Acta Palaeobotanica 47(1): 291–311, 2007

Botanical affinity of some Neogene sporomorphs and nomenclatural problems

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Rreceived 19 October 2006; accepted for publication 26. April 2007

ABSTRACT. Fossil sporomorphs dispersed in Neogene sediments are classified i two systems; natural system after the botanical affinity, and morphological system after the principles of morphology. The International Code of Botanical Nomenclature (ICBN) explicitly states the necessity of employment priority of taxonomic names for recent and fossil plants. This led to many nomenclatural paradoxes in the case of Neogene sporomorphs.

KEY WORDS: sporomorphs, nomenclature, botanical affinity, Neogene

The rules of botanical nomenclature are clearly definied in the ICBN (Greuter ed. 2000), with all actual changes in subsequent editions, and they are equally binding taxonomists of recent and fossil plants. In description and classification of plants an uniformly and clearly defined and comprehensible way, is necessary.

Fossil plant remains are usually found as various organs. They are most frequently pollen and spores, leaves, seeds, and fruits. Flowers and inflorescences with pollen grains *in situ* are rare. The fossil organs are mostly found as dispersed remains and there is rarely the possibility to connect them with one mother-plant. For that reason fossil remains are usually classified as form-organs. Fossil plant-remains from Neogene or younger sediments are mostly included with modern genera. For plant remains from older sediments the degree of precise determination of the botanical affinity is more general, possibly to modern family or even higher taxonomic units.

The most problems are given by fossil sporomorphs described from sediments of various age and classified with the morphological system created only on the basis of pollen morphology. For Tertiary sporomorphs the best known is the Thomson and Pflug (1953) system. All described species of dispersed sporomorphs are arranged in morpho-genera and higher units. However, the species concept is basic and can represent whole genus, or even family, of extanct or living plants. The diagnostic features of higher taxonomic units such as genera, are less precisely characterized, and may not give any botanical affinity of sporomorphs, too. Recently, Bruch (2004) began a discussion about the botanical nomenclature and classification of Neogene sporomorphs. In her opinion, both botanical and morphological nomenclatures should be applicable parallel. Similar suggestion were proposed by the German palynologists Potonié, Thomson and Thiergart (1950) in the middle of the 20th century. They proposed to use the morphological nomenclature (form-taxa) as transinional for

Tertiary taxa, and belived that in the future it would be possible to connect dispersed sporomorphs with their mother-plants. Then, the morphological nomenclature (morphotaxa) could be changed into botanical names and included in the natural system of plants. Three types of genera-names were proposed at that time:

1) The genus-name for the whole mostly actual living plant (name constant).

2) The organ-genus, created on the basis of a described plant organ, with the ending showing the organ. Such a name can be used for determination on different taxonomical levels of the botanical affinity of the described organ.

3) The form-genus for dispersed plant remains with unknown botanical affinity, created exclusively on the basis of morphology.

Thomson & Pflug (1953) accepted another point of view. They arranged, for practical use of rapid determination of the age and stratigraphy of brown coal seams, all Tertiary sporomorphs after morphological features in morpho-genera. Thomson and Pflug (1953) did not consider earlier elaborations among others those of Potonié, Thomson and Thiergart (1950) in which the botanical organ names for sporomorphs were used, e.g. *Osmunda-sporites primarius* Wolff, or *Liquidambar-Pollenites stigmosus* R.Pot.

The idea of contemporary (transitional) names for plant remains was not acctepted in the last editions of the ICBN (Greuter 1987, 1994, 2000). Names for all fossil genera with suggestions of botanical affinity, or those only described on morphological features, should be created (described) with the same priority rules as in description of recent plants. This raised doubt among some palynologists. To avoid clashes with fixed rules of the ICBN palynologists working in the Neogene are including fossil sporomorphs with recent genera of plants, or are describing new genera in accordance with the ICBN (Greuter 2000) and living only the type species for the morphogenera (e.g. *Trivestibulopollenites betuloides* for pollen of *Betula* or *Triatriopollenites rurensis* for pollen of *Myrica*).

Among a great number of described fossil genera of sporomorphs an extremely important role as a guidebook is played by the Catalogue (Genera file of fossil spores) edited by Jansonius and Hills (1976–2002). The Catalogue contains critical analysis of all hitherto described and published genera of fossil sporomorphs.

The problem of confrontation of the two method of describing Neogene sporomorphs – botanical and morphological – discussed by Bruch (2004), has existed in palynology for more than 70 years. Each of these two methods has positive and negative sides, so, the most appropriate way would be to elaborate a uniform method of describing fossil sporomorphs which would unite positive elements of both the methods. Such attempts have been undertaken by many authors e.g. Potonié (1931–1960), Thiergart (1937), Raatz (1937), Potonié, Thomson & Thiergart (1950), Nagy 1969, 1985, Planderová 1991. In the paper edited by Stuchlik (1994) a proposal was made, to enlarge this method by consequently using genera names for Neogene sporopmorphs with known botanical affinity. The first element of the compound genus-name should point out the botanical affinity and the second compound – the ending of the name – should point out the organ (e.g. pollenites, pollis, sporites, sporis). In addition it has the possibility been proposed to emphasize the taxonomic level at which the comparison with the recent taxon has been done, e.g. *Castaneoideaepollis* shows the affinity at subfamily level, a *Fagaceaepollis* at family level, and *Abiespollenites* on the genus level. Unfortunately these propositions were in many cases in discordance with the ICBN (Greuter 2000), and some names of taxa published in 1994 (Stuchlik 1994) are invalid or younger synonyms of earlier described taxa.

To follow exactly the priority rules of the ICBN provides sometimes paradoxes in nomenclature of the oldest names of fossil sporomorphs with clear botanical affinity. The authors of the “Atlas of pollen and spores of the Polish Neogene” (Stuchlik et al., 2001, 2002, in press) became convinced of this, when describing new genera. Following the rules of priority of the ICBN (Greuter 2000) the authors of the above mentioned atlas are using priority genera names, but anywhere, as far as it is possible, are giving names with the first module (with prefix) indicating the botanical affinity. The authors are including existing or newly created species to genera with the information about the botanical affinity in their names. However, it is not possible to avoid nomenclature paradoxes all together. Some of them are presented below.

MORPHOLOGICAL GENUS TO WHICH BELONG ALL SPECIES REPRESENTING ONE BOTANICAL GENUS

Baculatisporites Pflug & Thomson in Thomson & Pflug 1953 – botanical affinity ***Osmunda* L.** (Pl. 1, figs 1–3)

Fossil spores included in the atlas (Stuchlik et al. 2001) as the genus *Baculatisporites* Thomson & Pflug 1953 belong doubtless to the recent genus *Osmunda*. For this morphological type of spores in 1994 (Stuchlik 1994) have been used the name *Osmundacidites* Couper 1953. In accordance with the ICBN (Greuter 2000) the priority has the genus name *Baculatisporites* Pflug in Thomson & Pflug 1953 because it was published in March 1953, and the Couper paper, in which the genus name of the same spores with botanical stem, was published in August of the same year. In spite of all the many palynologists working in the Neogene it is clear that these spores belong to the genus *Osmunda*, but the morpho-genus *Baculatisporites* is valid.

Zonalapollenites Pflug in Thomson & Pflug 1953 – botanical affinity ***Tsuga*** Carr. (Pl. 1, figs 4–7)

Fossil pollen grains included in the atlas (Stuchlik et al. 2002) in the genus *Zonalapollenites* Thomson & Pflug 1953 doubtfully belong to the genus *Tsuga*. *Zonalapollenites* Thomson & Pflug 1953 is in accordance with the ICBN the priority name in relation to the botanical name *Tsugaepollenites* Potonié & Venitz 1934 validate only later by Potonié (1958a). However, all palynologists know that pollen of *Zonalapollenites* belong to *Tsuga* – the morphological name of the genus should be used for ever in the literature. Krutzsch (1971) also has not avoided some nomenclatural mistakes, when including into the genus *Zonalapollenites* 17 species binominated with botanical and morphological names (e.g. *Zonalapollenites gracilis* = *Tsuga gracilis*). This kind of record in new created species invalidated the binominal species names only later checking out by an other author only one of these binominals and publish it can validate the genus name e.g. *Zonalapollenites gracilis* Krutzsch 1971 ex Konzalová 1993.

ONE SPECIES OF A MORPHO-GENUS HAS A CLEAR BOTANICAL AFFINITY

Polyatriopollenites stellatus (Potonié 1931) Thomson & Pflug 1953 – botanical affinity ***Pterocarya*** Kunth (Pl. 2, figs 2–5)

Morphology of pollen grains assigned to *Polyatriopollenites stellatus* Th. & Pf. Indicate the relationship to the recent genus *Pterocarya* Kunth. This is confirmed by finding of pollen grains *in situ* in fossil inflorescence of *Pterocarya sosnicensis* (Kohlman-Adamska et al. 2004). However, it is not possible for the species name *Polyatriopollenites stellatus* to change the genus *Polyatriopollenites* Pflug 1953, for the genus *Pterocaryapollenites* Thiergart 1937 ex Potoniè 1960, because it is a younger synonym validly published in 1953. In Neogene sediments of Poland occur three species morphologically similar to the recent genus *Pterocarya* (Stuchlik et al. in press). The variability of fossil pollen grains of *Pterocarya* is distinct and permit to compare with pollen of three recent species: *Pterocarya rhoifolia* Sieb & Zucc.; *P. stenoptera* C.DC.; *P. fraxinifolia* (Lam.) Spach.

Periporopollenites stigmosus (Potonié 1931) Thomson & Pflug 1953 – botanical affinity ***Liquidambar*** L. (Pl. 2, figs 6–9)

Jansonius & Hills (1976, card no. 1962) and Jansonius, Hills & Hartkopf-Fröder (1998, card no. 5152) after consideration the priority of genus-names *Liquidambarpollenites* (Raatz 1937) Potoniè 1960 and *Periporopollenites* Pflug & Thomson in Thomson & Pflug 1953, finally came to conclusion, that the genus *Periporopollenites* is the oldest, validly published generic name of fossil pollen grains, morphologically identical with pollen of the recent genus *Liquidambar* L. This is confirmed by finding this type of pollen (*Periporopollenites stigmosus*) *in situ* in fossil inflorescence of *Liquidambar europaea* A. Braun (Kohlman-Adamska et al. 2004). However, a change of the morphological name of fossil pollen *Periporopollenites* for *Liquidambarpollenites* is impossible, because it is only a younger synonym of *Periporopollenites.* The morphological variability of fossil pollen grains of *Liquidambar* is distinct and permits the comparison with pollen grains of the recent species *Liquidambar styraciflua* L. and *L. orientalis* L.

SPECIES OF TWO FOSSIL GENERA BELONG TO ONE RECENT BOTANICAL GENUS

Multiporopollenites maculosus (Potonié 1931) Thomson & Pflug 1953 and ***Juglans-pollenites*** Raatz 1937 – botanical affinity ***Juglans* L.** (Pl. 4, figs 1–7)

Fossil pollen grains assigned to *Multiporopollenites maculosus* (Potonié 1931) Thomson & Pflug 1953 is comparable with pollen of some recent species of *Juglans* L. e.g. *Juglans regia* L. However, with regard to the rules of ICBN concerning for creation new genera, it is not possible to transfer this type species for the genus *Multiporopollenites* Thomson & Pflug to the genus *Juglanspollenites* Raatz 1937. In consequence we have fossil pollen of *Juglans* to be classified into two genera: morphogenus *Multiporopollenites* Thomson & Pflug with one species, and genus *Juglanspollenites* Raatz 1937 in relation to botanical affinity with several species (Stuchlik et al. in press).

Trivestibulopollenites betuloides Pflug in Thomson & Pflug 1953 and ***Betulaepollenites*** Potonié 1934 ex Potonié 1960 – botanical affinity ***Betula* L.** (Pl. 3, figs 2–8)

Fossil pollen grains of *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953 are comparable with some recent species of *Betula*. However, the rules of the ICBN do not permit to transfer this taxon to the genus *Betulaepollenites* Potoniè 1934 ex Potoniè 1960, though pollen grains of *Trivestibulopollenites betuloides*, being a type species for the genus, *Trivestibulopollenites* Pflug in Thomson & Pflug, have been found *in situ* in fossil inflorescence of *Betula salzhausensis* (Goeppert) Kohlman-Adamska et al. (2004). In consequence of this we have fossil pollen grains of two genera belonging doubtless to the genus *Betula*.

Triatriopollenites rurensis Pflug & Thomson in Thomson & Pflug 1953 and ***Myricipites*** Wodehouse 1933 – botanical affinity ***Myrica* L.** (Pl. 3, figs 9, 10)

Fossil pollen grains included to *Triatriopollenites rurensis* Pflug & Thomson in Thomson & Pflug 1953 are comparable with pollen of some recent species of *Myrica*. However, the rules of ICBN do not permit tranfer this species being type-species for the genus *Triatriopollenites* Pflug in Thomson & Pflug, to the genus *Myricipites* Wodehouse 1933, though, pollen grains of *Triatriopollenites rurensis* have been found *in situ* in fossil inflorescence of *Myrica goepperti* Kohlman-Adamska et al. (2004). In consequence of this we have fossil pollen grains of two genera belonging doubtless to the genus *Myrica*.

SCANNING ELECTRON MICROSCOPY (SEM) USEFUL IN MORPHOLOGICAL STUDIES OF SPOROMORPH EXINE ARE HELPFUL IN DETERMINATION OF BOTANICAL AFFINITY

The development of the Scanning Electron Microscope (SEM) in the 70s of the last century opened new possibilities for studying the sculpture of sporomorphs in particular, the acquiring of larger scale images led to the discovery sculpture elements that had been invisible under the Light Microscope (LM). Both above mentioned methods of pollen morphology studies have to be used parallel: LM give the possibility to study the inside structure of pollen grain and SEM the surface sculpture. Unfortunately many authors, particularly American (e.g. Nixon & Crepet 1989), do not see this necessity and are publishing only SEM of pollen grains. Only using both complementary methods of observation gave the possibility of botanical identification of fossil pollen grains, as shown below.

Cathayapollis Ziembińska-Tworzydło 2002 – **botanical affinity *Cathaya*** Chun & Kuang (Pl. 5, figs 1, 2)

Very important information concerning the botanical affinities of the fossil pollen of coniferous plants resulted from the observation under the SEM of pollen belonging to the genus *Cathaya* (Sivak 1975, 1976). Pollen grains of recent species of *Cathaya* and fossil of *Cathayapollis* Ziembińska-Tworzydło 2002 (Stuchlik et al. 2002) have their sacks and corpus surfaces covered by compactly and irregularly arranged granules of various shapes. The majority of the Tertiary pollen grains described under the LM as *Pinus haploxylon* type or *Podocarpidites* Cookson ex Couper have the same surface features which Sivak (1975, 1976) accepted as diagnostic for pollen of the genus *Cathaya* Chun & Kuang (Stuchlik et al. op.cit.).

Podocarpidites Cookson 1947 ex Cooper 1953 – botanical affinity ***Podocarpus*** L'Herit. ex Pers. (Pl. 5, fig. 3)

Observations carried out under the SEM of the recent pollen grains of *Podocarpus* and *Podocarpidites* Cookson 1947 ex Cooper 1953 reveal that the surfaces of the corpus and sacks are free of granulate elements; moreover, thanks to the clear structural differences in pollen sacks of recent *Cathaya* and *Podocarpus*, visible under the LM, the pollen of these two genera can now easily be distinguished (Stuchlik et al. 2002).

Tricolporopollenites pseudocingulum (Potonié 1931) Thomson & Pflug 1953; ***T. dolium*** Potoniè (1931) Thomson & Pflug 1953 and ***T. theacoides*** (Roche & Schuler 1976) Kohlman-Adamska & Ziembińska-Tworzydło 2000 – botanical affinity **Fagoideae** (Pl. 6, figs 1–3)

The authors used both types of microscope in their research to describe species belonging to the morphological genus *Tricolporopollenites* Pflug & Thomson, whose botanical affinities had up till than been unknown. The species which had been generally recognized due to their occurrence in the Tertiary brown coal sediments were *Tricolporopollenites pseudocingulum*, *T. dolium* and *T. theacoides.* The details of the exine surface revealed under the SEM and pollen morphology (under the LM) mentioned fossil pollen species, have a surface sculpture closely resembling that found in the Fagoideae subfamily.

Tricolporopollenites villensis (Thomson in Potonié, Thomson & Thiergart 1950) Thomson & Pflug 1953 – botanical affinity **Fagaceae** (Pl. 7, fig. 1)

The next fossil species, to be described as *Tricolporopollenites villensis*, displayed a different and more primitive type of the exine surface sculpture, combining features characteristic of the two subfamilies Castaneoideae and Fagoideae (Kohlman-Adamska & Ziembińska-Tworzydło 2000).

Fususpollenites fusus (Potonié 1931) Kedves 1978 – botanical affinity ***Trigonobalanus*** Forman (Pl. 7, figs 2, 3)

Kedves (1978), when elaborating the Palaeogene pollen flora from Hungary, asserted that the abundantly occurring subspecies *Tricolporopollenites cingulum fusus* (Potonié) Thomson & Pflug has sufficiently characteristic features to form the basis for a new morphogenus *Fususpollenites*, with *Pollenites fusus* Potonié (1931) as type. Konzalová (1990) suggested the botanical affinity of this species to the recent genera *Castanopsis* (D. Don) Spach or *Trigonobalanus* Forman of the Fagaceae family.

The SEM studies of the surface of dispersed fossil pollen grains of *Fususpollenites fusus* indicate, that the forms with the quercoidal surface sculpture is similar to the surface of the *Trigonobalanus* pollen (Kohlman-Adamska & Ziembińska-Tworzydło 2001). They might have come from the Tertiary species of *Trigonobalanopsis*, which was an important palaeotropical component of mesophilous mixed forest in Palaeogene and Early Neogene times in Europe (Mai 1995).

CONCLUSION

The authors consider that many nomenclature paradoxes could be avoided when the ICBN rule „nomina conservanda" could be applied, for genera with botanical core validly published by several authors (Potonié 1958, 1960, Nagy 1969, 1985, and others), already after the publication of the morphological system of Thomson and Pflug (1953), but often still used by palynologists of Neogene, and are as younger synonyms of morphogenera.

The general application of the "Genera file of fossil spores" (Jansonius & Hills 1976–2006) in Tertiary palynology is very important.

Publication photos of surface sculplture of recent and fossil sporomorphs only under SEM in magnification ×1000–2000 do not permit the determination the botanical affinity of fossil sporomorphs dispersed in sediments. Fossil sporomorphs especially newly described and new created taxa should be illustrated by photos under LM and SEM, the last with ×10 000 magnifications of sporomorph surface.

Palynologists interested in discussion of the problems presented in this article are kindly requested to contact us by e-mail. We are planning together all suggestions for presentation them to the Committee for Fossil Plant, which operates under the auspices of the International Association for Plant Taxonomy.

REFERENCES

BRUCH A.A. 2004. The botanical and the morphological approach in Neogene palynology – a practical comparison. Acta Palaeobot., 44(1): 87–92.

COOKSON I.C. 1947. Plant microfossils from the lignites of Kerguelen Archipelago. B.A.N.Z. Antarctic Research Expedition 1929–1931, A, 2(8): 127–142.

COUPER R.A. 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. Geol. Surv. Paleont. Bull., 22: 1–77.

GREUTER W. ed. 1987. International Code of Botanical Nomenclature (Berlin Code) adopted by the 14. International Botanical Congress, Berlin, July-August 1987.

GREUTER W. ed. 1994. International Code of Botanical Nomenclature (Tokyo Code) adopted by the 15. International Botanical Congress, Yokohama, August-September 1993.

GREUTER W. ed. 2000. International Code of Botanical Nomenclature (Saint-Louis Code) adopted by the 16. International Botanical Congress, St Louis, Missouri, July-August 1999.

JANSONIUS J. & HILLS L.V. 1976–2002. Genera File of Fossil Spores. Special Publication, Dept. Geol. Geophys. Univers., Calgary, Alberta, Canada.

JANSONIUS J., HILLS L.V. & HARTKOPF-FRÖDER C. 1998. Genera File of Fossil Spores – Supplement 12. Special Publication, Dept. Geol. Geophys. Univers., Calgary, Alberta, Canada.

KEDVES M. 1978. Paleogene fossil sporomorphs of the Bakony Mountains. Part 3. Studia Biol. Hung., 15: 5–166.

KONZALOVÁ M. 1990. Palynological investigation of the basal Tertiary sediments (Paleogene) in western Bohemia and their correlation with the Carpathian region. Západné Karpaty, Sér. Paleónt., 14: 73–103.

KONZALOVÁ M., RAKOSI L. & SNOPKOVA P. 1993. Correlations of paleogene palynoflora from the Bohemia, Hungary, Slovakia. Proceedings of the International Symposium 1992, Bratislava. Geol. Úst. D. Štúra, Bratislava.

KOHLMAN-ADAMSKA A. & ZIEMBIŃSKA-TWORZYDŁO M. 2000. Morphological variability and botanical affinity of some species of the genus *Tricolporopollenites* Pflug & Thomson from the Middle Miocene Lignite association at Lubstów (Konin region – Central Poland). Acta Palaeobot., 40(1): 49–71.

KOHLMAN-ADAMSKA A. & ZIEMBIŃSKA-TWORZYDŁO M. 2001. Morphological variability and botanical affinity of *Fususpollenites* Kedves 1978 (LM and SEM investigations). Acta Palaeobot., 41(2): 147–159.

KOHLMAN-ADAMSKA A., ZIEMBIŃSKA-TWORZYDŁO M. & ZASTAWNIAK E. 2004. *In situ* pollen in some flowers and inflorescences in the Late Miocene flora of Sośnica (SW Poland). Rev. Palaeobot. Palynol., 132: 261–280.

KRUTZSCH W. 1971. Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas 6. VEB, Gustav Fischer, Jena.

MAI D.H. 1995. Tertiäre Vegetationsgeschichte Europas. Gustav Fischer Jena, Stuttgart, New York.

NAGY E. 1969. Palynological elaborations the Miocene layers of the Mecsek Mountains. Ann. Inst. Geol. Pub. Hung., 52(2): 237–650.

NAGY E. 1985. Sporomorphs of the Neogene of Hungary. Geol. Hun., Ser. Palaeont., 47: 1–470.

NIXON K.C. & CREPET W. 1989. *Trigonobalanus* (Fagaceae): Taxonomic status and phylogenetic relationships. Amer. Jour. Bot., 76(6): 828–841.

PLANDEROVÁ E. 1991. Miocene microflora of Slovak Central Paratethys and its biostratigraphical significante. Dionýz Štúr Inst. Geol., Bratislava.

POTONIÉ R. 1931. Zur Mikroskopie der Braunkohlen. Tertiäre Blütenstaubformen. Braunkohle, 30(16): 325–333.

POTONIÈ R. 1934. Zur Morphologie der fossilen Pollen und Sporen. Arb. Inst. Paläobot. Petrogr. Brennsteine. 4: 5–24.

POTONIÈ R. 1958a. Synopsis. Teil 2. Sporites (Nachträge), Saccites, Aletes, Praecolpatec, Poliplicates, Monocolpates. Beih. Geol. Jb., 31: 1–114.

POTONIÈ R. 1958b. Synopsis. Teil 3. Nachträge Sporites, Fortsetzung Pollenites, mit Generalregister in Teil 1-3. Beih. Geol. Jb., 39: 1–189.

POTONIÈ R. 1960. Synopsis der Gattungen der Sporae dispresae III. Beih. Geol. Jb., 39: 3–189.

POTONIÈ R. & VENITZ H. 1934. Zur Mikrobotanik der miozänen Humodils der Niederrheinischen Bucht. Arbeit. Inst. Paläobot. Petrograph. Brenst., 5: 5–54.

POTONIÉ R., THOMSON T.W. & THIERGART F. 1950. Zur Nomenklatur und Klassifikation der neogenen Sporomorphae (Pollen und Sporen). Geol. Jahrbuch, 65: 35–70.

RAATZ G.V. 1937. Mikrobotanisch-stratigraphische Untersuchung der Braunkohle des Muskauer Bogen. Abh. Preuss. Geol. Landsan., Neue Folge, 183: 3–48.

ROCHE E. & SCHULER M. 1976. Analyse palynologique (pollen et spores) de divers gisements du Tongrien de Belgique. Serv. Geol. Belgique, Profess. Paper, 11: 1–57.

SIVAK J. 1975. Les caractères de diagnose des grain de pollens a ballonets. Pollen et Spores, 17(3): 349–421.

SIVAK J. 1976. Nouvelles espèces du genre *Cathaya* d'après leurs grains de pollen dans le Tertiaire du sud de la France. Pollen et Spores, 18(2): 243–488.

STUCHLIK L. ed. 1994. Neogene pollen flora of Central Europe Part 1. Acta Palaeobot. Suppl. 1: 5–30, 31–56.

STUCHLIK L., ZIEMBIŃSKA-TWORZYDŁO M., KOHLMAN-ADAMSKA A., GRABOWSKA I., WAŻYŃSKA H., SŁODKOWSKA B. & SADOWSKA A. 2001. Atlas of pollen and spores of the Polish Neogene vol. 1 – Spores. W. Szafer Inst. Bot. Pol. Acad. Sci., Kraków.

STUCHLIK L. ZIEMBIŃSKA-TWORZYDŁO M., KOHLMAN-ADAMSKA A., GRABOWSKA I., WAŻYŃSKA H., SŁODKOWSKA B. & SADOWSKA A. 2002. Atlas of pollen and spores of the Polish Neogene vol. 2 – Gymnosperms. W. Szafer Inst. Bot. Pol. Acad. Sci., Kraków.

STUCHLIK L., ZIEMBIŃSKA-TWORZYDŁO M., KOHLMAN-ADAMSKA A., GRABOWSKA I., WAŻYŃSKA H., SŁODKOWSKA B. & SADOWSKA A. (in press). Atlas of pollen and spores of the Polish Neogene vol. 3 – Angiosperms, part 1. W. Szafer Inst. Bot. Pol. Acad. Sci., Kraków.

THIERGART F. 1937. Die Pollenanalise der Niederlausitzer Braunkohle, besonders in Profil der Grubbe Marga bei Senftenberg. Jahrb. Preuss. Geol. Landesann., 58: 282–351.

THOMSON P.W. & PFLUG H.D. 1953. Pollen und Sporen des mitteleuropäischen Tertiärs. Palaeontographica, B, 94: 1–138.

WODEHOUSE R.P. 1933. Tertiary Pollen. II. The oil shales the Eocene Green River Formation. Bull. Torrey Bot. Club, 60: 479–524.

PLATES

Plate 1

Baculatisporites primarius (Wolff) Thomson & Pflug

1. Ostrzeszów Geo 3, Middle Miocene, × 1000, LM

Baculatisporites nanus (Wolff) Krutzsch

2. Ustronie 90/00, Lower Miocene, × 1000, LM

Baculatisporites irenae Kohlman-Adamska

3. Karolewo-Dąbki 3, Middle Miocene, × 1000, LM

Zonalapollenites verrucatus Krutzsch ex Ziembińska-Tworzydło

4. Parzyce 9, Lower Miocene, × 1000, LM
5. Lubstów outcrop, Middle Miocene
   a. general appearance, distal face, × 1800, SEM
   b. part of distal face sculpture, × 7500, SEM

Zonalapollenites oertlii (Sivak) Ziembińska-Tworzydło

6. Ostrzeszów Geo 3, Middle Miocene, × 1000, LM
7. Lubstów outcrop, Middle Miocene
   a. general appearance, distal face, × 1200, SEM
   b. part of distal faces sculpture, × 3000, SEM

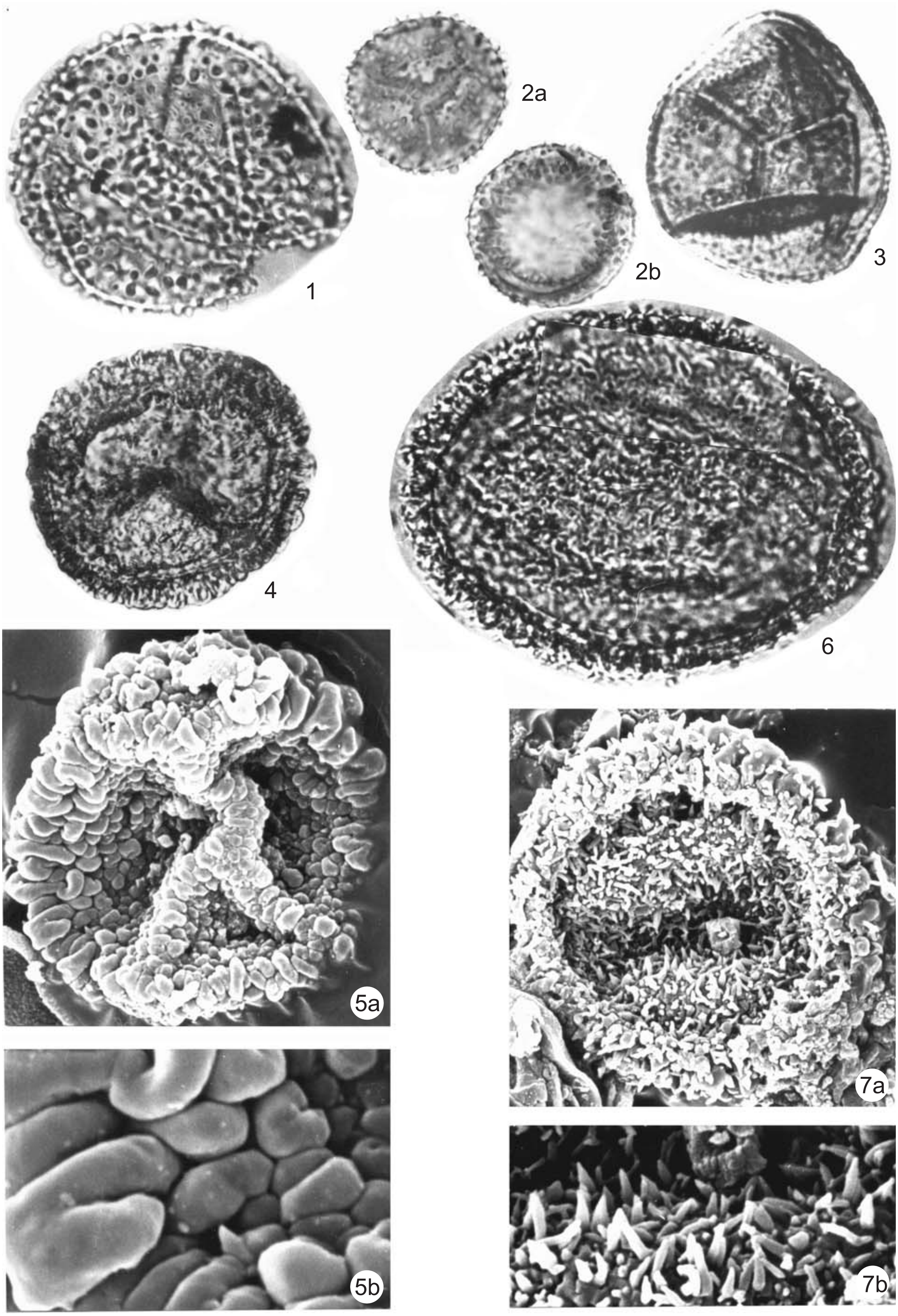

1
2a
2b
3
4
5a
5b
6
7a
7b

Plate 2

Pterocarya sosnicensis Kohlman-Adamska, Ziembińska-Tworzydło & Zastawniak

1. Impression of male flower, × 1, Sośnica outcrop, Upper Miocene, Geological Museum of the Wrocław University (MGUWr No. 2010p)

Polyatriopollenites stellatus (Potonié & Venitz) Pflug

2–4. Pollen grains isolated from the fossil flower, (MGUWr No 2010p); 2 – × 625, SEM; 3 – × 3000, SEM; 4 – × 1000, LM

5. Disperse pollen grain, × 1000, LM, Lubstów 28/42, Middle Miocene

Periporopollenites stigmosus (Potonié) Thomson & Pflug

6. Pollen grain isolated from male inflorescence of *Liquidambar europaea* A. Braun, × 1000, LM, Sośnica outcrop, Upper Miocene (MGUWr No. 2382p)
7. Disperse pollen grain, × 1000, LM, Orliska, Middle Miocene
8. Disperse pollen grain, Lubstów outcrop, Middle Miocene
   a. general appereance, × 2500, SEM
   b. surface sculpture with pore, × 10 000, SEM

Liquidambar formosana Hence

9. Recent pollen grain, × 1000, LM

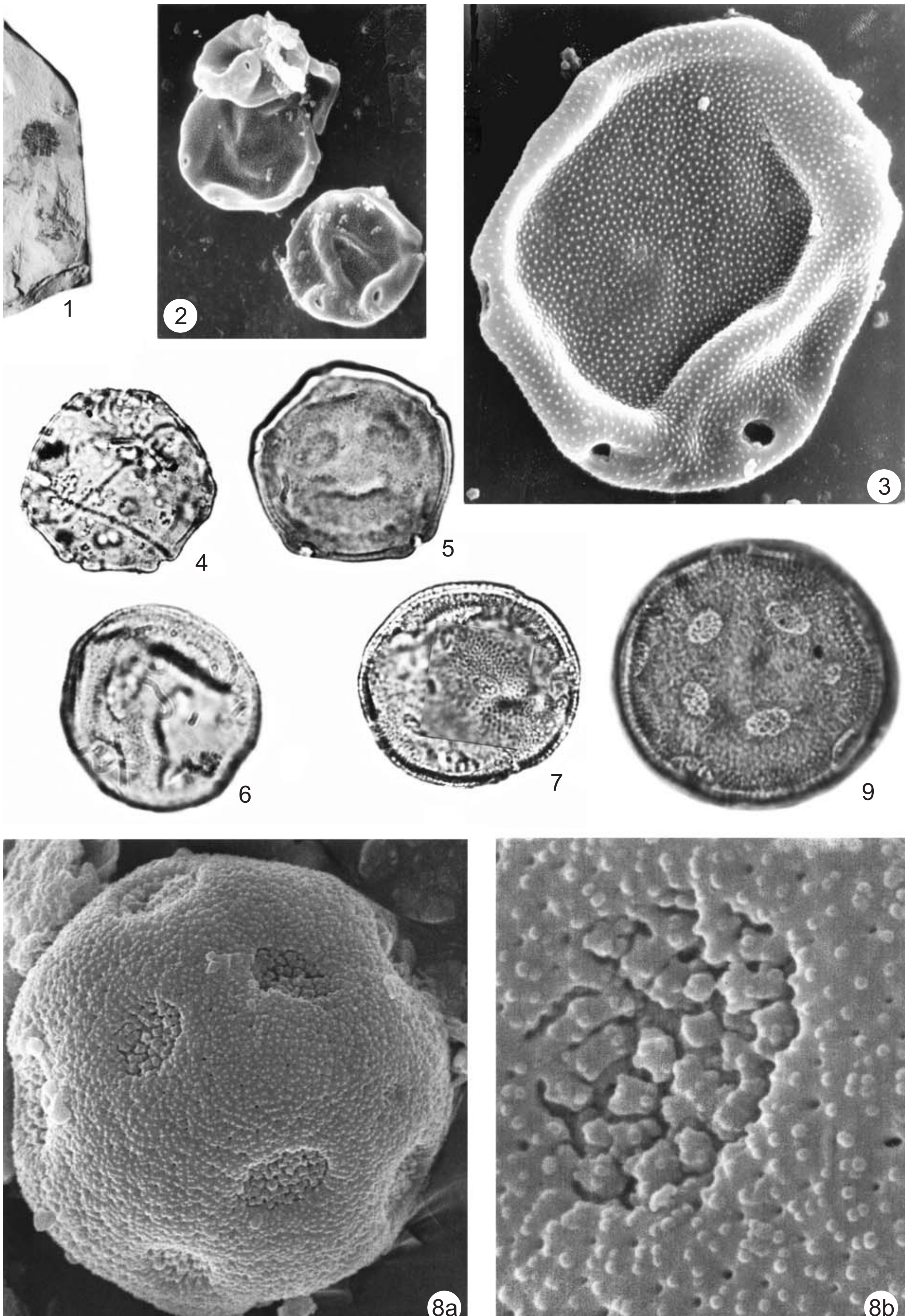

1
2
3
4
5
6
7
9
8a
8b

Plate 3

Betula salzhausensis (Goeppert) Kohlman-Adamska, Ziembińska-Tworzydło & Zastawniak

1. Fragment of male inflorescence, × 2.5, Sośnica outcrop, Upper Miocene (MGUWr No. 880p/30)

Trivestibulopollenites betuloides Pflug

2. Pollen grain isolated from male inflorescence of *Betula salzhausensis* (Goeppert) Kohlman-Adamska, Ziembińska-Tworzydło & Zastawniak, × 1500, SEM (MGUWr No. 880p/27)

3, 4. Pollen grain isolated from male inflorescence of *Betula salzhausensis* × 1000, LM, (MGUWr No. 880p/30)

5. Disperse pollen grain, × 1000, LM, Jawor, Middle Miocene

6. Disperse pollen grain, Lubstów outcrop, Middle Miocene
   a. general appearance, × 2500, SEM
   b. fragment of sculpture, × 10000, SEM

Betulaepollenites microexcelsus (Potonié) Potonié

7. Osina Wielka, Middle Miocene, × 1000, LM

8. Lubstów outcrop, Middle Miocene
   a. general appearance, × 2500, SEM
   b. fragment of sculpture, × 10000, SEM

Triatriopollenites rurensis Pflug

9a, b. Two optical sections, × 1000, LM, Tarnówka, Lower Oligocene

10. Lubstów outcrop, Middle Miocene
   a. general appearance, × 2500, SEM
   b. fragment of sculpture, × 10000, SEM

Myricipites bituitus (Potonié) Nagy

11. Bełchatów 54/21, Middle Miocene, × 1000, LM

12. Kaławsk, Middle Miocene, × 1000, LM

13. Lubstów outcrop, Middle Miocene
   a. general appearance, × 2500, SEM
   b. fragment of sculpture, × 10000, SEM

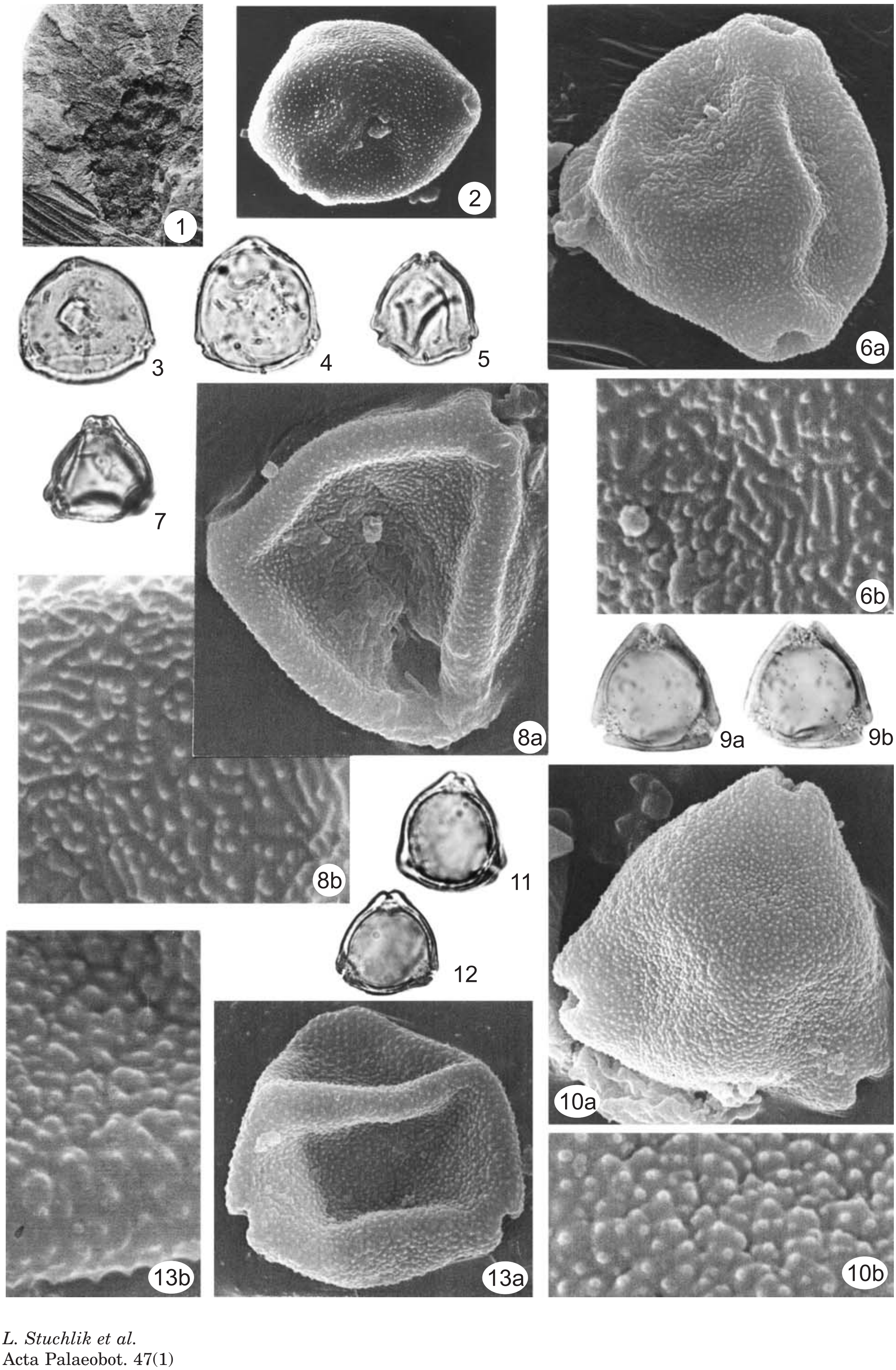

1
2
3
4
5
6a
7
8a
6b
9a
9b
8b
11
12
10a
13b
13a
10b

Plate 4

Multiporopollenites maculosus (Potonié) Thomson & Pflug

1. Lubstów outcrop, Middle Miocene
   a. general appearance, × 2500, SEM
   b. part of sculpture, × 10 000, SEM
2. Lubstów outcrop, Middle Miocene, × 1000, LM

Juglanspollenites verus Raatz

3. Lubstów outcrop, Middle Miocene
   a. general appearance, × 2500, SEM
   b. part of sculpture, × 10 000, SEM
4. Oczkowice 5W, Middle Miocene, × 1000, LM

Juglanspollenites juglandoides (Kohlman-Adamska) Kohlman-Adamska

5. Ochota, Miocene, × 1000, LM
6. Rypin II, Middle Miocene, × 1000, LM
7. Lubstów outcrop, Middle Miocene
   a. general appearance, × 2500, SEM
   b. part of sculpture, × 10 000, SEM

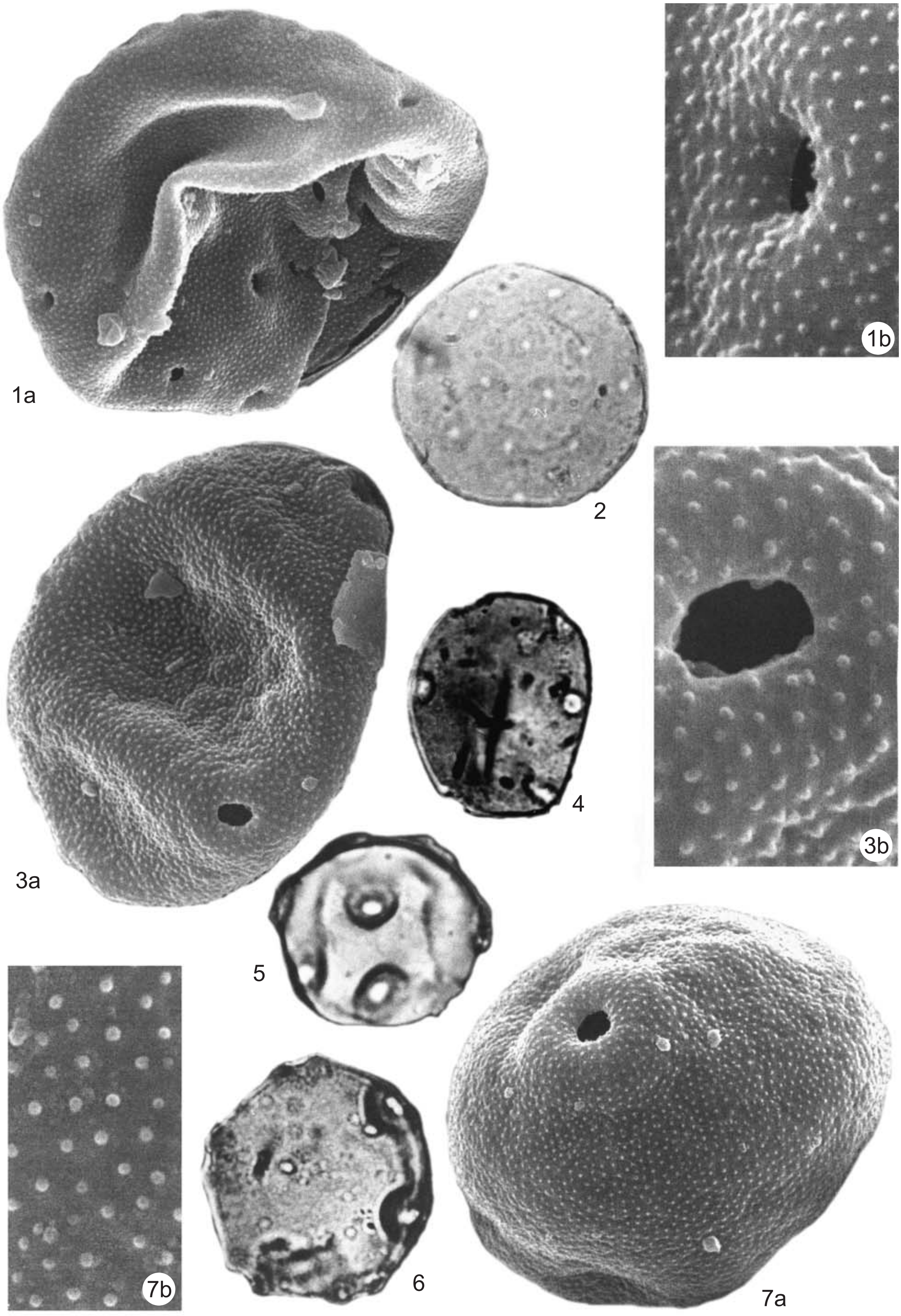

1a
1b
2
3a
3b
4
5
6
7a
7b

Plate 5

Cathayapollis wilsonii (Sivak) Ziembińska-Tworzydło

1a, b. Lubstów outcrop, Middle Miocene, two optical sections, × 1000, LM

Cathayapollis erdtmanii (Sivak) Ziembińska-Tworzydło

2. Lubstów outcrop, Middle Miocene
   a. general appearance, proximal face, × 1500, SEM
   b. part of corpus and saccus sculpture, × 5000, SEM

Podocarpidites eocenicus Krutzsch

3. Lubstów outcrop, Middle Miocene
   a. general appearance, polar view, × 1000, LM
   b. general appearance, proximal face, × 1500, SEM
   c. part of corpus sculpture, × 10 000, SEM

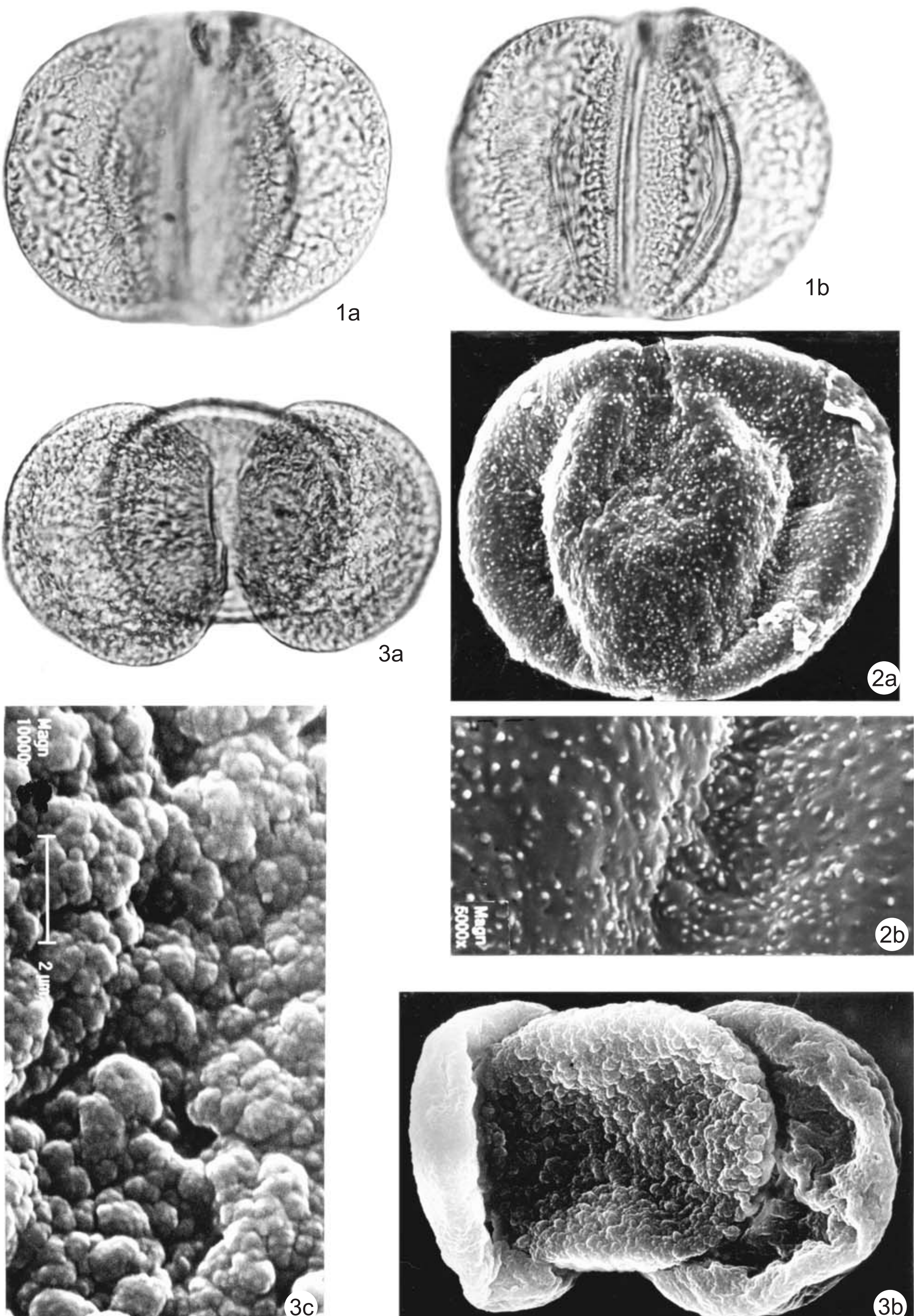

1a
1b
3a
2a
Magn 10000x
2 µm
Magn 5000x
2b
3c
3b

Plate 6

Tricolporopollenites pseudocingulum (Potonié) Thomson & Pflug

1. Lubstów outcrop, Middle Miocene
   a. general appearance, × 3000, SEM
   b. surface sculpture, × 10 000, SEM
   c, d, e. three optical sections, × 1000, LM

Tricolporopollenites dolium (Potonié) Thomson & Pflug

2. Lubstów outcrop, Middle Miocene
   a. general appearance, × 3000, SEM
   b. surface sculpture, × 10 000, SEM
   c, d. two optical sections, × 1000, LM

Tricolporopollenites theacoides (Roche & Schuler) Kohlman-Adamska & Ziembińska-Tworzydło

3. Lubstów outcrop, Middle Miocene
   a. general appearance, × 2500, SEM
   b. surface sculpture, × 10 000, SEM
   c, d. two optical sections, × 1000, LM

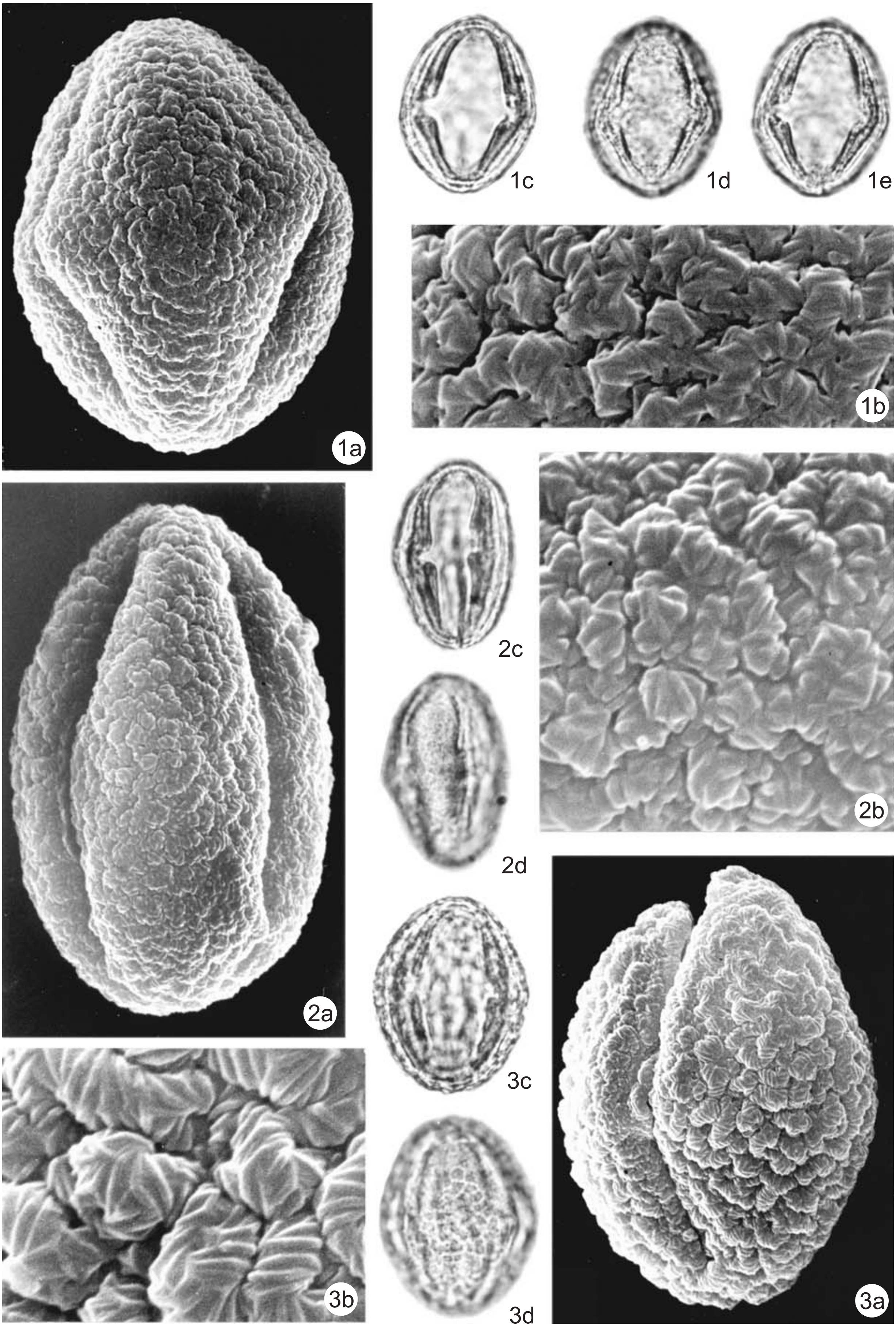

1a
1b
1c
1d
1e
2a
2b
2c
2d
3a
3b
3c
3d

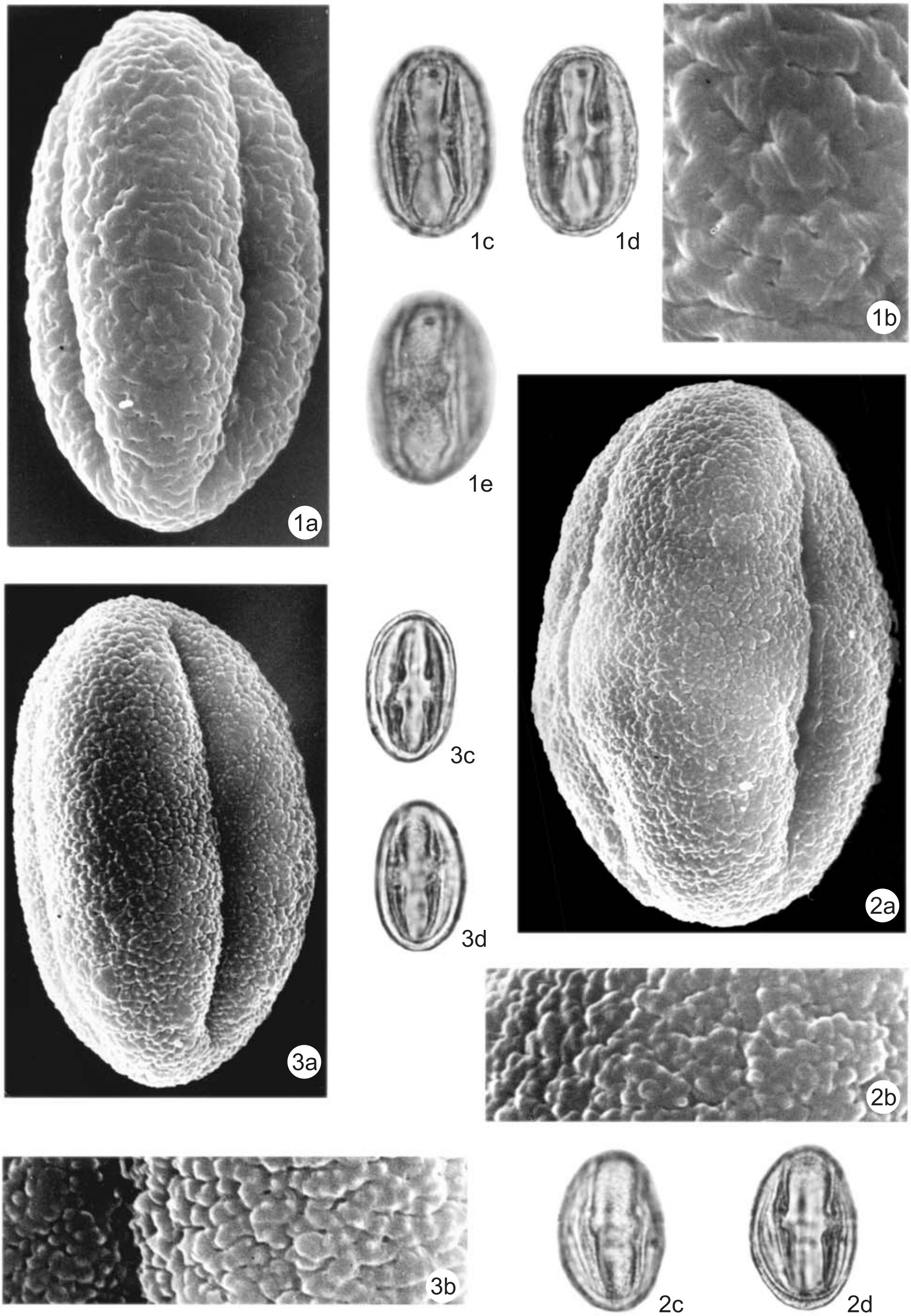
Plate 7

Tricolporopollenites villensis (Thomson) Thomson & Pflug

1. Lubstów outcrop, Middle Miocene
   a. general appearance, × 4000, SEM
   b. surface sculpture, × 10 000, SEM
   c, d, e. three optical sections, × 1000, LM

Fususpollenites fusus (Potonié) Kedves

2. Dąbrowa, Lower Oligocene
   a. general appearance, × 4000, SEM
   b. surface sculpture, × 10 000, SEM
   c, d. two optical sections, × 1000, LM
3. Budki Janowskie, Lower Oligocene
   a. general appearance, × 4000, SEM
   b. surface sculpture, × 10 000, SEM
   c, d. two optical sections, × 1000, LM


1a
1b
1c
1d
1e
2a
2b
2c
2d
3a
3b
3c
3d