively thick endocarp wall, single locule and rounded ribs. *Nyssa disseminata* is a common species known from the middle Oligocene to Pliocene (Mai 2001a), closely related to the extant *N. sylvatica* Marshall (Mai 2000b). *Nyssa sylvatica* is widely distributed in North American. Due to its broad habitat tolerance, it is associated with





**Plate 11.** 1. *Castanopsis* cf. *pyramidata* (Menzel) Kirchheimer, fruit with cupula remains at the base; scale bar = 1 mm; MZ VII/122/28; 2a, b. *Nyssa disseminata* (Ludwig) Kirchheimer, endocarp: a – dorsal side with germination valve, b – ventral side; scale bar = 1 mm; MZ VII/116/22; 3a–c. *Cornus* aff. *discimontana* (Mai) Martinetto, endocarp: a – apical view, b – internal view, c – lateral view; scale bar = 0.5 mm; MZ VII/121/28; 4a, b. *Nyssa ornithobroma* Unger, endocarp: a – lateral view, b – opposite site showing empty locule; scale bar = 2 mm; MZ VII/121/31; 5a, b. *Viburnum* aff. *hercynicum* Mai et Walther, endocarp: a – ventral view, b – apical view; scale bar = 0.5 mm; MZ VII/121/19; 6a, b. *Aralia* aff. *lusatica* Mai, endocarp, b – opposite side; scale bar = 0.5 mm; MZ VII/121/29; 7a, b. *Symplocos minutula* (Sternberg) Kirchheimer, endocarp, b – opposite side; scale bar = 1 mm; MZ VII/122/35



**Plate 12.** **1a, b.** *Aralia* aff. *dorofeevii* Mai, endocarp, **b** – opposite side; scale bar = 0.5 mm; MZ VII/121/30; **2, 3.** *Viburnum* aff. *hercynicum* Mai et Walther, endocarp, variability of shape; scale bar = 0.5 mm; MZ VII/121/19; **4, 5.** *Enkianthus maii* Kowalski, capsules; scale bar = 1 mm; MZ VII/121/32; **6a–c.** *Enkianthus maii* Kowalski (Holotype), seed removed from the capsule shown in fig 5: **a** – enlargement of **b**, showing seed coat cells, **b** – general view, **c** – enlargement of **b**, showing lateral wings; scale bar: **a** – 50  $\mu$ m, **b** – 0.5 mm, **c** – 250  $\mu$ m; MZ VII/121/10

many different forest communities (McGee & Outcalt 1990).

Occurrence in the fossil floras of Poland. Middle Miocene: Turów (Czeczott & Skirgiełło 1959); upper Miocene: Gozdnica (Łańcucka-Środoniowa et al. 1992, Stachurska et al. 1971); Pliocene: Krościenko (Szafer 1947), Huba (Szafer 1954).

### *Nyssa ornithobroma* Unger

Pl. 11, figs 4a, 4b

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

2004 *Nyssa ornithobroma* Unger; Mai, p. 73, Pl. 17, figs 4, 5.

Material. Lubstów A – 4 endocarps (MZ VII/122/16); Lubstów C – 1 endocarp (MZ VII/121/31).

Description. Endocarps fusiform, 9.0–16.0 mm long and 4.0–6.0 mm wide, and widest at 2/3 their length. Ribs mostly poorly preserved, rarely clearly visible and sharp. The endocarps are thin walled, 1–3 loculate, and locules cuspidate at the top. One specimen with preserved narrow ovoid germination valves.

Remarks. These fossils undoubtedly represent *Nyssa ornithobroma* Unger, as indicated by the shape, shape of the germination valves and thin endocarp wall (Mai 2000b, Mai & Gregor 1982).

According to Mai (2000b), none of the extant *Nyssa* species can be fully compared to *N. ornithobroma*, but in respect of the number of locules it resembles *N. sinensis* Oliv., but on the other hand the arrangements of the fibre strands is similar to that of *N. ogeche* Mabsh.

Occurrence in the fossil floras of Poland. Miocene: Turów (Czeczott & Skirgiełło 1959); Pliocene: Ruszów (Baranowska-Zarzycka 1988).

Ericales Dumortier

Symplocaceae Desf.

### *Symplocos* N.J. Jacquin

#### *Symplocos minutula* (Sternberg) Kirchheimer

Pl. 11, figs 7a, 7b

1866 *Symplocos gregaria* (Bronn) Braun; Unger, p. 31–31, Pl. 11, figs 1a–h, 2h, 2i.

1950 *Symplocos ludwigii* Kirchheimer, p. 16, Pl. 1, fig. 8.

1957 *Symplocos minutula* (Sternberg) Kirchheimer, p. 320, Pl. 50, figs 187a–b.

Material. Lubstów A – 4 endocarps, mostly incomplete (MZ VII/122/35).

Description. Endocarps narrowly ovoid, 0.8–1.0 cm long and 0.4–0.6 cm wide, apically truncate, with the apical aperture 0.2 cm in diameter. The endocarp wall is delicate, 0.1–0.2 mm thick. The surface is almost smooth, excepting the fine, longitudinal, broad, rounded ribs. The seed coat is fine reticulate.

Remarks. The specimens described here undoubtedly represent thin-walled endocarps of *Symplocos minutula*, which are well known from the upper Oligocene to the Pliocene of Central and Southern Europe. According to Mai and Martinetto (2006) comparable extant species is *Symplocos tinctoria* L'Herit. from South-eastern USA or *Symplocos ramosissima* Wallich et G. Don. from South and Southeast Asia.

Fossil occurrence in Poland. Upper Miocene: Gozdnica (Stachurska et al. 1971).

Cyrillaceae Lindl.

### *Pirocarpella aquisgranensis* Mai

Material. Gosławice, “sands intercalated between brown coal layers” – 71 specimens (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.17); Lubstów A – 7 specimens (Kowalski 2008 – UWPalaeo/mag.2004/18) + 19 specimens (MZ VII/122/15, 41).

Description and remarks and fossil occurrence in Poland. (see Kowalski 2008).

Ericaceae Juss.

### *Enkianthus* Lour.

#### *Enkianthus maii* Kowalski n. sp.

Pl. 12, figs 4, 5, 6a–6c

Holotype. Pl. 12, figs 6a–c (MZ VII/121/10), collection of the Museum of the Earth PAS.

Locus typicus. Lubstów.

Stratum typicum. Middle Miocene.

Derivatio nominis. The species name is

given in honour of Dieter H. Mai, recognizing his great contribution to study the carpological floras of the European Cenozoic.

**Diagnosis.** Seeds large, 1 per locule, winged.

**Material.** Lubstów C – 5 capsules (MZ VII/121/10, 17, 32); Gosławice, “sandstone in lower part of the coal bed” – 6 specimens (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.23).

**Description.** Capsules relatively big, 3.1–4.4 mm long and 2.7–3.5 mm wide loculicidal, elongated. Each valve of the capsule with median, longitudinal depression. The central axis is massive, and longitudinally ridged.

Seeds, one per locule, 2.3–3.3 mm long and 0.5–0.9 mm wide, ellipsoidal, slightly distorted; seed coat reticulate, seed coat cells slightly elongated, and laterally extended into narrow wing.

**Remarks.** Despite the relatively poor preservation, attributing these remains to *Enkianthus* is certainly based on the size of the seeds, the relation between the size of the fruit and seed, and number of seeds per locule, but especially the wing-like lateral extensions of the testa. A single or a few seeds per locule is not a very common feature among the extant Ericaceae: *Enkianthus*, *Arbutoideae* Nied., *Empetreae* D. Don, *?Elliottia* Muhl. ex Elliott (Wood 1961), *Styphelioideae* Sweet (*Prionoteae* Drude, *Oligarrheneae* Crayn & Quinn, *Richeeae* Crayn & Quinn, *Epacrideae* Dumort., *Cosmelieae* Crayn & Quinn, *Styphelieae* Bartl.), *?Craibiodendron* W. W. Sm., *Vaccinieae* Rchb. (*Gaylussacia* Kunth, *Costera* J.J. Sm., *Vaccinium* L.). Most of these taxa can be eliminated based on other characteristics, such as the position of the ovary and type of fruits. A closer relationship between the fossils from Lubstów and *Styphelioideae* (former *Epacridaceae* see Powell et al. 1996) is less probable, as they generally represent Southern Hemisphere Ericaceae. The presence of this group in Europe was questioned by Manchester et al. (2007).

The extant *Enkianthus* seeds are relatively big, with frequently only 1 per locule, with the seed coat being reticulate and, depending on the species, the seeds are wingless or may have wings and scales (Anderberg 1994, Drude 1897, Kron et al. 2002). Regarding seed characters, *Enkianthus perulatus* (Miq.) C.K. Schneid. sect. *Enkianthus* (sensu Tsutsumi

and Hirayama 2012) from Japan (Ohwi 1965) seems to be closest to the fossils from Lubstów.

There are only a few uncertain reports about the fossil *Enkianthus* carpological remains from Europe. A much smaller capsule with one seed, cautiously interpreted as a *?Enkianthus* sp., was described from the middle Miocene of FASTERHOLT/Denmark (Friis 1985). However, regarding the morphology of the seed and relation between the fruit and seed size, the relationship to *Enkianthus* is probable. An empty capsule from the Miocene of Gozdnicza/Poland was also reported (Łańcucka-Środoniowa et al. 1992) described as cf. *Enkianthus* sp.

### *Comarostaphylis* Zucc.

#### *Comarostaphylis globula* (Menzel) Mai

**Material.** Pątnów, “sandstone in lower part of the coal bed” – 22 specimens (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.20); Lubstów – 10 specimens (coll. Raniecka-Bobrowska, MuzPIG Warszawa 78.III.21); Lubstów A – 331 specimens (UWPalaeo/mag.2004/19; MZ VII/122/17-18); Lubstów B – 49 specimens (MZ VII/116/17); Lubstów C – over 500 specimens (MZ VII/121/14).

**Description and remarks.** (see Kowalski 2008).

**Fossil occurrence in Poland.** Middle Miocene: Wieliczka (Łańcucka-Środoniowa & Zastawniak 1997), Rypin (Łańcucka-Środoniowa 1957), Stare Gliwice (Szafer 1961).

#### *Maiella* Kowalski & Fagúndez

##### *Maiella miocaenica* Kowalski & Fagúndez

**Material.** Lubstów A – 1 specimen (MZ VII/122/45, 52); Lubstów B – 4 specimens (MZ VII/116/7, 25-27); Lubstów C – 11 specimens (MZ VII/121/26, 42).

**Description and remarks and fossil occurrence in Poland.** (see Kowalski & Fagúndez 2017).

##### *Kalmiocarpus* Kowalski gen. nov.

Pl. 13, figs 5, 6a, 6b, 7, 8

**Type species.** *Kalmiocarpus dorofeevi* Kowalski n. sp.

**Holotype.** Pl. 13, figs 6–8 (MZ VII/122/19), collection of the Museum of the Earth PAS.

**Locus typicus.** Lubstów.

**Stratum typicum.** Middle Miocene.

**Derivatio nominis.** The genus name refers to the fruits of *Kalmia* and the species epithet is given in honour of Pavel Ivanovich Dorofeev (1911–1985), recognising his great contribution to studying the carpological floras of the Russian Cenozoic.

**Diagnosis.** The fruit are septicidal capsules. The seeds are wingless, and the seed coat reticulate, with the cells elongated.

**Material.** Lubstów A – 1 fruit, 5 fragments (MZ VII/122/19, 53, 58)

**Description.** Capsules ovoid to globose, five-locular, septicidal and on some specimens partly loculicidal, 2–5 mm in diameter, 2.25–3 mm long, and the epicarp remains preserved on some specimens composed of isodiametric cells; Sepals up to 1/3 the length of the fruit, but mostly not preserved, pedicel delicate, straight. The placenta is broad, extending into loculi and encompassing most of their space.

Seeds oval or fusiform, flat, 0.75–1.0 mm long and 0.35–0.5 mm wide. The seed coat of the elongated cells is up to 190 µm long and 20–50 µm wide, with the outer periclinal walls collapsed and mostly not preserved, and the inner periclinal and anticlinal walls porous.

**Remarks.** Some capsules were previously incorrectly described as *Leucothoe lusatica* Mai (Kowalski 2008).

Described here capsules are identified to the Ericoideae, due to their septicidal dehiscence (Kron et al. 2002, Stevens 1971). The shape, size and general morphology relates these fossils to Phyllodoceae. However, it is difficult to unequivocally ascertain their generic affinity using only general characteristics of the fruit and seeds as a basis (Gillespie & Kron 2013, Kron et al. 2002). Several Phyllodoceae representatives can be compared to the fossils described here in respect of the morphology of the fruit and seeds, including *Elliottia pyroliflora* (Bong.) Brim & Stevens, *Kalmiopsis* Rehder, *Phyllodoce* Salisb., *Rhodothamnus* Reichb. and *Kalmia* s.l (Bohm et al. 1978, Copeland 1943, Ebinger 1974, Meinke & Kaye

2007, Southall & Hardin 1974, Stevens 1971). A new fossil genus, *Kalmiocarpus*, has been proposed for the carpological remains of an uncertain generic affinity, but is morphologically related to representatives of the Phyllodoceae tribe.

*Kalmia* fossils have been described several times based on their leaves (*Kalmiophyllum* Kräusel in Weyland – Mai & Walther 1991) and disseminules from the Oligocene to the Pliocene of Europe, but the generic affinity of at least some of the carpological remains may raise doubts. This applies to *Kalmia minutula* Mai & Walter seeds from the upper Miocene and Pliocene of Germany (Mai & Walther 1988, Mai 2001a). Distinguishing the genera of Ericaceae using the seed morphology as a basis alone is questionable. It is worth mentioning that Mai (Mai & Walther 1988, Mai 2001a) suggested that the fruits from the Maria Theresia open-pit mine near Herzogenrath (this probably refers to *Ehretiaecarpum parvulum* Menzel (Menzel 1913), can be attributed to *Kalmia* (*K. parvula* (Menzel) Mai) and that they may represent one species with *Kalmia minutula*.

### ***Rhododendron* L.**

#### ***Rhododendron polonicum* Kowalski n. sp.**

Pl. 13, figs 1a, 1b, 2–4, Pl 14, figs 1, 2

**Holotype.** Pl. 13, figs 1a, b (MZ VII/122/37) – collection of the Museum of the Earth PAS.

**Paratypes.** Pl. 13, figs 2–4 (MZ VII/122/37) – collection of the Museum of the Earth PAS.

**Locus typicus.** Lubstów.

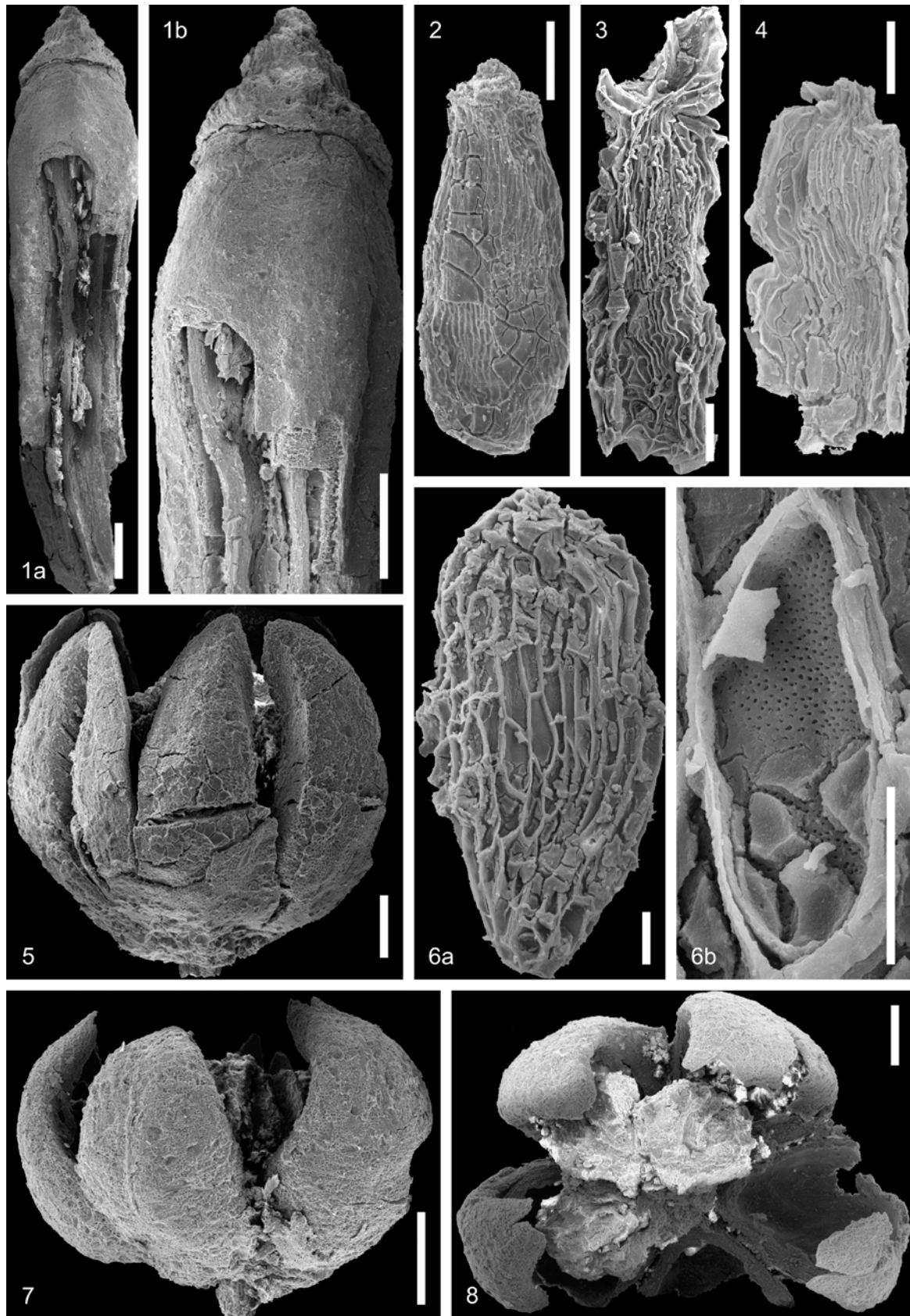
**Stratum typicum.** Middle Miocene.

**Derivatio nominis.** Epithet refers to Poland.

**Differential diagnosis.** *Rhododendron polonicum* differs from *R. germanicum* with its longer and cylindrical capsules and bigger, more evident wings on seeds. *Rhododendron polonicum* capsules are straight in contrast to the arcuate in *Rhododendron flavum* Don. foss.

**Material.** Lubstów A – 1 fruit, 5 fruits fragments (MZ VII/122/37–38); Lubstów B – 1 fruit (MZ VII/116/20).

**Description.** The capsules are narrow-cylindrical, straight, slightly tapering toward



**Plate 13.** **1a, b.** *Rhododendron polonicum* Kowalski (Holotype), capsule: **a** – general view, **b** – enlargement of **a**, showing the base and locules; scale bar = 1 mm; MZ VII/122/37; **2–4.** *Rhododendron polonicum* Kowalski (Paratypes), seeds removed from the capsule shown in fig 1a, b; scale bar = 200  $\mu$ m; MZ VII/122/37; **5.** *Kalmiocardus dorofeevi* Kowalski (Holotype), capsules: lateral view; scale bar: 5 = 0.5 mm; MZ VII/122/53; **7, 8.** *Kalmiocardus dorofeevi* Kowalski (Holotype), capsules: **5, 7** – lateral view, **8** – apical view, showing placenta and locules; scale bar: 5 = 0.5 mm, 7, 8 = 1 mm; MZ VII/122/19; **6a, b.** *Kalmiocardus dorofeevi* Kowalski (Holotype), seed removed from the capsule shown in fig 7 and 8; **b** – enlargement of **a**, showing details of seed coat cell; scale bar: **a** – 100  $\mu$ m, **b** – 50  $\mu$ m; MZ VII/122/19

the apex, 11 mm long and 2.5–3 mm wide, five-locular, septicidal; and concave along the capsule valves and between valves.

Seeds small, narrow, rectangular, 1–1.2 mm long and 0.3–0.4 mm wide, with narrow wings on each side and with hilum and chalazal appendages. Seed coat ribbed.

**Remarks.** Long and narrow, septicidal capsules and seeds with hilum and chalazal appendages certainly indicate that the above described remains represent *Rhododendron*.

There are only a few reports about *Rhododendron* fossils from Europe (Collinson & Craine 1978, Jessen 1948, Jessen et al. 1959). The capsules and seeds of *Rhododendron germanicum* Mai & Walther from Pliocene of Gerstungen/Thuringia (Mai & Walther 1988), clearly differ from here described specimens. According to Mai and Walther (1988) *R. germanicum* is morphologically related to *R. fimbriatum* Hutchinson (subgen. *Rhododendron*, sect. *Rhododendron* – Goetsch et al. 2005).

The remains of *Rhododendron flavum* Don. foss. from the Pliocene of Huba (Szafer 1954) are very close to the specimens from Lubstów in respect of size and proportion. According to Szafer (1954), the remains from Huba are morphologically close to the extant *R. luteum* Sweet (syn. *R. flavum* Don., subgen. *Hymenanthes*, sec. *Pentanthera*). It has to be noted, however, that *R. luteum* capsules and seeds are generally bigger (Hedegaard 1980, Kron 1993) than the Huba remains, but this could be caused by fossilisation.

The extant *Rhododendron* L. is represented by more than 1000 species, subdivided into 8 (Goetsch et al. 2005). Regarding the species' richness and diversity, it is difficult to indicate the closest extant species, based only on fruit and seed remains. There are, however, many similarities between the fossils from Lubstów and of the subgenus *Hymenanthes* representatives, especially sect. *Pontica* (e.g. *R. ponticum* L., *R. sperabiloides* Tagg & Forest or *R. wasonii* Hemsl. & E.H. Wilson). They are characterised, like *Rhododendron polonicum*, by relatively small, but elongated, capsules and small seeds with evident wings on both sides as well as appendages (type 1, sensu Collinson & Craine 1978) and elongated (ribbed sensu Hedegaard 1980) seed coat cells with elevated anticlinal walls.

## *Lyonia* Nutt.

### *Lyonia polonica* Kowalski n. sp.

Pl. 14, figs 3–6b

**Holotype.** Pl. 14, fig. 4 (MZ VII/116/1) collection of the Museum of the Earth PAS.

**Paratype.** Pl. 14, figs 6a, b (MZ VII/121/15).

**Locus typicus.** Lubstów.

**Stratum typicum.** Middle Miocene.

**Derivatio nominis.** Epithet refers to Poland.

**Differential diagnosis.** *Lyonia polonica* lacks sutures thickening in contrast to *L. danica*. Moreover, *L. polonica* differs from *L. danica* by clearly ellipsoidal, not subglobose, capsules, a much shorter calyx, and style and stigma completely sunken within the capsule.

**Material.** Gosławice, “sandstone in lower part of the coal bed” – 9 capsules (coll. Raniecka-Bobrowska – MuzPIG Warszawa 78.III.23); Lubstów A – 1 capsule (MZ VII/122/33); Lubstów B – 15 capsules (MZ VII/116/1, 18); Lubstów C – ca 150 capsules (MZ VII/121/15).

**Description.** The capsules are relatively small, ellipsoidal or ovoid (the length-to-width ratio is on average 1.4), 2.8–4 mm long and 1.5–3.5 mm wide; five-locular, loculicidal. Placentae axile and subapical. Pedicel clearly articulated. The sepals are very short, triangular, and acuminate.

The seeds are small, wedge-shaped, 0.5–0.7 mm long, and their coat cells elongated.

**Remarks.** Although the capsule and seed characteristics clearly correspond with the extant members of the tribe Lyonieae (Vaccinioideae), the generic affinity is less certain. Lyonieae are represented in European fossil records by *Pieris quinquealata* (Menzel) Mai from the lower to middle Miocene of Germany (Mai 1999c) and *Lyonia danica* Friis from lower to middle Miocene of Germany (Mai 1964, 2000c) and Denmark (Friis 1985). In comparison to the fossils from Lubstów, *Pieris quinquealata* seeds are much bigger, narrowly oval, flat, and have a wing. Judging from Plate 8, the seeds from Herzogenrath (Mai 1999c) appear to have a unilateral wing. This is rather unusual for the extant *Pieris* and may rather suggest *Craibiodendron* W.W. Smith.

On the other hand, *Craibiodendron* develops much bigger fruits and seeds (Judd 1986) than any fossil and extant *Pieris*.

Thickenings on the sutures are unique for *Lyonia* and are the major difference between the capsules of *Pieris* and *Lyonia* (Judd 1979, 1981). This would suggest that the remains from Lubstów represent *Pieris*. Among the extant *Pieris* only the seeds of *P. nana* (Maxim.) Makino, have a similar size and morphology. However, this phylogenetically isolated species from central and northern Japan and southern Kamchatka differ significantly from the Lubstów fossils, because it has much smaller, short ovoid or subglobose (much shorter than wide) capsules, equal to or exceeded by the calyx lobes, which is often deciduous. On the other hand, there are two extant species of *Lyonia*, *L. compta* (W.W. Sm. & Jeffrey) Hand.-Mazz. from China and *L. chapaensis* (Dop) Merr. from Vietnam, both considered by Judd (1981) to be the most primitive, with very poorly developed thickenings on the structures. Both are similar to the fossils from Lubstów in respect of the size and shape of the capsules, but only *Lyonia compta* has a comparable length of the calyx lobes. They differ in respect of the seeds, which are twice as big as the compared fossils. The foregoing discussion suggests that the fossils studied here may represent *Lyonia*. They seem to be morphologically closer to the *Lyonia* species of sect. *Pieridopsis* (especially *L. compta*), than to any extant *Pieris*. However, it should be noted that this attribution is based only on characteristics of little taxonomic value, at least when distinguishing between the extant *Lyonia* and *Pieris*.

#### *Lyonia danica* Friis

Pl. 14, figs 7–9

1985 *Lyonia danica* Friis, p. 45–46, Pl. 12, figs 1–6.

2000b *Lyonia danica* Friis; Mai, p. 66–67, Pl. 19, figs 1–9, Pl. 22, figs 9–10, Pl. 23, fig. 5.

2008 Ericaceae gen.; Kowalski, Pl. 2, figs 4, 5.

**Material.** Lubstów A – 3 capsules (MZ VII/122/24).

**Description.** Capsules globose or subglobose, 3.4–5.8 mm in diameter, robust, thick walled, five-locular, loculicidal. A distinct bevel along the margin of the capsule valves and rare, fragmentary, preserved dorsal thickening between the capsule valves. Placenta apical.

**Remarks.** Shape, size, other characteristics of the capsules and, especially, the dorsal

thickenings indicate that specimens from Lubstów and FASTERHOLT (Friis 1985) represent the same species. This species is known so far from several lower (Lausitz) to middle Miocene (Puschwitz, Merka, Berzdorf, Horschach) of Germany (Mai 2000b) and Denmark (Friis 1985).

According to Friis (1985) there is a morphological relationship between *Lyonia danica* and the extant *L. ligustrina* (L.) DC., deciduous or semi-evergreen species from southeastern North America (Judd 1981). On the other hand, Mai's (2000b) opinion is that only *L. ovalifolia* (Wallich) Drude, deciduous or evergreen species, broadly distributed in East, Southeast and South Asia (Judd 1981) can be compared with *L. danica*.

**Fossil occurrence in Poland.** This taxon has not been reported from Poland so far.

#### *Zenobia* D. Don

#### *Zenobia fasterholtensis* Friis

Pl. 15, figs 1a–1c, 4

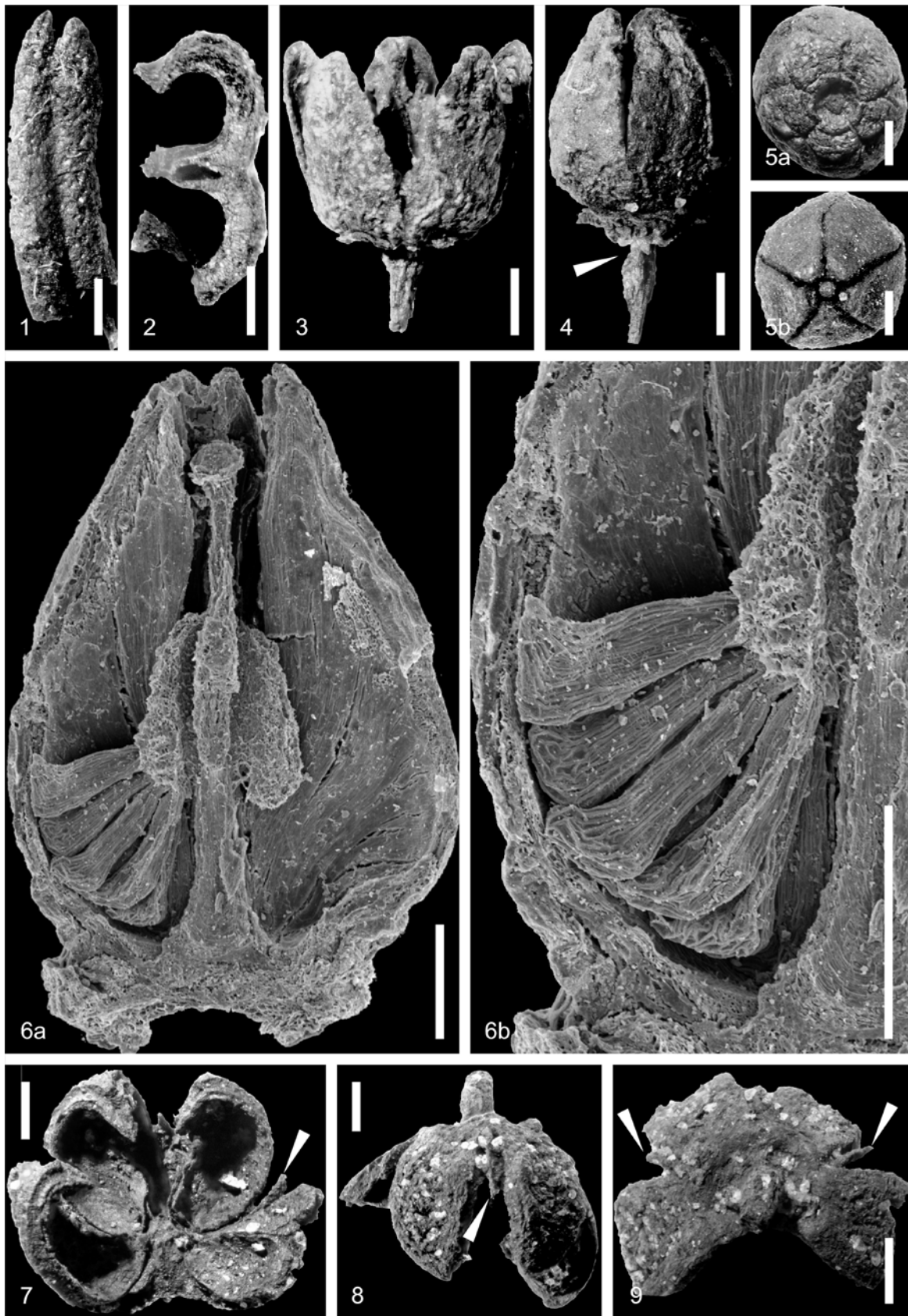
1985 *Zenobia fasterholtensis* Friis, p. 46–47, Pl. 12, figs 1–6.

**Material.** 2 fragments of capsule with seeds (MZ VII/121/).

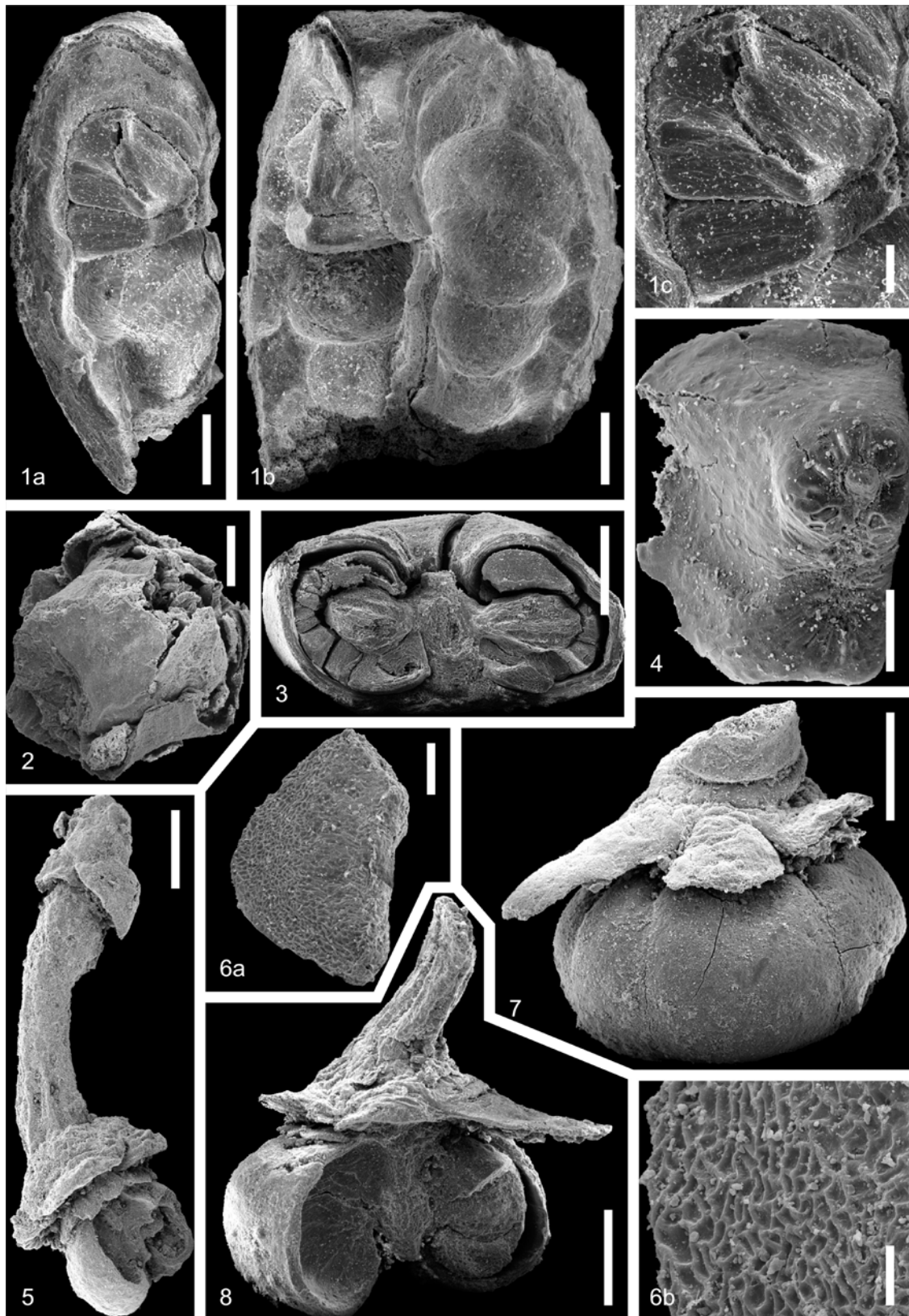
**Description.** The capsule fragments are ca 4 mm in diameter, robust, and thick walled. Placentation apical. Seeds generally in the shape of a trapezoidal prism, about 1 mm long, hilum sometimes with small but evident protrusion, the surface of the seeds is smooth, lustrous, and the seed coat cells not too visible, short and elongated, slightly convex, and thick walled.

**Remarks.** These fossils clearly correspond with *Zenobia fasterholtensis* from the middle Miocene of FASTERHOLT (Friis 1985). There are three other fossil *Zenobia* species described from Europe, *Z. eocaenica* Mai & Walther from the upper Eocene of White Elster Basin (Mai & Walther 1985), *Z. europaea* Mai & Walther from the lower Miocene of Lusatia (Mai 2000b) and the Pliocene of Thuringia (Mai & Walther 1988), and *Z. microcarpa* Mai from the lower Miocene of Lusatia (2000b). It is probable that *Z. europaea* and *Z. fasterholtensis* may represent the same species (Mai 2000b). The generic affinity of the *Z. microcarpa* is questionable, due to the fact that the extant *Zenobia* have pyramidal or trapezoidal seeds (Lu et al. 2010)





**Plate 14.** 1. *Rhododendron polonicum* Kowalski, external side of the capsule valve fragments, apical fragment; scale bar = 1 mm; MZ VII/122/38; 2. *Rhododendron polonicum* Kowalski, cross-section of the capsule valve; scale bar = 0.5 mm; MZ VII/122/38; 3, 4, 5a, b. *Lyonia polonica* Kowalski, capsules: 3 – open, 4 – closed (arrow indicate pedicel articulation) (Holotype), 5a – polar view, base, 5b – polar view, apex; scale bar = 1 mm; MZ VII/116/1; 6a, b. *Lyonia polonica* Kowalski (Paratype), capsule: a – two locules exposed longitudinally, b – enlargement of a, showing seeds and placenta details; scale bar = 0.5 mm; MZ VII/121/15; 7–9. *Lyonia danica* Friis, capsules: 7 – internal view, 8 – lateral view, 9 – basal view (arrows indicate thickenings between capsule valves); scale bar = 1 mm; MZ VII/122/24



**Plate 15.** 1a–c. *Zenobia fasterholtensis* Friis, capsule valve with seeds: **a** – lateral view, **b** – adaxial view, **c** – enlargement of a, showing two seeds; scale bar: a, b = 0.5 mm, c = 200  $\mu$ m; MZ VII/121/21; 2. *Zenobia microcarpa* Mai, capsule, apical view; scale bar = 0.5 mm; MZ VII/121/27; 3. *Leucotrys europea* Kowalski, capsule fragment, longitudinally exposed locules with seeds; scale bar = 1 mm; MZ VII/121/33; 4. *Zenobia fasterholtensis* Friis, seed, view of the hilum; scale bar = 200  $\mu$ m; MZ VII/121/27; 5. *Leucotrys europea* Kowalski (Paratype), young capsule preserved with pedicel and part of basal bracteoles; scale bar = 1 mm; MZ VII/121/34; 6a, b. *Leucotrys europea* Kowalski (Paratype), seed: **a** – lateral view, **b** – enlargement of a, showing details of the surface; scale bar: a – 200  $\mu$ m, b – 50  $\mu$ m; MZ VII/121/35; 7. *Leucotrys europea* Kowalski (Paratype), capsule with calyx remains; scale bar = 1 mm; MZ VII/121/36; 8. *Leucotrys europea* Kowalski (Holotype), capsule with calyx remains; scale bar = 1 mm; MZ VII/121/16

not splint-like (Mai 2000b). The relationship between *Z. eocaenica* and specimens from Lubstów is less probable regarding the age of the White Elster finds.

The extant *Zenobia* is a monospecific genus (*Z. pulverulenta* (Bartr.) Pollard) distributed along the East Coast of the USA (Godfrey & Wooten 1981).

Fossil occurrence in Poland. This taxon has not been reported from Poland so far.

### *Zenobia microcarpa* Mai

Pl. 15, fig. 2

2000b *Zenobia microcarpa* Mai, p. 71, Pl. 19, figs 26–31, Pl. 22, figs 15, 16, Pl. 23, figs 10–12.

Material. Lubstów C – 4 fruits (MZ VII/121/27).

Description. The capsules are ellipsoid or spheroid, below 2 mm in diameter, five-locular, and the capsule valves have a median, longitudinal depression. Calyx lobes up to 2/3 the length of the fruit.

Remarks. Specimens from Lubstów correspond with *Zenobia microcarpa* from the lower Miocene of Sandförsstgen (Mai 2000b) in respect of the size and general shape.

According to Mai (2000b) there is only a general resemblance between *Zenobia pulverulenta* (Bartram ex Willdenow) Pollard, and the only extant species and *Z. microcarpa*. He suggested also that these remains are difficult to compare due to the fact they may represent immature fruits. Given the splint-like (Mai 2000b) seeds inside the capsules, their generic assignment is questionable.

### *Leucotryx* Kowalski n. gen.

Pl. 15, figs 3, 5, 6a, 6b, 7, 8

Type species. *Leucotryx europea* Kowalski n. sp.

Holotype. Pl. 15, fig 8 (MZ VII/121/16), collection of the Museum of the Earth PAS.

Paratypes. Pl. 15, figs 5–8 (MZ VII/121/33–36), collection of the Museum of the Earth PAS.

Locus typicus. Lubstów.

Stratum typicum. Middle Miocene.

Derivatio nominis. From Europe.

Generic and specific diagnosis. Capsules loculicidal. Seeds semicircular, angular;

seed coat cells reticulate, isodiametric. Basal bracteoles. Pedicel not articulated.

Material. Lubstów A – 3 capsules (MZ VII/122/47; UWPalaeo/mag.2004/21); Lubstów B – 7 capsules (MZ VII/116/19); Lubstów C – ca 500 capsules (MZ VII/121/16, 33–37).

Description. The capsules are oblate spheroid, 3–4 mm in diameter and 2–2.5 mm long, five-locular, loculicidal, and the capsule valves clearly articulated. Pedicel not articulated, up to 4 mm long, with the pair of the basal, opposite bracteoles. The calyx is wide-open, with calyx lobes up to 1/2 the length of the fruit, 2 mm long, imbricate. Placentae central, extended into the locule and completely covered by seeds.

Seeds semicircular, 0.6–1 mm long and 0.35–0.5 mm wide, the side walls are concave or flat, hilum region frequently protrudes, pointed. Seed coat composed of isodiametric cells, outer periclinal walls concave.

Remarks. These remains conform to the Vaccinioideae. Shape, size and morphology of the seeds correspond to those of the extant *Eubotrys racemosa* (L.) Nutt (Gaultherieae). On the other hand, the basal bracteoles relate these fossils to the extant *Leucothoe* (Judd et al. 2012, 2013, Stevens et al. 2004). Careful observation did not indicate pedicel articulation, which is rather unusual among Gaultherieae; this characteristic can be found only in *Oxydendrum* DC. and some Vaccinieae (Kron et al. 2002). While there is not much doubt as to the subfamilial affinity of the *Leucotryx*, its tribal affinity remains uncertain. These remains represent an extinct genus, probably closely related to both *Eubotrys* and *Leucothoe*. The shape and the morphology of the seeds is attributed to *Eubotrys* sp. from FASTERHOLT flora (Friis 1985), suggesting that they may represent *Leucotryx*.

### Gaultherieae gen. et sp. indet.

Pl. 16, figs 1, 2

Material. Lubstów C – 35 fruits (MZ VII/121/38–41)

Description. Fruits oblate spheroid, 2.5–4.5 mm in diameter; fruit walls parenchymatous, relatively thick at the base, getting thinner toward the apex. The calyx remains at the base.

The seeds are small, ellipsoid, 0.4–0.42 mm long and 0.33–0.35 mm wide. Seed coat cells

isodiametric to slightly elongated, and the periclinal walls convex.

**Remarks.** The fruits appear to be immature capsules. The seeds are comparable to some representatives of the Gaultherieae, especially to *Gaultheria* Kalm. ex L. Generally, the fruits of the extant *Gaultheria* develop berries or capsules surrounded by a fleshy calyx, but there are species in some sections (sect. *Monoanthea*, ser. *Myrtilloideae*; sect. *Brossaea*, ser. *Leucothoides*, *Rupestres*, *Nubigenae*) in which the calyx remains unchanged (Middleton 1991a, 1991b).

Apiales Nakai

Araliaceae Juss.

### *Aralia* L.

#### *Aralia* aff. *dorofeevii* Mai

Pl. 12, figs 1a–1b

1991 *Aralia dorofeevii* Mai; Mai & Walther, p. 114, Pl. 14, fig. 22.

1997 *Aralia dorofeevii* Mai, p. 70–71, Pl. 10, fig. 11.

**Material.** Lubstów A – 1 endocarp (MZ VII/122/48); Lubstów C – 3 endocarps (MZ VII/121/30).

**Description.** The endocarps are more or less semicircular, 2.8–3.0 mm long and 1.7–1.9 mm wide, and flat. The ventral edge is straight, apically and basally rounded. The surface is covered with disorganised tubercles.

**Remarks.** The general shape of the endocarps described here corresponds with *Aralia dorofeevii* from the Oligocene (Bockwitz) and Miocene (Muldenstein) of Germany (Mai & Walther 1991), but they differ in terms of size and sculpture. The specimen types of the *A. dorofeevii* are up to 2.6 mm long and 1.5 mm wide, and have a directional tubercles arrangement. Another fossil species, comparable in shape to the specimens from Lubstów, is *A. rugosa* Dorofeev from the Oligocene of Dunaevki Jar/Russia (Dorofeev 1963), except that the latter have smaller endocarps, up to 2.5 mm long and 1.8 mm wide, and a pitted surface. The sculpture relates the specimens from Lubstów to the *A. dorofeevii*, but it is unclear whether the differences in size and

the observed tubercles arrangement indicates inter- or intraspecific variability.

**Fossil occurrence in Poland.** This taxon has not been reported from Poland so far.

#### *Aralia* aff. *lusatica* Mai

Pl. 11, figs 6a, 6b

1991 *Aralia lusatica* Mai; Mai & Walther, p. 114–115, Pl. 14, fig. 21.

2000b *Aralia lusatica* Mai, p. 31.

**Material.** Lubstów C – 2 endocarps (MZ VII/121/29).

**Description.** The endocarps are semicircular, flat, 2.5–2.7 mm long and 1.3–2.0 mm wide. The ventral side is straight or concave, basally and apically slightly tapered, but not pointed. The surface is lustreless.

**Remarks.** These endocarps mostly resemble *Aralia lusatica*, based on the general shape and size, but they differ with the absence of transverse striae on the surface. The differences in ornamentation may be due to poorer preservation of the Lubstów specimens. *Aralia lusatica* has been reported from the late Oligocene to early Miocene of Germany (Mai 1997, 2000b). According to Mai & Walther (1991), a comparable extant species is *A. spinosa* L. from eastern North America. This species exhibits a broad ecological amplitude, but prefers moist conditions and is found in Eastern North American shrub bogs, so-called “pocosins” (Sullivan 1992). It is also worth mentioning that a few prickles, resembling those of the extant *Aralia*, were found in Lubstów C. (Pl. 11, fig. 2).

**Fossil occurrence in Poland.** This taxon has not been reported from Poland so far.

Dipsacales Berchtold et J. Presl

Adoxaceae E. Mey.

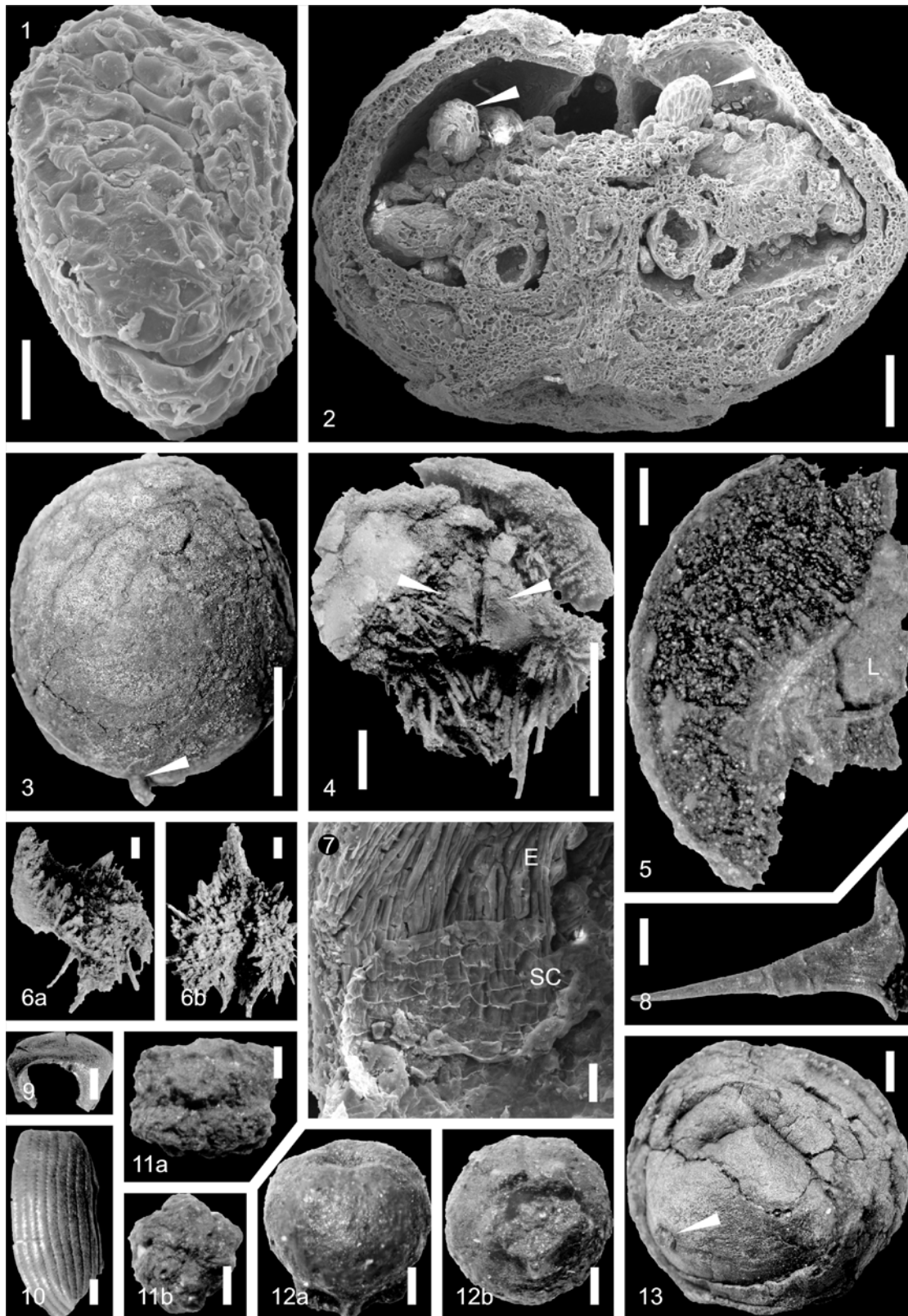
### *Viburnum* L.

#### *Viburnum* aff. *hercynicum* Mai et Walther

Pl. 11, figs 5a, 5b, Pl. 12, figs 2, 3

1988 *Viburnum hercynicum* Mai & Walther, p. 195, Pl. 37, figs 8–10.

**Material.** Lubstów B – 1 seed (MZ VII/116/24); Lubstów C – 29 seeds (MZ VII/121/19).



**Plate 16.** 1. Gaultherieae gen. et sp. indet., seed; scale bar = 0.1 mm; MZ VII/121/39; 2. Gaultherieae gen. et sp. indet., fruit in longitudinal section (arrows indicate seeds); scale bar = 0.5 mm; MZ VII/121/38; 3. *Carpolites drupifera* Kowalski (Paratype), fruits, lateral view (arrow indicates pedicel); scale bar = 5 mm; MZ VII/122/50; 4. *Carpolites drupifera* Kowalski, fruits fragment (arrows indicate two part of endocarp); scale bar = 5 mm; MZ VII/122/50; 5. *Carpolites drupifera* Kowalski, longitudinal section of the fruits fragment (L – locule); scale bar = 1 mm; MZ VII/122/50; 6a, b. *Carpolites drupifera* Kowalski, separated endocarp: a – lateral view, b – abaxial view; scale bar = 1 mm; MZ VII/122/50; 7. *Carpolites drupifera* Kowalski, locule fragment, (E – endocarp, SC – seed coat); scale bar = 50  $\mu$ m; MZ VII/122/50; 8. *Aralia?* prickle; scale bar = 1 mm; MZ VII/121/39; 9. Coleoptera, thorax; scale bar = 1 mm; MZ VII.121/38; 10. Coleoptera, elytra; scale bar = 1 mm; MZ VII.121/38; 11a, b. Lepidoptera caterpillars coprolite: a – lateral view, b – polar view; scale bar = 0.5 mm; MZ VII/121/40; 12a, b. Gall?: a – lateral view, b – polar view; scale bar = 0.5 mm; MZ VII/121/41; 13. *Carpolites drupifera* Kowalski (Holotype), fruit, polar view (arrow indicates pedicel); scale bar = 2 mm; MZ VII/122/51

**Description.** The endocarps are mostly elliptic or ovate, compressed, undulate, 2.3–3.9 mm long and 1.8–2.9 mm wide. Surface relatively even (eroded?) or tubercled. Delicate, two ventral and one dorsal groove, sometimes not developed. The endocarps' edge rounded, and relatively smooth.

**Remarks.** The general shape, size and characteristic ornamentation of these endocarps conforms to *Viburnum*. Among previously recognised fossil species, the specimens from Lubstów appear to be morphologically closest to *V. hercynicum* from the Pliocene of Thuringia (Mai & Walther 1988), except that they are almost half the size of the specimens from Thuringia.

*V. hercynicum* has been reported only in the Pliocene. Mai (2004) suggested that remains from the Pliocene of Czorsztyn, described by Szafer (1954) as *V. sp. dilatatum* Thunb, can be related to *V. hercynicum*.

According to Mai (2004), *V. hercynicum* correspond to the extant *V. wrightii* Miq., *V. dilatatum* Thunb. and *V. hupehense* Rehd from sect. *Succodontotinus* sensu (Winkworth and Donoghue 2005). However, given the size, the Lubstów specimens are closer to those of the extant *Viburnum*, which develops the smallest endocarps (Jacobs et al. 2008), such as for example *V. luzonicum* Rolfe (sect. *Succodontotinus*) from China, Taiwan and Philippines (Hui-Lin 1963).

**Fossil occurrence in Poland.** Pliocene: Czorsztyn? (Szafer 1954).

Incertae sedis

### *Carpolites* Sternberg

#### *Carpolites lubstovens* Kowalski n. sp.

Pl. 17, figs 1a–7b

**Holotype.** Pl. 17, figs 1a–c (collection of the Museum of the Earth PAS).

**Paratypes.** Pl. 17, figs 2a, 2b, 3–6, 7a, 7b (collection of the Museum of the Earth PAS).

**Locus typicus.** Lubstów.

**Stratum typicum.** Middle Miocene.

**Derivatio nominis.** From Lubstów.

**Material.** Lubstów A – 63 fruits (MZ VII/122/32, 34, 39, 40), Lubstów B – 1 fruit (MZ VII/116/6).

**Diagnosis.** The fruits are drupaceous, the style long and continuous with the ovary, and the stigma slightly lobed. The calyx has short valvate sepals. The pericarp surface is smooth, and the endocarp 2–4 fold, thin-walled. The seeds' coat is single layered. The pedicel is bent, close to the fruit.

**Description.** Fruits with fleshy epicarp, variable in shape, but mostly pyriform or campanulate, 4–8 mm long and 2.5–8.5 mm wide. Depending on the fruits' shape, gradually or abruptly tapering into the style. The stigma is slightly 5 lobed. The calyx is very short, and the sepals valvate, round. Pedicel robust, moderately long, and abruptly bent close to the fruit base. The epicarp is smooth, and the mesocarp is composed of broad, isodiametric parenchymatous cells. The endocarp is 2–4 fold, delicate, membranous, and composed of small, elongated cells perpendicularly oriented to the central column of the vascular bundles. Each part of the endocarp, if fertile, contains a single ovoid seed. The cells of the testa are isodiametric or slightly elongated.

**Remarks.** The lack of seeds in most of the investigated specimens suggests that *Carpolites lubstovens* may represent aborted fruits with unfertilized ovules. On the other hand, judging from the wide spectrum of the fruit shapes and their parenchymatous mesocarp, it looks like they were fleshy and soft enough to deform while hanging on mother plant branch.

The general morphology of these fruits strikingly resembles the extant Ericaceae, especially Arbutoideae, but they exhibit a combination of characteristics unseen in the extant Arbutoideae, and differ in the erect pedicel, a persistent style and lobed stigma. Further comparative studies are needed to verify whether these fossils represent Ericaceae.

#### *Carpolites drupifera* Kowalski n. sp.

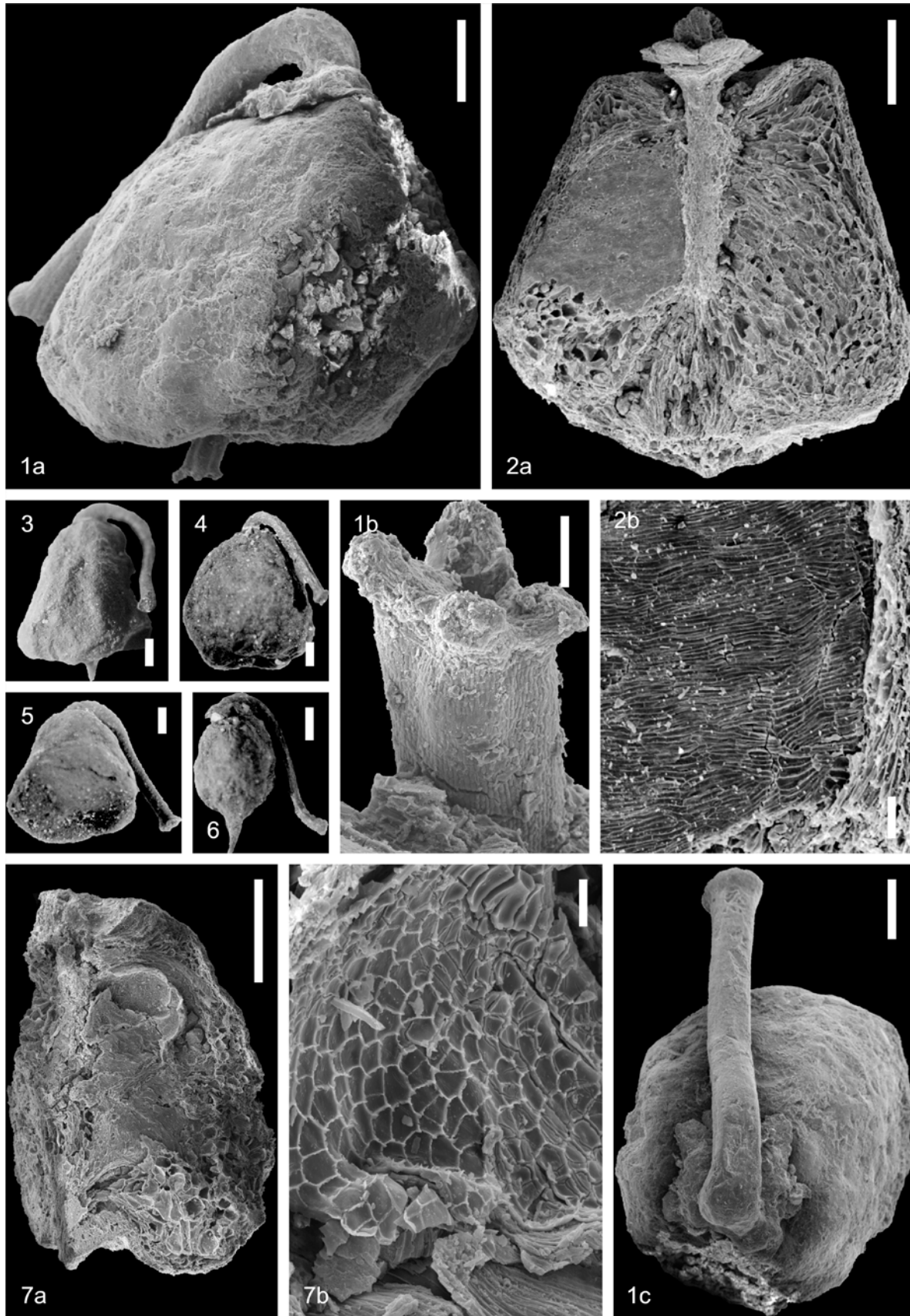
Pl. 16, figs 3–7, 13

**Holotype.** Pl. 16, figs 13 (MZ VII/122/51) – collection of the Museum of the Earth PAS.

**Locus typicus.** Lubstów.

**Stratum typicum.** Middle Miocene.

**Derivatio nominis.** The epithet *drupifera* = drupe bearing.



**Plate 17. 1a–c.** *Carpolites lubstovenskis* Kowalski (Holotype), fruit: **a** – lateral view, **b** – enlargement of **a**, showing style and stigma, **c** – basal view; scale bar: **a**, **c** = 1 mm, **b** = 200  $\mu$ m; MZ VII/122/ 32; **2a, b.** *Carpolites lubstovenskis* Kowalski (Paratype), fruits, cross-section: **a** – general view, **b** – enlargement of **a**, showing detail of the endocarp structure; scale bar: **a** = 1 mm, **b** = 100  $\mu$ m; MZ VII/122/ 39; **3–6.** *Carpolites lubstovenskis* Kowalski (Paratypes), fruits, variability of shape; scale bar = 1 mm; MZ VII/122/ 34; **7a, b.** *Carpolites lubstovenskis* Kowalski (Paratype), fragment of the fruits in cross-section: **a** – general view, **b** – enlargement of **a**, showing detail of seed coat; scale bar: **a** – 1 mm, **b** = 50  $\mu$ m; MZ VII/122/40

Material. Lubstów A – ca 100 fruits (MZ VII/122/50, 51, 54)

Description. The fruits are drupaceous, spheroid, and up to 1.5 cm in diameter. The style is knob like. The pedicel is very short (partially preserved?). The calyx is absent, caducous, and the epicarp smooth. The mesocarp is thick, and composed of broad, isodiametric parenchymatous cells and numerous fibres. Close to the fruit base central vascular bundle branch into numerous, smaller fibres, and some are incorporated into the endocarp structure and some penetrate the mesocarp. The endocarp consists of five separate parts, radially from the central column of the vascular bundles, and fused basally along the ventral margin. The endocarp parts are sinuous in their lateral view and cordate from the abaxial side view, and are densely covered with scattered fibre bundles protruding from the surface. The endocarp wall is relatively thin, hard, and woody-fibrous, with each part containing three, interconnected cells. The seed coat is single layered, and composed of isodiametric cells.

Remarks. The familial affinity of these fruits is unknown. The morphology of their seed coat resembles that of *Carpolithes lubstovens* but, in contrast to *C. lubstovens*, the internal construction of the *Carpolites drupifera* is not like any extant Ericaceae.

#### NON-CARPOLOGICAL AND ANIMAL REMAINS

Many fossil fruits and seeds remain undetermined and have not been included in this paper. Besides those described or illustrated above, other plant and animal remains were found in Lubstów, including Coleoptera (thorax and elytra) (Lubstów B – MZ VII/116/26 and Lubstów C – MZ VII/121/38 – Pl. 16, fig. 9, 10) and Lepidoptera caterpillar coprolites representing “type 2” sensu Łańcucka-Środoniowa (1979) (Lubstów C – Pl. 16, figs 11a, 11b). In Lubstów A and C gall-like fossils were also found (Pl. 16, figs 12a, 12b).

Resin particles (up to 5 mm long) and numerous, differently sized, fusain fragments were found in each of the three Lubstów sites.

#### FLORISTIC COMPOSITION

The conclusions presented in this monograph are based mainly on fossil assemblages from Lubstów. Remains from Gosławice and Pątnów barely contribute in flora and vegetation reconstruction, in addition to climatic conclusions, because they were accidentally collected and accompanied only by very limited data concerning their provenance. Despite these limitations, Gosławice and Pątnów assemblages provide valuable complementation to knowledge of the Konin region palaeovegetation.

In the present monograph more than 3000 specimens were studied (Lubstów A, B, C – ca 2686 specimens; Gosławice and Pątnów – ca 405 specimens), and as a result 59 taxa (including the 16 taxa reported before – Kowalski 2008, Kowalski & Fagúndez 2017) were recognised, revised and documented (Lubstów – 52; Gosławice and Pątnów – 23) (Tab. 1). Fifty-six species are securely assignable to modern families; with one (*Cupressospermum saxonicum*) representing the extinct conifer family, Geinitziaceae, and two species (*Carpolites*) whose familial affinities remain uncertain. Lubstów floras provide nine new forms, including three genera (*Kownasia*, *Leucotrys*, *Maiella*), and three species (*Enkianthus maii*, *Rhododendron polonicum*, *Lyonia polonica*) and three morphotypes (*Kalmiocarpus dorofeevi*, *Carpolites lubstovens*, *C. drupifera*).

Familial and species diversity of the floras studied here is relatively low (Lubstów – 23 families and 52 species), although some families are exceptionally diverse. Taking into account the number of species per family the most diverse are Ericaceae: 11 (Lubstów: A – 7, B – 5, C – 8), Pinaceae – 4 (Lubstów: A – 3, B – 3, C – 4), Cupressaceae – 4 (Lubstów: A – 4, B – 2, C – 1), and Cyperaceae – 4 (Lubstów: A – 4, B – 1, C – 1). When considering all three Lubstów sites together the most common remains are: *Comarostaphylis globula* (33%), *Leucotrys europea* (19%), *Lyonia polonica* (6%), *Epipremnites reniculus* (6%), *Brasenia victoria* (5%), *Fothergilla europaea* (4%) and *Carpolites drupifera* (4%), with the remaining taxa making up less than 3% each. When evaluating each individual site, the most common remains are as follows: Lubstów A: *Comarostaphylis globula* (49%), *Carpolites drupifera* (15%), *Carpolites lubstovens* (9%), *Pirocarpella aquisgranensis* (4%); Lubstów B: *Brasenia victoria* (27%),



*Fothergilla europaea* (27%), *Comarostaphylis globula* (13%), *Ampelocissus* aff. *lobatum* (12%), *Pinus thomasi* (6%), *Lyonia polonica* (4%); Lubstów C: *Comarostaphylis globula* (31%), *Leucotrys europea* (31%), *Epipremnites reniculus* (10%), and *Lyonia polonica* (9%).

The collected disseminules of Angiosperms (96%) distinctly outnumber those of Conifers. This disproportion does not exactly reflect the real composition of the fossil floras, but is rather a consequence of inconsistency in the collecting and extracting method, and is also the result of the relations between the sedimentary environment and the size of the transported disseminules. When considering field observations, *Pinus urani*, on par with *Comarostaphylis globula*, were two the most common species in all the three sites of Lubstów.

There is a constant group of 13 taxa (ca 30% of all taxa) shared between all three fossil assemblages of Lubstów, and Pinaceae and Ericaceae constitute half of this group. Beside this stable group, each site has its own distinctive taxa and set of taxa, as can be seen in detail in Tab. 1.

## VEGETATION RECONSTRUCTION

Most of the studied remains were found deposited within fluviatile sands, and therefore they are considered as allochthonous. Relatively long-distance transport is especially clear with respect to some robust or eroded remains (*Prunus*, *Nyssa*, *Myrica burghii*). However, many remains indicate that they have been transported relatively short distances; this is due to their delicacy and good preservation (this especially applies to Ericaceae remains). Consequently, although the studied fossil assemblages are generally allochthonous, it seems that they may represent a mixture of local and extra-local floras, but with a high contribution of the local flora remains. Therefore, the vegetation types and their taxonomic composition presented below are only speculative.

As has already been mentioned, Miocene sedimentation in Lubstów, Gosławice and Pałnów developed within vast river valleys. Certainly, the flat bases of those valleys were favourable for developing diverse wetland vegetation.

The fossil assemblages of all the sites are dominated (regarding taxonomic diversity and

the number of specimens) by woody plants (85%), among which Ericaceae and conifers (Cupressaceae, Pinaceae, Geinitziaceae) are fundamental components. The high percentage of Ericaceae indicates prevailing acidic, infertile, xeric mesic and hydric substrates on which most of their modern representatives are tolerable. Today, many coniferous trees, especially pines (4 species in Lubstów) occupy habitats similar to those occupied by Ericaceae, and they frequently coexist. The modern analog suggests vegetation in the Lubstów valley (probably also Gosławice and Pałnów) was dominated by relatively species-poor, plant communities composed mainly of Ericaceae, with an admixture of *Fothergilla*, *Magnolia*, *Myrica*, *Pirocarpella* (extinct Cyrillaceae), *Aralia*, *Viburnum*, *Frangula*, and *Castanopsis*. Depending on the succession, and the hydrologic-edaphic conditions, the shrubs may have shared these habitats with conifers (*Pinus*, *Cunninghamia*, *Cupressus*, *Cupressospermum*, *Chamaecyparis* – Lubstów; *Sciadopitys*, *Sequoia* – Gosławice). Conifers may have occurred both in patches and more extensive forests. It is likely that these plants were the components of shrub bogs, pine bogs and other mixed coniferous bogs, but the contribution of each of these vegetation types has not been established.

Mixed coniferous bogs, pine bogs and shrub bogs are regarded as the important and unique types of the peat-forming vegetation of the European Tertiary. These azonal vegetation have been classified by Mai (1995, 2000b, 2001b) into “Lorbeer-Koniferen-Wälder, Kiefern-Lorbeer-Wälder and Moor-Lorbeer-Gehölze”. The first type is characterised by dominance of the genera formerly assigned to the Taxodiaceae (*Cunninghamia*, *Sequoia*), *Sciadopitys* and understory of taxonomically diverse evergreen angiosperms. The dominant pines and diverse understory are specific to the second type noted. A diverse mixture of shrubs, including representatives of Ericaceae, Myricaceae, and Symplocaceae, etc., distinguishes the third type from the others. Judging from the taxonomic composition, each of these three vegetation types may have occurred in Lubstów, but in Gosławice only “Lorbeer-Koniferen-Wälder” elements have been found. There is no direct evidence that these were the types of vegetation from which the brown coals (the 1<sup>st</sup> group of seams) exposed in Lubstów originated. While

in Gosławice, at least some types of the peat forming vegetation can be determined. *Sciadopitys* remains preserved in coal clearly indicate that this tree contributed to the I-Middle Polish seam group formation process, and this was suggested before by Raniecka-Bobrowska (1970). Using dispersed cuticles from Miocene brown coal seams as a basis five facies have been distinguished, representing different vegetation types (Schneider 1992). They developed in chronological sequence and represent palustrine floral succession on the Miocene peat bogs. The *Sciadopitys* raised bog represents the final stage of this succession and was preceded by *Pinus* bog, reed marsh, bush swamp and *Glyptostrobus* swamp stages. The composition of the Lubstów fossil assemblages demonstrates a similar successional process which has possibly occurred in peat bogs in the Konin region.

*Glyptostrobus* and *Nyssa* remains indicate vegetation submersed by seasonal inundation. They may have grown as a major component of forested borders of rivers, swamps, or ponds of Lubstów and Gosławice valleys. The species-poor *Glyptostrobus* swamp forest represents the initial stage of the palustrine floral succession (Schneider 1992). It has been suggested that *Glyptostrobus* grew in association with *Nyssa* (Mai 2001b). Two *Nyssa* species were found in Lubstów, but they probably replace one another depending on the edaphic conditions and inundation regime, comparable to the modern *Taxodium* and *Nyssa* assemblage in North America (Christensen 2000). Shrubs (*Myrica* cf. *ceriferiformis* and perhaps some Ericaceae) and aquatic herbs may have occurred around the tree bases.

Herbaceous plants are represented by aquatic macrophytes, composed of helophytes (*Cladium*, *Scirpus*, *Sparganium* and probably also *Kownasia*, *Cladiocarya*, *Epipremnites*, and *Urospatites*) and ephydates (*Nymphaea*, *Brasenia* and the previously reported *Nuphar*). Plants with floating leaves suggest standing or slow-flowing waterbodies.

Some types of vegetation described above resembles the modern wetlands' vegetation of the palustrine type sensu Cowardin et al. (1979). There is no doubt that small, stagnant, water bodies may have existed at least in some parts of the Lubstów valley and that they were periodically or episodically flooded. They sustained various wetland vegetation, aquatic macrophytes and swamp forests, besides shrub

bogs, pine bogs or mixed coniferous bogs. The ecological requirements of the fossil assemblage components indicate that shrub bogs and coniferous swamp forests from Lubstów resemble to some extent two modern, palustrine wetland types from North America, such as pocosins and "Atlantic white cedar swamp forest" (AWCSF) (see Kowalski 2008). Generally, pocosins are shrub dominant bogs with scattered trees (pines) and AWCSF are swamp forests dominated by *Chamaecyparis* (Christensen 2000). The soil moisture certainly varied and, consequently, we can expect that both hydric and mesic habitats occurred in the flat bottom of the valleys. Up to four different pine species have been found on a single site in Lubstów. This may reflect the wide variety of habitats. As there is no evidence that bogs dominate in the studied part of the depositional sequence, other vegetation types must also be taken into account. Pine-dominated vegetation in the Konin region may have also resembled modern "flatwoods" and "savannas" from the Atlantic and Coastal Plains/ USA. The dominant trees in these communities are *Pinus palustris*, *P. elliotii* and *P. serotina*. Generally, flatwood has a well-developed understory, and in savannas a herbaceous layer is more prominent. These communities are widespread in mesic habitats, on acidic and relatively infertile sandy soils that have little organic matter (Christensen 2000).

All of the mentioned modern communities are strongly affected by fire. Numerous fusain fragments (up to 3 cm long) occurring in the same layers, along with the carpological remains, suggest that fire was also an important factor controlling the development of at least some of the plant communities in the Lubstów area (if not in the Konin region).

Few remains indicate zonal vegetation, developed on fertile soils in mesic (*Myrica burghii*, *Asimina brownii* + previously reported taxa – Kowalski 2008) and xeric (*Prunus spinosa* foss.) habitats. Regarding their hard and resistant, but abraded disseminules, these remains may have been transported long distances, probably by floodwaters. Nonetheless, they are evidence of vegetation which resembled extant evergreen broad-leaved or mixed mesophytic forests sensu (Wang 1961), somewhere in the highest locations of the Lubstów valley (probably also Gosławice and Pątnów) or further upstream.

## COMPARISON WITH SOME SELECTED EUROPEAN FOSSIL FLORAS

It is difficult to propose the clear biostratigraphic position of the Lubstów floras based on floristic analysis. However, based on the lithostratigraphic division of the Neogene of the Polish Lowland we can clearly determine the timeframe for biostratigraphic correlation. According to Piwocki and Ziemińska-Tworzydło (1997) VI and VII climatic phases (*Tricolporopollenites megaexactus* zone and *Iteapollis angustiporatus* zone) correspond with deposits of the Adamów Formation, and they can be correlated with IX and X macrofloristic zones sensu Mai (1967). The VIII and IX climatic phases correspond, however, with the lowermost part of the Poznań Formation deposits, which can be correlated with the XI and XII macrofloristic zones. This would suggest that Lubstów A and B floras represent the “Kleinleipisch – Františkové Lázně” Floristic Complex (former IX and X macrofloristic zones; correlated with Hemmorium/Reinbekium and Karpatian/Badenian = ca 16.3 Ma – Mai 2001b) and Lubstów C flora represents the “Klettwitz – Salzhausen” Floristic Complex (former XI and XII macrofloristic zones; correlated with Reinbekium and Badenian; <16.3 Ma – Mai 1995, 2001b). Presence of *Lyonia danica* and *Zenobia fasterholtensis* (Lubstów C) relates Lubstów floras with Fasterholt flora (Friis 1985), which was included by Mai (2001b) to the “Kleinleipisch – Františkové Lázně” Floristic Complex. The first noted taxon was found in site A, whereas the second was in site C. This may suggest that the floras of all the sites represent one floristic complex, probably “Kleinleipisch – Františkové Lázně”. However, in view of the estimated absolute age, Lubstów floras should be seen as “Klettwitz – Salzhausen” floras. Among the Badenian carpological floras from Poland, only fossil flora from Wieliczka correlate with the “Klettwitz – Salzhausen” Floristic Complex (Mai 2001b). This flora, however, represents the “transeuropean-Paratethys” bioprovince, and despite the great number of documented taxa, shows very little overlap with Lubstów. This applies to only some of the most common and widespread species.

Another species-rich fossil flora of the “transeuropean-Paratethys” bioprovince occurs in Stare Gliwice (Szafer 1961). This flora cannot be linked with Lubstów, in terms of taxonomic

composition, vegetation and habitats. The Kędzierzyn Formation, where this flora occurred, represents the Sarmatian stage, and according to Mai (2001b) correlates with the floras of the “Schipkau - Konin” Floristic Complex.

Fossil floras from Lubstów, Gosławice and Pątnów represent the “Atlantic – Boreal” bioprovince sensu Mai (1995). There are a few fossil floras from Poland that belong to this bioprovince, Morzysław, Rypin, Gozdnicza. However, the biostratigraphic position and bioprovince where Lubstów, Gosławice and Pątnów floras belong gave them a unique position among the fossil macrofloras described so far from Poland.

The flora from Morzysław, near Konin (Raniecka-Bobrowska 1954, 1959), cannot be linked with Lubstów floras, because it is stratigraphically younger (it is a grey clay member of the Poznań Formation, above the sands, with Lubstów C flora – see Fig. 2). Morzysław flora has a different taxonomic composition, vegetation and habitat, and according to Mai (2001b) can be included with the “Schipkau – Konin” Floristic Complex. The main vegetation type reflected in the composition of this flora is swamp forest, with *Glyptostrobus* and *Cephalanthus* as a dominant element and *Cornus*, *Decodon* as associates. Presence of the *Alnus* and *Populus* suggests floodplain forests, which are missing in Lubstów. Even the composition of the aquatic macrophyte communities differs from those reported in Lubstów. Helophytes were represented by *Diclidocarya*, *Lysimachia*, *Proserpinaca*, *Dulichium*, and *Phragmites*, and ephydates by *Salvinia*, *Ceratophyllum*, *Aldrovanda*, *Callitriche*, *Potamogeton*, *Euryale*, *Nuphar*, and *Stratiotes*.

Some resemblance to the Lubstów floras can be found in the taxonomic composition of the Rypin flora (Łańcucka-Środoniowa 1957). The genera shared between those two sites are: *Glyptostrobus*, *Sequoia*, *Myrica suppani*, *Aralia*, *Comarostaphylis*, *Brasenia*, and *Nymphaea*. There is no clear picture as to the age of the Rypin flora and the lithostratigraphic position of the sediments where the fossils were found. According to Łańcucka-Środoniowa this flora belongs to the upper Miocene (see also Stuchlik 1964). Mai (2001b) included Rypin flora to the “Schipkau – Konin” Floristic Complex. That would mean the Rypin flora correspond with the uppermost middle–upper Miocene floras of the Poznań Formation. While

according to Piwocki et al. (2004) the Rypin sequence encompasses the lower and middle Miocene, with the youngest sediments of the Adamów Formation.

The Gozdnicza flora is much younger (late Miocene – Zastawniak 1992) and represents different vegetation, but is worth mentioning because of *Mastixia thomsonii* (Łańcucka-Środoniowa et al. 1992), which is a relatively rare species, characteristic of upper Miocene Rhenish floras. Common Neogene taxa shared between Gozdnicza and Konin region floras include: *Pirocarpella aquisgranensis*, *Ampelocissus chandleri*, *Ternstroemia sequioides*, *Symplocos incurva*, *Symplocos casparyi*, and *S. minutula*.

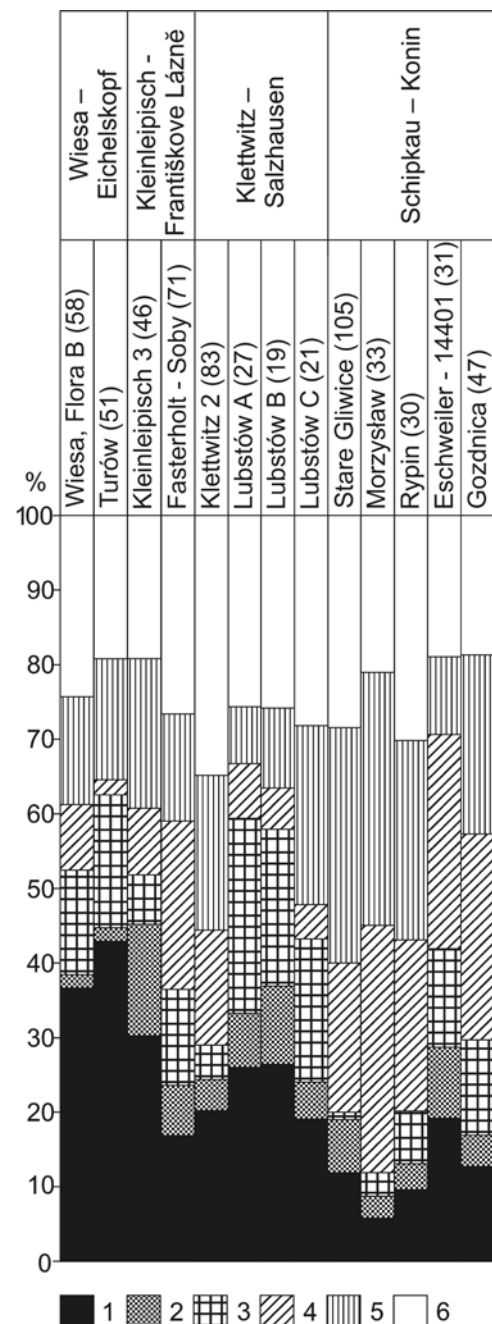
Certainly, many Miocene floras from Europe can be compared with the floras studied here in respect of the taxonomic composition. Surprisingly, particularly close are the upper Miocene (Tortonian – King et al. 2016) floras from the lower Rhenish Basin (Kilpper 1968a, b, Van der Burgh 1987), but especially sample 14401 from Eschweiler (Van der Burgh 1987). Several common Neogene taxa are shared between Lubstów and Eschweiler, but rare species, such as *Pinus urani*, *Cupressus rhenanus*, *Pinus thomasiana*, *P. uranii* and *Mastixia thomsonii*, are of greater importance (Kilpper 1968a, b, Van der Burgh 1987). A few additional rare species reported earlier from the Lower Rhenish Basin (Kilpper 1968a, b, Van der Burgh 1987), including *Pinus leitzii*, *P. spinosa* and *Asimina brownii*, were also found in Gosławice and Pałnów. The presence of *Ruppia* fruits suggests marine influences in at least some of the Rhenish floras, distinguishing them from Konin region floras.

### CLIMATIC INTERPRETATION

In the author's view, the fossil assemblages studied here do not provide appropriate data for using standardised quantitative methods of palaeoclimate reconstruction, such as the "coexistence approach" (Mosbrugger & Utescher 1997). Despite these concerns the flora presents some important insights about the palaeoclimate.

For some taxa, the identifications are clear, like *Mastixia* and *Ternstroemia* (Kowalski 2008), which are quite consistent in their climatic requirements and may be used as climate indicators. Extant representatives of *Mastixia* and *Ternstroemia* are distributed

within tropics and subtropics, but frequently occur in cooler, mountainous areas. According to Mai & Walther (1978a), the presence of *Mastixia*, indicate the coldest month mean temperature (CMMT) above +10°C (but extant *Mastixia microcarpa* Liu and Peng (2009) may suggest even around +6°C), and an average annual precipitation of above 1000 mm/y (Mai 1995). The climatic requirements of the extant



**Fig. 3.** Percentage of the plantgeographical elements in the Lubstów A-C in comparison to index floras or well related to the particular floristic complex (after Mai 2000b, 2001b). Number in brackets – number of genera. 1 – Tropical, subtropical, 2 – Mediterranean, 3 – Extinct, 4 – Cosmopolitan, 5 – East Asian – North American, East Asian, North American, 6 – Panholarctic

**Table 2.** Phytogeographic elements recognized in the Lubstów, Gosławice and Pątnów floras

Element	Taxa
Tropical – subtropical	<i>Mastixia</i> , <i>Ternstroemia</i> , <i>Magnolia</i> , <i>Brasenia</i> , <i>Ampelocissus</i> , <i>Rhododendron</i> , <i>Symplocos</i> , <i>Myrica</i> , <i>Castanopsis</i>
Mediterranean	<i>Comarostaphylis</i> , <i>Cupressus</i>
Extinct	<i>Cladiocarya</i> , <i>Cupressospermum</i> , <i>Epipremites</i> , <i>Leucotrystis</i> , <i>Pirocarpella</i> , <i>Urospatites</i> , <i>Kownasia</i>
Cosmopolitan	<i>Cladium</i> , <i>Gaultherieae</i> , <i>Nymphaea</i> , <i>Scirpus</i>
East Asian – North American	<i>Aralia</i> , <i>Chamaecyparis</i> , <i>Lyonia</i> , <i>Nyssa</i>
East Asian	<i>Cunninghamia</i> , <i>Enkianthus</i> , <i>Glyptostrobus</i> , <i>Sciadopitys</i>
North American	<i>Asimina</i> , <i>Fothergilla</i> , <i>Sequoia</i> , <i>Zenobia</i>
Panholartic	<i>Frangula</i> , <i>Kalmiocalyx</i> , <i>Nuphar</i> , <i>Nymphaea</i> , <i>Pinus</i> , <i>Prunus</i> , <i>Sparganium</i> , <i>Cornus</i> , <i>Viburnum</i>

*Ternstroemia* are generally comparable to that of the *Mastixia*, but some species tolerate light frost ( $-2^{\circ}\text{C}$ ) (Fang et al. 2011).

The presence of *Brasenia* does not specify any particular climatic condition, due to the broad spectrum of climate ranges from tropical to a temperate zone, although some seeds from Lubstów have verrucae on the surface, which has been suggested as only having developed in tropical and subtropical representatives (Koch 1931).

Despite limited evidence we can safely relate these few broad-leaved evergreen trees from Lubstów to the extant vegetation of the warm-temperate or subtropical climatic zone sensu (Box 2016). They would suggest rather mild winters with occasional light frost ( $\geq -2^{\circ}\text{C}$ ). Harsher winters with moderate frost nearly every year were also possible, but the temperature probably did not drop below  $-15^{\circ}\text{C}$ , which is suggested as the temperature limit for broad-leaved evergreen trees (Box & Fujiwara 2012).

The previous climatic outline for Lubstów also applies to Gosławice and Pątnów and is in accordance with the climate types suggested by Mai (2001b) for “Kleinleipisch – Františkové Lázně” (average annual temperature =  $15\text{--}18^{\circ}\text{C}$ , winter absolute minimum =  $-9^{\circ}\text{C}$ , average annual precipitation =  $800\text{--}2000\text{ mm}$ ) and “Klettwitz – Salzhausen” (average annual temperature =  $13\text{--}17^{\circ}\text{C}$ , winter absolute minimum =  $-9^{\circ}\text{C}$ , average annual precipitation =  $500\text{--}1500\text{ mm}$ ) Floristic Complexes.

## PHYTOGEOGRAPHIC RELATIONSHIPS

For simplifying the phytogeographic considerations the floras treated here (Lubstów, Gosławice and Pątnów) were counted collectively as the Konin region floras.

When considering the Konin region flora in terms of Engler’s and Chaney’s concepts (see, Grímsson et al. 2015), Arcto-Tertiary elements clearly dominate ( $>50\%$ ), but this is not surprising for the floras younger than “Wiesa – Eichelskopf” Floristic Complex.

Modern geographic distribution of the genera found in Lubstów A–C floras has also been analysed. Using a simplified nomenclature and classification proposed by Mai (1995), the fossil genera have been grouped into six phytogeographic units (Tab. 2, Fig. 3).

This phytogeographic classification provides one more argument to clarify the biostratigraphic position of the studied floras. The proportion of the thermophylic (tropical – subtropical, Mediterranean) and extinct genera is of crucial importance. According to Mai (2001b), thermophylic and extinct genera represent  $45\text{--}53\%$  (usually  $50\%$ ) of all the genera found in the floras of the “Kleinleipisch-Františkové Lázně” floristic complex, and  $40\text{--}45\%$  in floras of the “Klettwitz – Salzhausen” floristic complex. Among 42 genera found in Lubstów, slightly more than  $40\%$  have been attributed to thermophylic and extinct genera. Consequently, this may suggest a closer relationship with the floras of the “Klettwitz – Salzhausen” floristic complex.

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