# DIPLOMARBEIT

Titel der Diplomarbeit

## The microflora of the uppermost Eocene (Priabonian) Florissant Formation, a combined method approach

Verfasser

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# Content

# Abstract

The palynoflora of the uppermost Eocene (Priabonian) Florissant Formation was invest-igatigated, using LM and SEM techniques for a combined method approach for identific-ation, description, documentation and analysis of the palynological content.

Ninety-one different taxa were identified, one Bryophyte spore taxon, seven spore taxa of Pteridophyte origin, nine pollen taxa of gymnosperm and seventy-four pollen taxa of angiosperm origin.

The additional SEM-observations revealed the presence of previously undetected plant families and genera (*Gingko*, *Cathaya*, *Tetracentron*, *Alangium*, *Diospyros*, *Lithocarpus*, Lamiaceae and Menispermaceae). Pollen belonging to the genera *Acer* and *Quercus* already reported in previeous publications could be assigned to infrageneric groups. Previous uncertain identification and affiliation for some families and genera (Ranuncu-laceae, Hamamelidaceae, Rosaceae, *Fraxinus* und *Castanaea*) could be clarified.



# Zusammenfassung

Die Palynoflora des spätesten Eozän (Priabonium) Florissant Formation wurde im Um-fang dieser Arbeit unter Anwendung kombinierter Methoden (LM und REM) zur Bestim-mung, Beschreibung, Dokumentation und Auswertung untersucht.

Es wurden insgesamt 91 Taxa nachgewiesen und beschrieben, davon 1 Bryophyta taxon, 7 Pteridophyta Taxa, 9 Gymnospermen Taxa und 74 Angiospermen Taxa.

Der zusätzliche Einsatz des REM führte zum Nachweis aus dieser Fundstelle unbekan-nten Pflanzenfamilien und -gattungen (*Gingko*, *Cathaya*, *Tetracentron*, *Alangium*, *Diospyros*, *Lithocarpus*, Lamiaceae und Menispermaceae). Es konnten in bereits vorhergehenden Arbeiten nachgewiesene Genera (*Acer* und *Quercus*) in infragen-erische Gruppen differenziert werden. Zur Klärung von bisher bekannten und als un-sicher geltenden Familien und Gattungen (Ranunculaceae, Hamameli- daceae, Ros-aceae, *Fraxinus* und *Castanaea*) konnte beigetragen werden .

# 1. Introduction

In the Late Eocene the Thirtinine Mile volcanic field was active and episodically lahars blocked the drainage of a close-by valley. This lead to the formation of the Florissant palaeo-lakes, in which the Florissant Formation was deposited.

The exceptional preservation of this Reservat-Lagerstätte has caught the attention of several palaeontologists since the 1870ies (Veatch & Meyer, 2008) and finally in 1969 lead to the conservation and protection of this site as the Florissant Fossil Beds National Monument, Colorado, USA. During the 140 years of scientific work, resulting in over 220 publications, focussed on this particular site, 1850 fossil species have been described.

Leopold & Clay-Poole (2001) and Wingate & Nichols (2001) delivered two extensive catalogs on the palynomorphs of Florissant´s three shale units, investigated under light microscope (LM).

# 2. Geological setting

In the area of the Florissant Fossil Beds four formal units can be identified, the Pikes Peak Granite, the Wall Mountain Tuff, the Florissant Formation and breccias of the Thirtynine Mile Andesite.

## 2.1. Geology of the Florissant Formation Area

The Pikes Peak Granite, a pink to reddish-tanned, medium to coarse-grained, biotitic or biotite-hornblende granite and quartz monzanite (Wobus & Epis, 1978), is the oldest formation in the area. The radiometric age of this rock was dated at approximately around 1080 Ma (Wobus 1994). In the late Eocene a palaeo-river system cut a long dentritic valley into this granite, which later was filled with volcanic rocks and sediments.

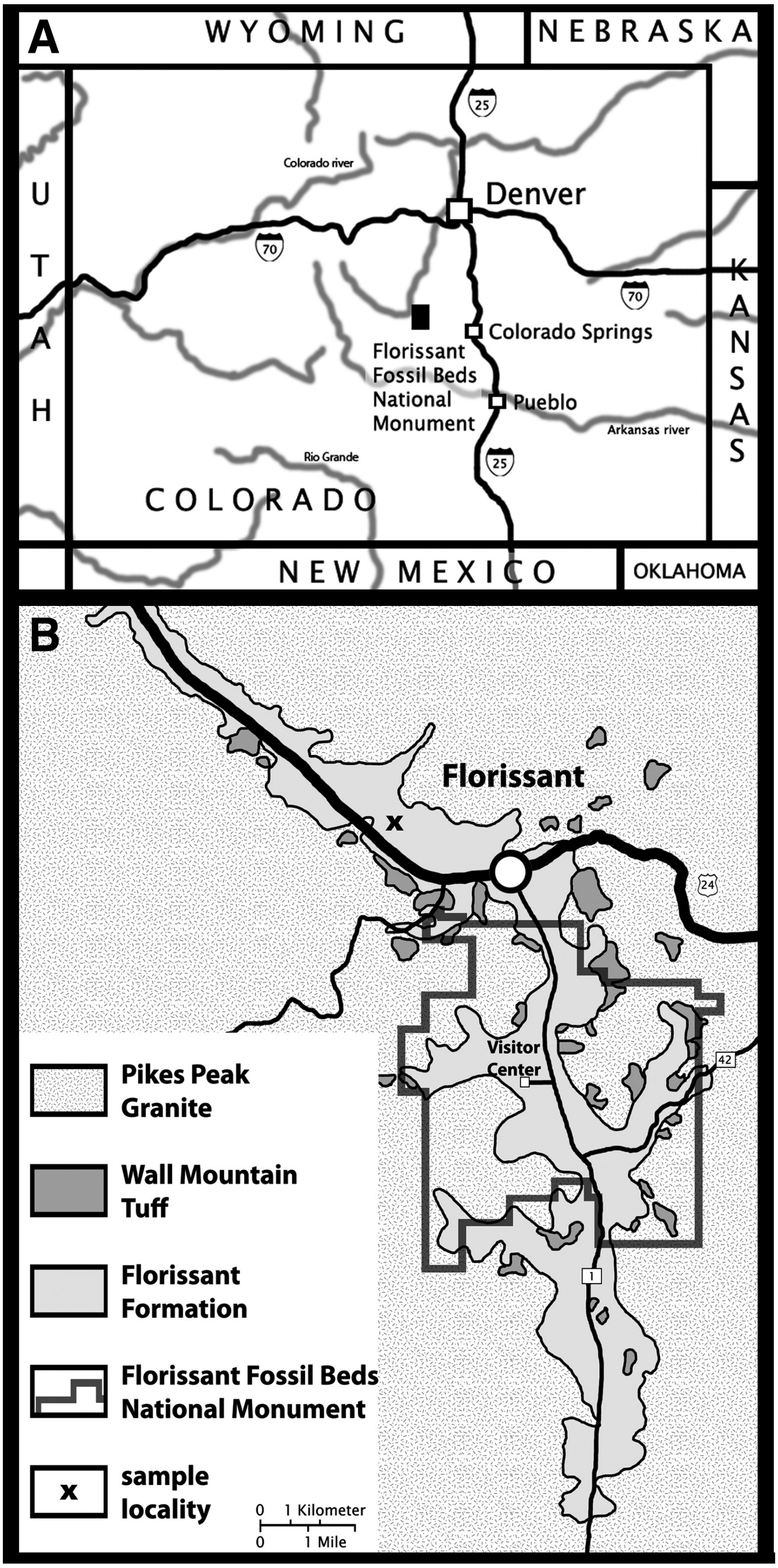


**Figure 1. A**. Showing the geographical position of the Florissant Fossil Beds National Monument. **B**. Geological map of the area surrounding the Florissant Formation (modified after Wobus & Epis, 1978)

The granite is exposed as boulders, tors and ridges at the flanks of the palaeo-valley (Evanoff et al. 2001).

The Wall Mountain Tuff is the oldest Paleogene rock in the area, dated at 36.73 Ma ± 0.07 by McIntosh & Chapin (1994). It lies unconformably on the irregular erosion surface cut in the Pikes Peak Granite and was the result of a pyroclastic flow that draped the welded tuff over the local topography. The tuff also shows erosion patterns that occurred before the younger Paleogene units were formed (Evanoff et al. 2001).

The Thirtynine Mile Andesite consists of poorly sorted brown to purple muddy breccias that contain intermediate volcanic clasts and granite fragments. It is assured that it represents lahars and volcanic debris flows derived from the Thirtynine Mile volcanic field, whose remnants are located southwest of the Florissant valley. Episodically, these lahars dammed the palaeo-valley and as such blocked the valleys drainage, which led to the formation of the Florissant lake deposits (Evanoff et al., 2001).

The 34.07 ± 0.10 Ma old Florissant Formation is a heterolihtic accumulation of shale tuffaceous mudstone and siltstone, tuff, arkosic- and volcaniclastic sandstone and conglomerate (Evanoff et al. 2001). The formation consists of six informal units: the Lower Shale, the Lower Mudstone, the Middle Shale, the Caprock Conglomerate, the Upper Shale and the Upper Pumice Conglomerate.

## 2.2. Lithostratigraphy of the Florissant Formation

Evanoff et al. (2001) extensively described the units of the Florissant Formation (Figure 2.) and their composition. In the following, a brief summary is provided for each unit.

The Lower Shale unit is a sequence of alternating tuffaceous siltstone and paper shale beds and reaches a thickness of approximately 6 m. From this unit, plant-, insect-, fish- and nearly all bird-fossils were reported (Evanoff et al., 2001). Leopold & Clay-Poole (2001) described the fossil pollen assemblages of this unit.

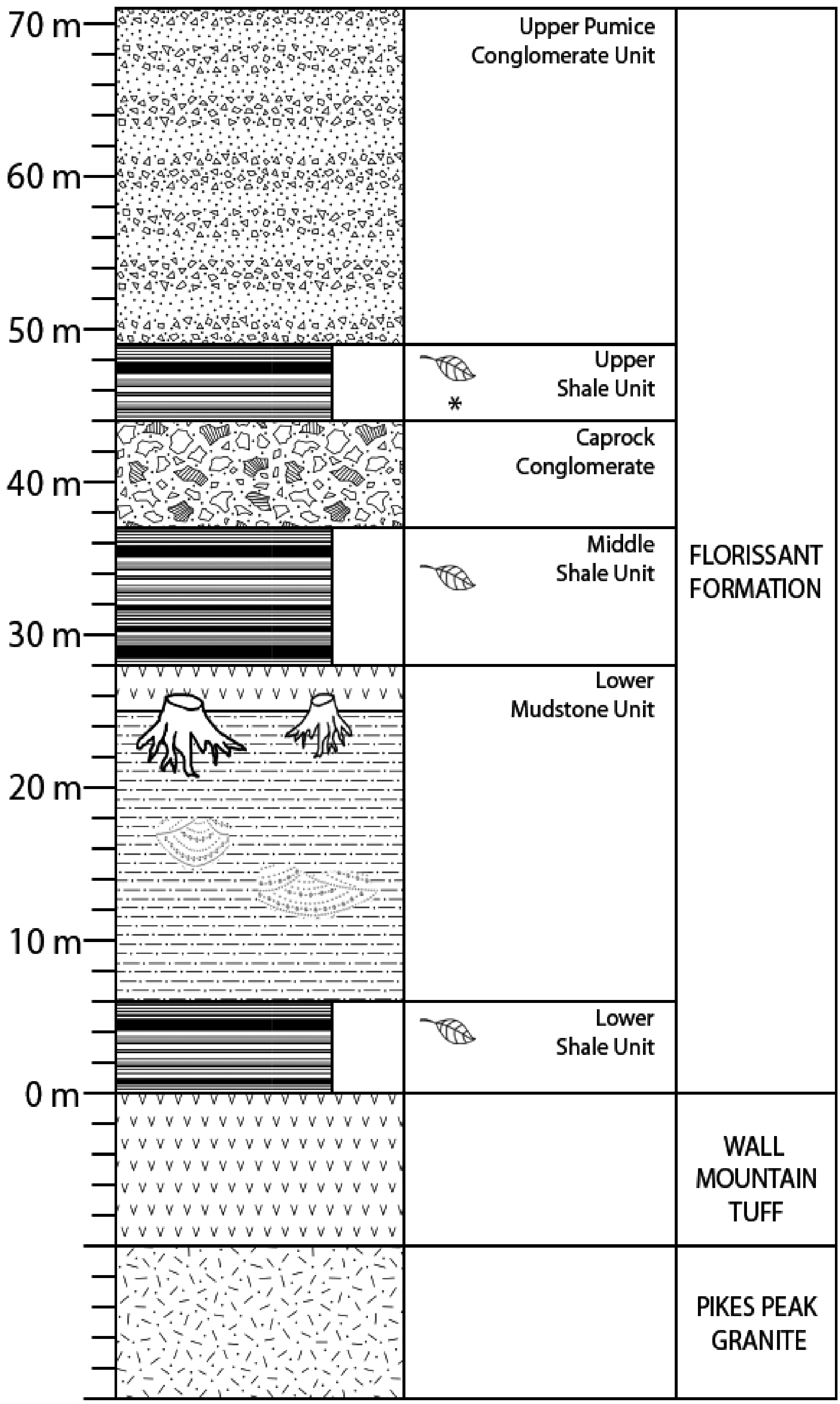


**Figure 2.** Cross-section of the Florissant Formation (modified after Evanoff, 2001),

* = sample

The Lower Mudstone unit reaches a thickness of 10.4 m and is characterized by tuffaceous mudstone beds and rare cross-bedded sandstone and conglomerate ribbons, overlain by a thick, structureless mudstone (Evanoff et al., 2001). The structureless mudstone represents a single mudflow event which buried an ancient forest and led to the fossilization of a stump horizon. Most petrified wood and fossil mammals of Florissant are known to come from this unit (Wheeler, 2001; Lloyd et al., 2008).

The Middle Shale unit is mainly composed of platy, papery shale beds interbedded with thin pumiceous conglomerate beds and scattered blocky to platy tuffaceous mudstone, siltstone, tuff and sandstone. The lamination of the shale is composed of alternating smectite clay and diatomite (McLeroy & Anderson, 1966; O´Brien et al., 1998). Common fossils of this unit are plants and insects whereas fish, mollusks and ostracods occur rarely.

The Caprock Conglomerate is a crudely graded volcaniclastic conglomerate that was formed initially by lahar. The unstructured base of this unit is characterized by pebble- up to boulder-sized fragments of granite and volcanic rocks. The upper part and top of the caprock is composed of horizontally bedded muddy sandstone. These are lacustrine deposits that represent reworked remnants of the lahar capping the middle shale unit. Freshwater fingernail clams occur in this part of the unit. The Caprock Conglomerate is only present in the southern parts of the palaeo-valley and pinches out just north of the border of the Florissant Fossil Beds National Monument.

The Upper Shale unit displays a mainly paper shale character with secondary interfingering blocky mudstone and pumice conglomerate. Plant- and insect-fossils, fish scales and ostracods are abundant locally. Wingate & Nichols (2001) investigated the pollen flora of this unit.

The Upper Pumice conglomerate reaches a maximum thickness of 22.8 m and is composed of pumice-rich, white sandstone and conglomerate. The base of this unit is structureless and shows cross-bedding towards the top.

## 2.3. Biostratigraphy

The paper shales of the lower, middle and upper shale unit are the main fossil-bearing strata which yield the exceptionally well-preserved insect-, plant-, fish- and bird-fossils. An individual of the genus *Herpetotherium* (an extinct small opossum) is known from these strata. The specimen is almost complete and remarkably well-preserved. All the stratigraphically relevant mammal fossils were found in the lower mudstone unit. Two species of Lipotyphyla, six species of Rodentia, two species of Lagomorpha, four species of Artiodactyla and two species of Perissiodactyla are known to come from this unit and suggest a middle to late Chadronian age (NALMA) (Lloyd et al., 2008) or Priabonium age (ICS). This corresponds with the $^{40}Ar/^{39}Ar$ weighted mean age of 34.07 ± 0.10 Ma of pumice samples taken from the upper parts of the Florissant Formation (Evanoff et. al., 2001).

# 3. Material and Methods

The material for this investigation was collected in 1987 by Steven Manchester in the backyard of the house of Mrs. Stoll, west of Florissant (Figure 2.), near the old Denver Museum Locality (MacGintie, 1953). The sediment sample investigated in this study was taken from a slab of the palaeobotany and palynology collection of the Florida Museum of Natural History labelled as UF15880 – 7285. The sample originated from the Upper Shale Unit.

To process a sample for LM and SEM examination the mineral and much of the organic matter has to be removed.

A few drops of concentrated HCl showed that the sample did not contain carbonate. For the next step, the removal of mineral components, the sample was washed, dried and ground to a fine powder with pestle and mortar. The sediment was put in a HF-resistant vessel, moistened and 40% HF was slowly added, to avoid heavy reaction. The sample stayed in a fume cabinet for a week and was stirred twice a day.

After this dissolving phase the contents were diluted in 4-5 l of water in a HF-resistant vessel. After settling, the liquid was decanted and the sediments were cooked in 100-150 ml concentrated HCl for 10–15 minutes to remove flour-spar/ fluorite, one hour later the residue had settled and the liquid could be decanted.
The sample was filled into a centrifuge tube together with some water, which was added to neutralize the acid. The tube was put in a centrifuge (Heraeus Instruments Laborfuge 400) and turned up to 3000 revolutions per minute and decanted. This procedure was repeated 3 times.

Now with the mineral compound dissolved the sample was ready for acetolysis, a combination of chlorination and acetylation. First the sample was covered with a layer of (1.5 cm) of glacial acetic acid and a layer (approx. 3 cm) of freshly prepared solution of cold saturated sodium chlorate. After adding 3–4 drops of concentrated HCl, the mixture containing tube was put in boiling water for 3 min and carefully stirred with a glass rod.

The residue was centrifuged, decanted, washed twice and finally washed with acetic anhydride to remove the water. The acetolysis liquid (Erdtmann 1954) contains nine parts of acetic anhydrite and one part $H_2SO_4$; it stains the organic matter. After adding the acetolysis liquid to the water-free sample it was put in boiling water bath for 10 min and decanted. The residue, displaying a brownish colour, was washed once with acetic anhydrite, to get rid off the acetolysis liquid. Now the sample was put in the centrifuge and the liquid fraction decanted, this was repeated three times with water. Glycerine was added to the sample to form a suspension, and stored in small glass tubes.

The single grain technique (Zetter, 1989; Ferguson et al., 2007) was used to document the pollen and spores in more detail. For this technique the same spore or pollen grain that was first photographed in glycerol under LM, and then transferred to a SEM stub with a micro-manipulator, cleaned in a drop of ethanol, sputtered with gold and investigated under SEM.

Approximately 1100 pollen and spores were counted to construct a relative abundance chart; fungal spores were observed but not included in the abundance chart (Figure 3.).

A Nikon Eclipse 80i LM (magnifications 10x, 20x, 40x and 60x) and a Samsung Digimax V70 digital camera were used to take LM photos. The SEM pictures were taken with a Joel JSM 6400 SEM. Pictures were edited with Photoshop CS3.

For the description of taxa Punt et al. (2007) was used for LM-observations and Hesse et al. (2009) for SEM-observation was used to determine and describe the diagnostic features of the spores and pollen. The taxonmic section starts with the division Bryophyta followed by Pteridophyta, then the gymnosperms with the class of Gingkophyta and Coniferopsida (including Gnetales) following the higher systematic system of Strasburger – Lehrbuch der Botanik (36th edition). The angiosperm pollen configuration follows the APG III (2009). Families and genera appear in alphabetical order.

# 4. Systematic Palaeobotany

All of the described fern spores lack the perispore. For determination to family/ generic level the perispore is necessary, thus the spores could not be attributed to a specific extant group.

## 4.1. Bryophyta

**Bryophyta fam. gen. et spec. indet.** (Plate 1, Figure A-C)

Description: Spore, monad, shape spheroidal, amb circular, equatorial diameter 47-52 µm wide (LM); exospore 1.3-1.5 µm thick (LM); sculpturing reticulate (LM & SEM), luminae 3-5 µm in diameter (SEM), supra-sculpturing verrucate (SEM).

Remarks: This spore shows affinity to Marchantiopsida

## 4.2. Pteridophyta

**Family Polypodiaceae** Brecht. St J.S. Presl

**Polypodiaceae gen. et spec. indet.** (Plate 2, Figure J-L)

Description: Spore, monad, shape oblate, amb elliptic, polar axis 48-52 µm long (LM), equatorial diameter 50-62 µm wide (LM); exospore 1.0-1.3 µm thick, monolete; sculpturing rugulate to verrucate (LM), verrucate (SEM).

Remarks: Wingate & Nichols (2001) identified this type of spore as *Polypodiisporites* sp. cf. *Polypodiisporites secundus*.

**Pteridophyta fam. gen. et spec. indet. 1** (Plate 1, Figure. D-F)

Description: Spore, monad, shape oblate to spheroidal, amb circular, equatorial diameter 42-47 µm wide (LM); exospore 1.0-1.3 µm thick, trilete, labrum present, laesurae extend one-half to two-thirds of the radius; sculpturing psilate (LM), perforate and microrugulate to microverrucate (SEM).

**Pteridophyta fam. gen. et spec. indet. 2** (Plate 1, Figure G-I)

Description: Spore, monad, shape oblate, amb convex triangular, equatorial diameter 28-34 µm (LM), exospore 1-1.3 µm thick; trilete, labrum present, laesurae extend nearly to the equator, single line of perforations adjacent to the laesurae (SEM); sculpturing psilate (LM), microverrucate, granulate (SEM).

**Pteridophyta fam. gen. et spec. indet. 3** (Plate 1, Figure J-L)

Description: Spore, monad, shape oblate, amb circular to convex triangular, equatorial diameter 55-60 µm wide (LM); exospore 0.8-1.0 µm thick; trilete mark, labrum present, laesurae extend nearly to the equator; sculpturing psilate (LM), microverrucate (SEM).

Remarks: Wingate & Nichols (2001) identified this type of spore as *Biretisporites* sp.

**Pteridophyta fam. gen. et spec. indet. 4** (Plate 2, Figure A-C)

Description: Spore, monad, shape oblate, amb convex triangular, equatorial diameter 30-33 μm (LM); exospore 1.0-1.5 μm thick, outer exospore thicker than inner exospore; trilete, laesurae sinuous, laesurae extending nearly to the equator; sculpturing rugulate on distal side (LM & SEM), proximal side microverrucate (SEM).

**Pteridophyta fam. gen. et spec. indet. 5** (Plate 2, Figure D-F)

Description: Spore, monad, shape oblate to spheroidal, amb circular, cingulum present, equatorial diameter including cingulum 37-50 μm wide (LM), width of cingulum 4-8 μm wide (LM); trilete, laesurae extend less than one-third of the radius (LM & SEM), trilete mark surrounded by a lacuna; sculpturing verrucate (LM), microverrucate (SEM).

Remarks: Wingate & Nichols (2001) identified this spore type as *Polycyngulatisporites* and Leopold & Clay-Poole (2001) identified this spore type as *Selaginella* cf. *densa* Rydberg.

**Pteridophyta fam. gen. et spec. indet. 6** (Plate 2, Figure G-I)

Description: Spore, monad, shape oblate to spheroidal, amb circular to convex triangular, equatorial diameter 38-44 μm wide (LM), exospore 2-3 μm thick; trilete, laesurae extend half to two-third of the radius (LM & SEM); sculpturing verrucate, rugulate (LM), microverrucate under SEM, area surrounding the proximal pole less sculptured.

Remarks: Leopold & Clay-Poole (2001) identified this type of spore as *Selaginella* cf. *mairei.* H Lév..

## 4.3. Gymnosperms

**Class Ginkgopsida**

**Family Ginkgoaceae** Engelhardt

**Genus *Ginkgo*** Linné

***Ginkgo* sp.** (Plate 5 Figure D-F)

Description: Pollen, monad, shape oblate, outline circular to elliptic, equatorial diameter 28-32 µm wide (LM); exine 0.8-1.0 µm thick; sculpturing scabrate (LM), rugulate to microrugulate (SEM), rugulae slightly crested.

Remarks: In the North American fossil record the presence of *Gingko* can be verified from Maastrichtian to Oligocene (e.g. Graham, 2011 et seq.).
Today the monotypic genus *Ginkgo,* with the species *Ginkgo biloba* L., is restricted to East China.

**Class Coniferopsida**

**Family Cupressaceae** Richard ex Bartling (incl. Taxodiaceae)

**Genus *Sequoia*** Endlicher

***Sequoia* sp.** (Plate 3 Figure A-D)

Description: Pollen, monad, shape spheroidal, papillate, equatorial diameter 24-29 µm (LM); sculpturing scabrate (LM), verrucate with microechinate sculpturing (SEM), orbicule with densely packed microechinae

Remarks: Reported macro-fossils also suggest the presence of this genus in Eocene Florissant. From the lower mudstone unit the massive petrified stumps of *Sequoioxylon pearsallii* (Gregory-Wodzicki, 2001) and from the three shale units, male cones, female cones and branches of *Sequoia affinis* (MacGinitie, H. D. 1953) are reported. Leopold & Clay-Poole (2001) processed a male cone of *Sequoia affinis* from Florissant, the pollen obtained showed papillate and non papillate specimens, these were described as TCT-type (Taxodiaceae/Cupressaceae/Taxaceae).
Today *Sequoia* is restricted to relic areas in western North America (southwest Oregon to California) and was widely distributed across the Northern Hemisphere in the Paleogene and Neogene. The oldest fossils are of Cretaceous age. The extant species, *Sequoia sempervirens* (D. Don) Endl, has an altitude range from sea-level up to 920m, it

thrives in Mediterranean, warm temperate, climate but receives additional water from fog percipitation.

**Family Pinaceae** Lindley

**Genus *Abies*** Miller

***Abies* sp.** (Plate 3, Figure E-H)

Description: Pollen, monad, bisaccate, shape oblate, corpus elliptic in equatorial view, sacci nearly spherical, sacci attachment area narrow, angle between corpus and sacci 135°-145° wide (equatorial view), pollen diameter including sacci 121-133 µm wide (LM), pollen height including sacci 76-83 µm long (LM), corpus diameter 94-97 µm wide (LM), corpus height 65-70 µm long (LM), sacci diameter 60-65 µm wide (LM), sacci height 46-50 µm long (LM); leptoma, exine in cappa region 4-8 µm thick, sacci with alveolate structuring, proximal part of alveolae hexagonal; sculpturing scabrate in cappa region and psilate in leptoma region (LM), corpus rugulate to microrugulate, perforate (SEM), sacci slightly rugulate, perforate (SEM).

Remarks: *Abies*-type palynomorphs (Leopold & Clay-Poole, 2001; Wingate & Nichols, 2001) and an isolated winged seed determined as *Abies longiorostris* (MacGinitie, 1953; Manchester, 2001) further corroborates the presence of *Abies* in the vicinity of the Florissant palaeolake.

First convincing fossil *Abies* leafy twigs, cone scales, winged seeds and pollen are known from the late early Eocene McAbee Flora, British Columbia, Canada (Dillhoff et al., 2005).

The genus *Abies* comprises 40-55 species across the Northern Hemisphere, primarily in mountain regions. In North America *Abies* generally does not reach the arctic treeline and reaches as far south as the Mexican-Guatemalan border. All recent species of *Abies* require high levels of humidity during their growing period. They need well drained soils and thus are not part of the wetland community.

**Genus *Cathaya*** Chun et Kuang

***Cathaya* sp.** (Plate 3, Figure I-P)

Description: Pollen, monad, bisaccate, shape oblate, corpus rhombic in polar view, sacci nearly spherical, attachment area of sacci broad, pollen diameter including sacci 65-87 µm wide (LM), corpus diameter 35-43 µm wide (LM), corpus width 32-62 µm wide (LM), sacci diameter 42-66 µm wide (LM), sacci height 23-30 µm long (LM); leptoma, sacci with alveolate structuring, sculpturing in leptoma area scabrate (LM), microechinate (SEM), cappa rugulate, microverrucate to microechinate and fossulate to perforate (SEM), sacci microechinate, perforate (SEM).

Remarks: Aberrant pollen of *Cathaya* (Plate 3 Figure M-P) has been described by Wingate & Nichols (2001) as *Podocarpidites* sp.

The fossil record of *Cathaya*-type pollen has been summarized by Liu et al. (1997) and Liu & Basinger (2000) and dates back to the Early Cretaceous of Canada. During the Cenozoic it had a Northern Hemispheric distribution, mostly known from pollen grains, which have a very distinct shape and supra-sculpturing (microechinate under SEM). Due to *Cathaya* macro-fossils and pollen occurrences in lowland sediments it is possible that the ecological range of this genus was wider (altitude, substrate and climate) than it is today (cf. Grímsson & Zetter, 2011).

The genus *Cathaya* consists of only one living species endemic to China, *C. argyrophylla* Chun & Kuang. Its habitat is today restricted to elevations of 900-1900 m in evergreen to evergreen/deciduous broad-leaved forests on mountain slopes and ridges (Wang, 1961).

### Genus ***Picea*** Dietrich

***Picea* sp.** (Plate 3, Figure A-D)

Description: Pollen, monad, bisaccate, outline elliptic in equatorial view, sacci half spherical, sacci attachment area broad, pollen diameter including sacci 134-146 µm wide (LM), pollen height including sacci 98-103 µm long (LM); leptoma, exine in cappa region 3-4 µm thick, sacci with alveolate structuring (LM), sacci sculpturing verrucate, perforate (SEM); corpus sculpturing rugulate, fossulate (SEM).

Remarks: At Florissant fossil seeds of *Picea magna* MacGinitie are present (MacGintie, 1953; Manchester, 2001). Leopold & Clay-Poole (2001) and Wingate & Nichols (2001) also reported the occurrence of *Picea* type pollen. The genus *Picea* includes 34-38 species across the Northern Hemisphere.

Unambiguous *Picea* macro-fossils are known from middle Eocene Axel Heiberg Island (LePage, 2001).

The ten species native to North America reach from the arctic cycle to the mountain regions of central Mexico. In Eurasia *Picea* is considered a common element from boreal to mountain regions (Eckenwalder, 2009). The ecological parameters in which *Picea* thrives vary largely from species to species.

**Genus *Pinus*** Linné

**Subgenus *Strobus*** Lemmon (Haploxylon)

***Pinus* subgenus *Strobus* sp.** (Plate 4, Figure E-H)

Description: Pollen, monad, bisaccate, shape oblate, corpus elliptic in equatorial view, sacci half spherical, sacci attachment area broad, angle between corpus and sacci 135°-140° wide (equatorial view), pollen diameter including sacci 82-91 µm wide (LM), pollen height including sacci 58-64 µm long (LM), corpus diameter 54-68 µm wide (LM), corpus height 40-45 µm long (LM), sacci diameter 42-48 µm wide (LM), sacci height 21-29 µm long (LM); leptoma, exine in cappa region 1.0-1.5 µm thick, sacci with alevolate structuring; sculpturing scabrate in cappa region and psilate in leptoma region (LM), corpus rugulate, fossulate (SEM), sacci perforate, slightly rugulate relief (SEM)

Remarks: Schorn (in Manchester, 2001) identified from Florissant macro-fossils, cones, needles; of three species of *Pinus* subgenus *Strobus* (Haploxylon-type), *P. florissantii* Lesquereux, *P. wheeleri* and *Pinus* subgenus *Strobus* sp. Leopold & Clay-Poole (2001) and Wingate & Nichols (2001) also reported the occurrence of *Pinus*-type pollen (*Pityosporites*).

Macro-fossils and palynomorphs of *Pinus* are known since the Early Cretaceous, with regular occurrences, throughout the Northern Hemisphere (e. g. Eckenwalder, 2009).

Today the genus *Pinus* consists of about 100-115 species and is native to most of the Northern Hemisphere. In America they range from 66°N in Canada south to 12°N in Nicaragua; in Eurasia they range north just over 70°N and South to northernmost Africa, the Himalaya and Southeast Asia, with the Sumatra Pine crossing the Equator in

Sumatra at approximatively 2 °S (Farjon, 1984). The different *Pinus* species cover a wide ecological and climatic range, from the cold taiga forests to dry desert-like areas (Farjon, 2010).

**Genus *Tsuga*** (Endlicher) Carrière

***Tsuga* sp.** (Plate 4, Figure I-L)

Description: Pollen, monad, monosaccate, shape oblate, circular in polar view, equatorial diameter 59-67 µm wide; leptoma, sculpturing verrucate to rugulate (LM & SEM), fossulate to perforate (SEM), suprasculpture in distal pole area microechinate (SEM), verrucae and rugulae in saccus area slightly larger.

Remarks: Leopold & Clay-Poole (2001) and Wingate & Nichols (2001) reported also the occurrence of *Tsuga*-type pollen (*Zonalapollenites*).

*Tsuga* macro-fossils and pollen have been found across the Northern Hemisphere since the Late Cretaceous (e.g. Ferguson, 1967).

The extant nine species of *Tsuga* have a disjunct distribution in North America and South-East Asia. In areas with sufficient precipitation, they can be found from sea- level up to 3500 m.

**Order Gnetales**

**Family Ephedraceae** Dumortier

**Genus *Ephedra*** Linné

***Ephedra* sp.1** (Plate 4, Figure M-O)

Description: Pollen, monad, inaperturate, shape oblate, equatorial outline elliptic, polar axis 23-28 µm long (LM), equatorial diameter 50-58 µm wide (LM); exine ca. 1 µm thick, tectate; sculpturing is characterized by plicae (LM), fossulae running parallel to plicae, fossulae sinuous and with perpendicular branches (LM & SEM), suprasculpture psilate (SEM).

Remarks: Wingate & Nichols (2001) identified this pollen type as *Ephedripites*

*claricristatus*. Leopold & Clay-Poole (2001) identified this grain type as *Ephedra* cf. *nevadensis* S.Wats..
The earliest *Ephedra* fossils are known from Early Jurassic China (Wang & Zheng, 2010) and are common in the Paleogene/Neogene of the Northern Hemisphere.
Today the 35-45 species of the genus *Ephedra* show a Eurasian, North African, South and North American distribution.

***Ephedra* sp. 2** (Plate 4, Figure A-C)

Description: Pollen, monad, inaperturate, shape oblate, outline elliptic to circular, polar axis 20-24 µm long (LM), equatorial diameter 24-28 µm wide (LM), exine ca. 1.0 µm thick, tectate; sculpturing is characterized by plicae (LM), fossulae running parallel to plicae, fossulae sinous and with perpendicular branches (LM & SEM), suprasculpture microverrucate (SEM).

Remarks: Wingate & Nichols (2001) described this pollen type as *Ephedripites exiguous*.

## 4.4. Angiosperms

**Class Magnoliophyta**
**Clade Monocots**
**Order Arecales**
**Family Arecaceae** Schultzenstein
**Arecaceae gen. et spec. indet.** (Plate 5, FigureG-I)

Description: Pollen, monad, shape spheroidal, outline circular, diameter 12-15 µm wide (LM); semitectate, exine 0.8-1.2 µm thick, sulcate; sculpturing psilate (LM), microreticulate to microverrucate, perforate to microfossulate (SEM).

Remarks: From Florissant a single fossil leaf, *Palmacitites* (Manchester, 2001), and possible fossil Arecaceae pollen (Leopold & Clay-Poole, 2001) were reported.

In the fossil record of the North American Arecaceae presence can be verified since the late Cretaceous (e.g. Graham, 2011 et seq.).
The Arecaceae (palms) include approximately 183 genera with over 2360 species. Palms are native to tropical and subtropical climates (e.g. Stevens, 2011 et seq.).

**Clade Commelinids**

**Order Poales**

**Family Poaceae** Barnhart

**Poaceae cf. *Stipa* sp.** (Plate 5, Figure J-L)

Description: Pollen, monad, shape spheroidal, outline circular, diameter 22-25 µm wide (LM); eutectate, exine 0.5-0.7 µm thick, ulcerate; sculpturing scabrate (LM), rugulate, microechinate, perforate (SEM).

Remarks: MacGintie (1953) assigned fossil fruits from Florissant to *Stipa florissantii*. Leopold & Clay-Poole (2001) identified Poaceae pollen from Florissant and Wingate & Nichols (2001) determined a Poaceae pollen type as *Graminidites crassiglobolosus*.

**Family Typhaceae** Jussieu

**Genus *Sparganium*** Linné

***Sparganium* sp.** (Plate 6, Figure A-C)

Description: Pollen, monad, shape spheroidal, outline circular to elliptic, equatorial diameter 23-32 µm wide (LM); semitectate, exine 0.8-1.2 µm thick, nexine and sexine of same thickness, ulcerate; sculpturing heterobrochate reticulate (LM & SEM), lumina 0.4-1.0 µm wide, muri 0.3-0.6 µm wide, muri with ribbed suprasculpture (SEM).

Remarks: *Typha/Sparganium*-type pollen has previously been recorded from the Florissant Formation (Leopold & Clay-Poole, 2001; Wingate & Nichols, 2001).
Since the middle Eocene the presence of *Sparganium* can be verified in Europe (e.g. Mai, 1995; Collinson, 1988).
The 14-20 species of *Sparganium* thrive mainly in temperate and arctic climates. This

perennial plants are native to aquatic and marsh environments of North America, Eurasia, North Africa, Australia and New Zealand (e.g. Stevens, 2011 et seq.).

**Genus *Typha*** Linné

***Typha* sp.** (Plate 6, Figure D-F)

Description: Pollen, monad, shape spheroidal, outline circular, diameter 35-40 µm wide (LM); semitectate, exine 0.9-1.2 µm thick, ulcerate; sculpturing heterobrochate reticulate (LM & SEM), lumina 0.3-1.0 µm wide, muri 0.4 -0.6 µm wide (SEM), muri often incomplete.

Remarks: Fossil leaves assigned to *Typha lesquereuxi* Cockrell (Manchester, 2001) and *Typha/Sparganium*-type pollen (Leopold & Clay-Poole, 2001; Wingate & Nichols, 2001) are known from the Florissant Formation.

Macro-fossils of *Typha* from North America are known since the middle Eocene of Idaho, Thunder Mountain Flora (Axelrod, 1989).

*Typha* consists of approximately 15-27 species and shows a cosmopolitan distribution. The plants are perennial and native to aquatic and marsh environments.

**Clade Eudicots**

**Order Buxales**

**Family Buxaceae** Linné

**Buxaceae gen. et spec. indet.** (Plate 6, Figure G-I)

Description: Pollen, monad, outline circular, diameter 21-29 µm wide (LM); semitectate, exine 1.5-2.0 µm thick, sexine thicker than nexine, pantoaperturate; sculpturing heterobrochate reticulate (LM & SEM); luminae suculpturing microverrucate, perforate, lumina 0.5-5.0 µm wide, muri suprasculpture microechinate, muri 0.8-1.4 µm wide (SEM).

Remarks: Wingate & Nichols (2001; Plate 8, Figures 21 & 23) described a similar pollen type as *Persicarioipollis*. Leopold et al. (2008) compared this type with pollen from *Pachysandra* and *Sarcococca.* However, the botanical affinity to these two genera can

be ruled out.
Fossil buxaceous flowers, *Spanomera*, are known from the Late Cretaceous of North America (Drinnan et al., 1991).
Today the Buxaceae consist of 3-5 genera with about 120 species. The largest genus, *Buxus* (ca. 90 species), is widely distributed on all continents except Australia (Von Balthazar et al., 2000). This evergreen family can be found in tropic to temperate climates and ranges from shrubs to small trees.

**Order Proteales**

**Family Platanaceae** Lestibudois

**Genus *Platanus*** Linné

***Platanus* sp.** (Plate 6, Figure J-L)

Description: Pollen, monad, shape spheroidal, outline circular to lobate, diameter 20-24 μm wide (LM); semitectate, exine 1.0-1.4 μm thick (LM), nexine thicker than sexine, tricolpate, colpi broad; sculpturing scabrate (LM), microreticulate (SEM).

Remarks: Fossil *Platanus* leaves (MacGintie, 1953) and *Platanus*-type pollen (Wingate & Nichols, 2001) are known from Florissant.
Platanaceae have a good fossil record dating back to the Early Cretaceous (e.g. Graham, 2011 et seq.), showing that the family was much more diverse during the Cretaceous and Paleogene (e.g. Friis et al., 2011).
The extant genus *Platanus* consists of 7-11 species with a western Eurasian, Southeast Asian and Central and North American distribution. This deciduous to evergreen trees are moderately resistant to flooding (Sullivan, 1994).

**Order Ranuncales**

**Family Menispermaceae**

**Menispermaceae gen. et spec. indet.** (Plate 7, Figure A-C)

Description: Pollen, monad, shape spheroidal, circular in equatorial view, polar axis 20-

23 μm long (LM), equatorial diameter 21-24 μm wide (LM); semitectate, exine 2-3 μm thick (LM), nexine thinner than sexine, tricolpate; sculpturing reticulate (LM & SEM), muri 0.4-0.6 μm wide, muri suprasculpture microechinate (SEM).

Remarks: Since the Late Cretaceous fossil Menispermaceae can be verified from European, Asian and North American sites (e.g. Graham, 2011 et seq.). From the Eocene Clarno Formation, Oregon, USA, a high diversity of fossil Menispermaceae fruits and endocarps was reported by Manchester (1994).
Today the Menispermaceae consist of 70 genera with 442 species. The lianas of this family show an Asian, Australian, African, Oceanian, South and North American distribution.

**Family Ranunculaceae** Linné

**Ranunculaceae gen. et spec. indet.** (Plate 7, Figure D-F)

Description: Pollen, monad, shape prolate to spheroidal, diameter 23-28 μm wide (LM); eutectate, exine 1.0-1.4 μm thick (LM), tricolpate, colpi broad with rounded ends; sculpturing scabrate (LM), microechinate and perforate (SEM).

Remarks: Wingate & Nichols (2001; Plate 5, Figure 4) described pollen with affinity to this type.
Earliest macro-fossils are known from the Early Cretaceous of China (Sun et al., 2011).
The cosmopolitan Ranunculaceae include 62 genera with over 2500 species (Tamura, 1993).

**Order Trochodendrales**

**Familiy Trochodenrales** Eichler

**Genus *Tetracentron*** Oliver

***Tetracentron* sp.** (Plate 7, Figure G-I)

Description: Pollen, monad, shape prolate to spheroidal, polar axis 12.5-15.0 μm long (LM), equatorial diameter 11-13 μm wide (LM); semitectate, exine ca. 1 μm thick (LM), nexine thinner than sexine, tricolpate; sculpturing scabrate to striate (LM), striatoreticulate (SEM).

Remarks: The earliest macro-fossils of *Tetracentron* are of Palaeocene to early Eocene age from Kamchatka, Russia (Chelebaeva & Shancer, 1988). Infructescences, leaves and pollen are also known from middle Eocene to Miocene sedimentary formations of western North America (Pigg et al., 2007; Manchester & Chen, 2006).
Today the deciduous genus *Teracentron* is monotypic and restricted to South-East Asia.

**Clade core eudicots**

**Order Caryophyllales**

**Family Amaranthaceae** Jussieu

**Subfamily Chenopodiodeae** Burnett

**Chenopodiodeae gen. et spec. indet. 1** (Plate 7, Figure J-L)

Description: Pollen, monad, shape spheroidal, outline circular, pollen diameter 22-25 µm wide (LM); eutectate, exine 1.0-1.3 µm thick (LM), nexine thinner than sexine, pantoporate, pori diameter 2-4 µm wide (LM), pori with anulus (LM & SEM), pori membrane built by numerous microechinae (SEM); sculpturing scabrate (LM), microechinate, perforate (SEM).

Remarks: This type shows affinity to the pollen of *Salsola*. *Chenopodium*-type pollen is known from Florissant and is described by Leopold & Clay-Poole (2001) and Wingate & Nichols, (2001; *Chenopodipollis sp*).
This type of pantoporate pollen is fairly abundant in the fossil record through the Paleogene and Neogene (e.g. Muller, 1981).
The Amaranthaceae is one of the species-rich lineages in Caryophyllales with aproximately 180 genera, ca. 2500 species (Kühn et al., 1993; Townsend, 1993). Amaranthaceae are mainly herbaceous, rarely subshrubs and prefer dry or saline habitats (Stevens, 2011 et seq.).

**Chenopodiodeae gen. et spec. indet. 2** (Plate 8, Figure A-C)

Description: Pollen, monad, shape spheroidal, outline circular, diameter 20-23 µm wide (LM); eutectate, exine 0.8-1.0 µm thick, nexine thinner than sexine, pantoporate, pori diameter 1.2-1.5 µm wide (LM & SEM), pori membrane characterized by 5-8 microechinae (SEM); sculpturing scabrate (LM), sparsly microechinate, perforate (SEM).

Remarks: This pollen type shows affinity to the pollen of *Chenopodium*.

**Chenopodiodeae gen. et spec. indet. 3** (Plate 8, Figure D-F)

Description: Pollen, monad, shape spheroidal, outline circular, diameter 22-29 µm wide (LM); eutectate, exine 0.5-0.8 µm thick (LM), nexine thinner than sexine, pantoporate, pori diameter 2-3 µm (LM & SEM), pori surrounded by an annulus, pori membrane microechinate; sculpturing scabrate (LM), densely microechinate (SEM).

Remarks: This and the following pollen types, Chenopodiodeae gen. et spec. indet. 3 and 4, share similarities with *Sarcobatus*-pollen, annulate pori and microechinate sculpturing. They differ from *Sacrobatus*-pollen in the microechinae density and number of pori.

**Chenopodiodeae gen. et spec. indet. 4** (Plate 8, Figure G-I)

Description: Pollen, monad, shape spheroidal, outline circular, diameter 18-25 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, pantoporate, pori diameter 2.5-4.0 µm (LM & SEM), pori surrounded by an annulus (LM & SEM), pori membrane characterized by microechinae; sculpturing scabrate (LM), microechinate, perforate (SEM).

**Order Saxifragales**

**Family Hamamelidaceae** Brown

**Hamamelidaceae gen. et spec. indet. 1** (Plate 8, Figure J-L)

Description: Pollen, monad, shape prolate to spheroidal, outline circular, diameter 22-30 µm wide (LM); semitectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, tri-colpate; sculpturing microreticulate (LM & SEM), muri 0.4-0.8 µm wide (SEM), muri with microechinate suprasculpture (SEM).

Remarks: In the North American fossil record fossil flowers of this family can be verified since the Late Cretaceous (e.g. Friis et al., 2011). Manchester (2009) summarized fossil Hamamelidaceaen pollen, leaf and seed occurrences of Asia, Europe and North America from the Paleogene and Neogene.
Today the Hamamelidaceae comprise approximately 100 species in 27 genera, this trees and shrubs have a disjunct Northern Hemispheric distribution.

**Hamamelidaceae gen. et spec. indet. 2** (Plate 9, Figure A-C)

Description: Pollen, monad, shape prolate to spheroidal, polar axis 42-48 µm long (LM), equatorial diameter 40-45 µm wide (LM); semitectate, exine 2.0-2.5 µm thick (LM), nexine thinner than sexine, tricolpate; sculpturing heterobrochate reticulate (LM & SEM), brochi size decreasing in areas surrounding colpi, lumen perforate, fossulate with freestanding columellae (SEM), muri 0.5-1 µm wide, muri surface smooth (SEM).

## Clade Rosids

## Order Vitales

### Family Vitaceae Jussieu

**Vitaceae gen. et spec. indet. 1** (Plate 9, Figure D-F)

Description: Pollen, monad, shape prolate, elliptic in equatorial view, polar axis 38-42 µm long (LM), equatorial diameter 26-28 µm wide (LM); semitectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, tricolporate; sculpturing microreticulate to reticulate (LM & SEM), nexine perforate, muri 0.5-0.8 µm wide, brochii 0.4-0.8 µm wide, brochi diameter decreases in the area surrounding the colpi.

Remarks: From Florissant fossil leaves of *Vitis florissantellus* (Manchester, 2001) were

reported and Lepold & Clay-Poole (2001) described pollen with affinity to Vitaceae.
Since the middle Eocene macro-fossils of Vitaceae are known in the North American fossil record (e.g. Graham, 2011 et seq.).
Today the cosmopolitan family of Vitaceae consists of 11-12 genera and approximately 770 species, which are mainly distributed in areas characterised by tropic to subtropic climates, with some species thriving in temperate regions (e.g. *Vitis* sp.). This family is composed of woody vines and lianes (e.g. Stevens, 2001 et seq.).

**Vitaceae gen. et spec. indet. 2** (Plate 9, Figure G-I)

Description: Pollen, monad, shape prolate, elliptic in equatorial view, polar axis 40-44 µm long (LM), equatorial diameter 28-30 µm wide (LM); semitectate, exine 1.0-1.2 µm thick (LM), nexine thinner than sexine, tricolporate; sculpturing microreticulate (LM), perforate to fossulate (SEM), perforations ca. 0.5 µm wide.

**Clade Eurosids I (fabids)**
**Order Fagales**
**Family Betulaceae** Gray
**Genus *Betula*** Linné
***Betula* sp.** (Plate 9, Figure J-L)

Description: Pollen, monad, shape oblate, convex triangular in polar view, elliptic in equatorial view, polar axis 16-18 µm long (LM), equatorial diameter 18-21 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine and sexine have the same thickness, triporate, atrium present, annulate pori, pori diameter including annulus 5-6 µm (LM), aperture diameter 0.5-1.0 µm (LM); sculpturing scabrate (LM), rugulate, microechinate (SEM), rugulae length 1.0-1.5 µm.

Remarks: Fruits, leaves (Manchester, 2001) and pollen of Betulaceae (Leopold & Clay-Poole, 2001; Wingate & Nichols, 2001) are known from Florissant.
Since the Paleogene macro-fossils with distinct Betulaceae characteristics can be verified in the North American fossil record (e.g. Graham, 2011 et seq.)

Today the shrubs and trees of Betulaceae include six genera with over 125 species. This family shows a Northern Hemispheric distribution, primarily in boreal to cool temperate climates. *Betula* comprises 35 species and reaches from arctic to temperate climates.

**Family Fagaceae** Dumontier

**Genus *Castanea*** Miller

***Castanea* sp.** (Plate 10, Figure A-C)

Description: Pollen, monad, shape prolate, elliptic in equatorial view, polar axis 12-15 µm long (LM), equatorial diameter 8-10 µm wide (LM); eutectate, exine 1.0-1.4 µm thick (LM), tricolporate, colpi length 6-8 µm long (SEM); sculpturing scabrate (LM), rugulate, striate, perforate-fossulate (SEM), rugulae 1.0-1.5 µm long, rugulae more prominent in the equatorial area, rugulate-striate in colpus area (REM).

Remarks: A fossil leaf of *Castanea dolichophylla* Cockrell is known from Florissant but its generic identity is in need of revision (Manchester, 2001).
Fossil *Castanea* inflorescences are known from the middle Eocene of Tennessee, USA (Crepet & Daghlian, 1980).
Today *Castanea* consists of 8-12 species with a Northern Hemispheric distribution. This deciduous shrubs and trees can be found from sea-level up to 1300 m provided that precipitation ranges from 100-150 cm per year (Pridnya et al., 1996).

**Genus *Lithocarpus*** Blume

***Lithocarpus* sp.** (Plate 10, Figure D-F)

Description: Pollen, monad, shape prolate, elliptic in equatorial view, polar axis 11-13 µm long (LM), equatorial diameter 8-9 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, tricolporate; sculpturing scabrate (LM), rugulate, striate and perforate (SEM).

Remarks: Possible fossil acorn cups of *Lithocarpus* are known from the Eocene Green

River Formation, Colorado, USA (MacGinitie, 1969).
Today the shrubs and trees of the genus *Lithocarpus* have their main distribution in East and Southeast Asia with about 120 species. Native to North America is only one species, *Lithocarpus densiflorus* (transferred to a new genus *Notholithocarpus* by Manos et al., 2008) with two varieties, *L.* (*N.*) *d. densiflorus* (tanoak) and *L.* (*N.*) *d. echinoides* (dwarf tanoak). They require well-drained soils, relatively high moisture levels and mild temperatures. The tanoak grows from sea-level up to 1500 m, the dwarf tanoaks distribution boundary can be located at 2200 m (McDonald et al., 1987).

**Genus *Quercus*** Linné

***Quercus* sp. 1 Cyclobalanopsis-type** (Plate 11, Figure J-L)

Description: Pollen, monad, circular in polar view, pollen diameter 24-26 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, tricolporate; sculpturing scabrate (LM), platy verrucae, perforate (SEM).

Remarks: This type of pollen has affinities to pollen of *Quercus glauca* and *Q. acuta*, both are part of the *Quercus* infrageneric group of *Cyclobalanopsis.*
Today the evergreen small trees of *Cyclobalanopsis* are native from West to East Asia (Menitsky & Federov, 2005).
From Florissant at least nine different *Quercus* species can be distinguished based on leaf and fruit fossils (MacGinitie, 1953; Manchester, 2001); quercoid pollen is known (Leopold & Clay-Poole, 2001; Wingate & Nichols, 2001).
The earliest distinct *Quercus* macro-fossils from North America are known from the Eocene Clarno Formation, Oregon, USA (Bones, 1979; Manchester, 1981), fossil wood of evergreen oaks is also known from the Eocene London Clay Formation, Great Britain (Brett, 1960). Denk & Grimm (2009) used pollen characteristics to distinguish infrageneric groups of the genus *Quercus*. Here the same terminology to discriminate the found types of pollen is used.
Today *Quercus* consists of approximately 400 species in Eurasia, Northern Africa, North and Central America, ca. 90 species are native to North America (Nixon, 1997). This shrubs and trees range from evergreen to deciduous and grow from sea-level up to 2500m.

***Quercus* sp. 2 Protobalanus-type** (Plate 10, Figure J-L)

Description: Pollen, monad, shape prolate, elliptic to cirular in equatorial view, outline in polar view lobate, polar axis 18-21 µm long (LM), equatorial diameter 14-20 µm wide (LM); eutectate, exine 1.0-1.4 µm thick (LM), nexine thinner than sexine, tricolporate, colpi 12-13 µm long (LM); sculpturing scabrate (LM), microrugulate, microperforate (SEM).

Remarks: Pollen of *Quercus* sp. Protobalanus-type 2 and 3 are known from the Miocene Clarkiaflora, Washington and show similarities with *Protobalanus* pollen grains (personal communication Prof. Zetter; Bayer, 2004).

***Quercus* sp. 3 Protobalanus-type** (Plate 11 Figure. A-C)

Description: Pollen, monad, shape prolate, elliptic to circular in equatorial view, polar axis 22-25 µm long (LM), equatorial diameter 18-20 µm wide (LM); eutectate, exine 0.8.-1.2 µm (LM) thick, nexine thinner than sexine, tricolporate, colpi length 17-20 µm (LM); sculpturing scabrate (LM), rugulate, fossulate perforate, long rugulae with microverrucate suprasculpture (SEM).

***Quercus* sp. 4 Lobatae-type** (Plate 11 Figure. D-F)

Description: Pollen, monad, shape prolate to spheroidal, circular to elliptic in equatorial view, circular to lobate in polar view, polar axis 20-27 µm long (LM), equatorial diameter 17-21 µm wide (LM); eutectate, exine 1.4-1.8 µm thick (LM), nexine thinner than sexine, tricolporate, colpi length 14-16 µm (LM), bridge over pori present (LM & SEM); sculpturing scabrate (LM), rugulate, verrucate, fossulate, perforate (SEM), rugulae with microverrucate, microechinate suprasculpture (SEM).

Remarks: Quercus sp. 4 and 5 show affinity to the *Quercus* Lobatae infrageneric group.

***Quercus* sp. 5 Lobatae-type** (Plate 11 Figure. G-I)

Description: Pollen, monad, shape prolate, elliptic in equatorial view, polar axis 26-30 µm long (LM), equatorial diameter 17-23 µm wide (LM); eutectate, exine 1.0-1.5 µm thick, nexine thinner than sexine, tricolporate, colpi length 20-23 µm (LM); sculpturing scabrate (LM), verrucate, fossulate, microechinate (SEM).

**Family Juglandaceae** Perleb

**Genus *Carya*** Nutall

***Carya* sp.** (Plate 11, Figure J-L)

Description: Pollen, monad, shape oblate, outline circular, equatorial diameter 33-39 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, triporat, aperture diameter 3-5 µm (LM), one or more pori can be positioned slightly subequatorial (tending towards a pole) (LM & SEM); sculpturing psilate (LM), microechinate (SEM), microechinae count on a 2x2 µm square 16-19.

Remarks: From Florissant *Carya* leaves, fruits (Manchester, 2001) and pollen (Leopold & Clay-Poole, 2001; Wingate & Nichols, 2001, *Caryapollenites*) are reported.

Fossil *Carya* nuts are also known from the middle Eocene (ca. 45 Ma) of Axel Heiberg Island, Canada (Wilson et al., 2012). *Carya* was widely distributed in the Northern Hemisphere during the Paleogene and Neogene (Manchester, 1987).

Today the 18 species of this genus show a North American and East Asian distribution.

**Genus *Engelhardia*** Lesch ex Blume

***Engelhardia* sp.** (Plate 12, Figure A-C)

Description: Pollen, monad, shape oblate, outline triangular, equatorial diameter 21-26 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, brevicolporate, colpori situated along the equator region; sculpturing psilate (LM), microechinate (SEM), microechinae count on a 2x2 µm square 7-9.

Remarks: *Engelhardia*-type pollen is known from Florissant (Leopold & Clay-Poole 2001; Wingate & Nichols, 2001; *Momipites microfoveolatus*).

Earliest *Engelhardia*-type (*Momipites*) pollen is known from the Maastrichtian of North America (Nichols, 1973). Since the middle Eocene fossil leaves, fruits and wood are common in the fossil record of Asia, Europe and North America (Manchester, 1987). Today the approximately seven species of *Engelhardia* show a mainly Asian distribution, reaching from the Himalayas to Papua New Guinea. Two closely related species, *Alforea* and *Oreomunea*, are native to Central America (Mexico to Colombia). This evergreen to deciduous trees grow in lowland to submontane forests.

***Engelhardia* aff. *Palaeocarya*** (Plate 12, Figure D-F)

Description: Pollen, monad, shape oblate, outline circular to convex triangular, equatorial diameter 30-34 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, triporat, exine slightly thickend around pori, aperture diameter 3-4 µm (LM), pori situated on the equator, sculpturing psilate (LM), microechinate, perforate (SEM), microechinae count on a 2x2 µm square 9-10.

Remarks: This pollen resembles the *Palaeocarya*-type, an extinct genus belonging to the *Engelhardia*-group (Manchester, 1989). Wingate & Nichols (2001) described this pollen type as *Momipites coryloides.*

**Genus *Juglans*** Linné

***Juglans* sp.** (Plate 12, Figure G-I)

Description: Pollen, monad, shape oblate, pollen outline circular, equatorial diameter 35-41 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, stephanoporate with some pori in the polar area, pori annulate, aperture diameter 2-3 µm wide (LM); sculpturing scabrate (LM), microechinate, microperforate (SEM), microechinae count on a 2x2 µm square 13-15.

Remarks: From Florissant possible *Juglans* leaflets, *J. coloradensis* (Wolfe, 1959), and nutshell impressions of *J. sepultus* were reported, their definitive allocation to *Juglans* is debateable (Manchester, 1987). *Juglans*-pollen is described in Leopold & Clay-Poole (2001) and Wingate & Nichols (2001) as *Juglanspollenites nigripites*.
Earliest definitive *Juglans* fruits/nuts are known from middle Eocene, Clarno Formation, USA (Manchester, 1994) and possibly Axel Heiberg Island, Canada (Wilson et al.,

2012).
Today *Juglans* consist of ca. 20 species. This deciduous trees, rarely shrubs, thrive in temperate to tropical climates of South Eurasia to New Guinea, North and South America (eg. Stevens, 2011 et seq.).

**Order Malpighiales**

**Family Salicaceae** Mirbel

**Genus *Salix*** Linné

***Salix* sp.** (Plate 12, Figure J-L)

Description: Pollen, monad, shape prolate, outline eliptic in equatorial view, outline circular to lobate in polar view, polar axis 36-40 µm long (LM), equatorial diameter 30-36 µm wide (LM); semitectate, exine 2-3.5 µm thick (LM), nexine thinner than sexine, tricolpate; sculpturing heterobrochate reticulate (LM & SEM), muri 0.5-1 µm wide, luminae 2-3 µm wide (SEM), area surrounding colpi psilate.

Remarks: Manchester (2001) confirms the presence of four different species of *Salix* at Florissant. Wingate & Nichols (2001) describe three types of *Salixipollenites.*
In the North American fossil record unequivocal fossil *Salix* leaves are known from the middle Eocene Thunder Mountain Flora, Idaho, USA (Axelrod, 1998). In Europe the presence of *Salix* can be verified since the middle Oligocene (Collinson, 1992).
Today the genus *Salix* includes over 450 species, its shrubs and trees show an almost worldwide distribution, excluding New Zealand. *Salix* is intolerant to drought and shade, can survive short periods of standing water and is commonly found as a riparian element, in localities featuring enough moisture and light.

**Family Euphorbiaceae** Marcano-Berti

**Euphorbiaceae gen. et spec. indet. 1** (Plate 13, Figure A-C)

Description: Pollen, monad, shape prolate, elliptic in equatorial view, polar axis 34-37 µm (LM), equatorial diameter 25-28 µm (LM), semitectate, exine 1.5-2.0 µm thick (LM), nexine thinner than sexine, sculpturing microreticulate (LM), funnelshaped microreticulate, perforate (SEM)

Remarks: Fossil inflorescences of Euphorbiaceae are known from middle Eocene of Claiborne Formation, Tennessee, USA (Crepet & Daghlian, 1982). Wingate (2001) described *Malvacipollis* with affinity to Euphorbiaceae pollen from Florissant.
The family of Euphorbiaceae consists of 218 genera with 5735 species and shows a global distribution. This herbs, shrubs, lianes and trees thrive from pan-tropical to cool temperate climates.

**Euphorbiaceae gen. et spec. indet. 2** (Plate 13, Figure D-F)

Description: Pollen, monad, shape spheroidal, lobate to circular outline in polar view, equatorial diameter 20-24 µm (LM), semitectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, tricolporate, sculpturing scabrate (LM), funnelshaped reticulate, perforate (SEM)

**Order Rosales**

**Family Rosaceae** Jussieu

**Genus *Crataegus*** Tournefort in Linné

***Crataegus* sp.** (Plate 13, Figure G-I)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 26-28 µm long (LM), equatorial diameter 24-26 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, tricolporate, pori cicular, in areas surrounding endopori sexine is forming a bridge (LM); sculpturing scabrate (LM), rugulate, rugulae are built by striae (SEM), striae are expressed parallel to the polar axis, striae densly packed.

Remarks: In the Florissant Flora three different species of *Crataegus* (*C. copeana*, *C. hendersonii* & *C. nupta*) can be discerned (Manchester, 2001).
From the late early Eocene McAbee Flora, British Columbia, Canada, the earliest presence of *Crataegus* macro-fossils in North America can be verified (Dillhoff et al., 2005).

The genus *Crataegus* includes more than 200 species showing a Northern Hemispheric distribution. The shrubs and trees of this genus thrive in temperate climates.

**Rosaceae gen. et spec. indet. 1** (Plate 13, Figure J-L)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 21-23 µm long (LM), equatorial diameter 15-17 µm wide (LM); eutectate, tricolporate; sculpturing scabrate (LM), striate (SEM), striae 0.3-0.6 µm wide, striae densly packed, striae show no preferred orientation.

Remarks: From the Florissant Flora fossils leaves of *Amelanchier*, *Cercocarpus* (also fruits), *Crataegus*, *Malus*/*Prunus*, *Rosa* and *Vauquelinia* were reported (Manchester, 2001). Pollen with Rosaceae affinity was described by Wingate & Nichols (2001) and Leopold & Clay-Poole (2001).
This herbs, shrubs and trees are known since the early to middle Eocene of North America, Okanagan Highlands (De Vore & Pigg, 2007).
The Rosaceae feature approximately 122 genera, over 3370 species and show a world-wide distribution with its highest diversity in the north temperate regions (Heywood, 1993).

**Rosaceae gen. et spec. indet. 2** (Plate 14, Figure A-C)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 20-22 µm long (LM), equatorial diameter 15-17 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), nexine thinner than sexine, tricolporate, aperture membrane microechinate; sculpturing scabrate (LM), striate (SEM), strie running mainly parallel to the polar axis.

**Rosaceae gen. et spec. indet. 3** (Plate 14, Figure D-F)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, outline circular to lobate in polar view, polar axis 17-19 µm long (LM), equatorial diameter 14-16 µm wide (LM); eutectate, exine 1.0-1.5 µm thick, nexine thinner than sexine, tricolporate; sculpturing scabrate (LM), striate (SEM), striae densly packed, striae show no preferred orientation.

**Rosaceae gen. et spec. indet. 4** (Plate 14, Figure G-I)

Description: Pollen, monad, tricolporate, shape prolate, outline elliptic in equatorial view, polar axis 14-16 μm long (LM), equatorial diameter 7-9 μm wide (LM); eutectate, exine ca. 1 μm thick, nexine thinner than sexine, tricolporate; sculpturing scabrate (LM), striate (SEM), striae densly packed, striae show no preferred orientation.

**Family Ulmaceae** Mirbel

**Genus *Cedrelospermum*** (Saporta) Manchester

***Cedrelospermum* sp.** (Plate 14, Figure J-L; Plate 15, Figure A-C)

Description: Pollen, monad, shape spheroidal to oblate, outline convex triangular to polygonal, equatorial diameter 18-24 μm wide (LM); eutectate, exine 1.0-1.5 μm thick (LM), nexine thinner than sexine, tri- to pentaporate, aperture diameter 1.5-2.0 μm, sexine around pori slightly thickend; sculpturing verrucate (LM & SEM), verrucae have microechinate suprasculpture, high density of microechine between verrucae.

Remarks: Fossil leaves and fruits from *Cedrelospermum* are known from Florissant (Manchester, 2001).
Macro-fossils of the extinct genus *Cedrelospermum* are known from the middle Eocene of Europe, Messel Formation, Germany and North America, Clarno Formation, Oregon, USA (Manchester, 1994). It vanished from North America in the Oligocene and from Europe in the late Miocene (Manchester, 1981).

**Genus *Ulmus*** Mirbel

***Ulmus* sp.** (Plate 15, Figure D-I)

Description: Pollen, monad, shape oblate, outline circular to polygonal, equatorial diameter 27-37 μm wide (LM); eutectate, exine 1.0-1.5 μm thick, nexine thinner than sexine, stephanoporate (3-5), pori diameter 3-4 μm (LM), sexine around pori slightly thickend; sculpturing rugulate (LM & SEM), rugulae have microechinate supra-sculpturing, microechinae diameter 0.1-0.3 µm.

Remarks: From Florissant fruits and leaves of *Ulmus tenuinervis* (Manchester, 1989) and *Ulmus*-type pollen (Leopold & Clay-Poole, 2001; Wingate & Nichols, 2001; *Ulmipollenites undulosus*) were reported.
Fossil leaves and fruits of *Ulmus* are known from middle Eocene of Republic, Washington, USA and Princeton, British Colombia, Canada (Denk & Dillhoff, 2005).
The deciduous to semi-deciduous trees, rarely shrubs, of *Ulmus* comprise of 25–45 species. This plants thrive in temperate climate, with some tropical-montane exceptions and show a North American, European, Asian and Indonesian distribution.

**Ulmaceae gen. et spec. indet** (Plate 16, Figure A-C)

Description: Pollen, monad, shape oblate, outline quadrangular in polar view, equatorial diameter 24-28 µm wide (LM); eutectate, exine 1.0-1.5 µm thick, nexine thinner than sexine, tetraporate, aperture diameter 1.5-2.0 µm wide; sculpturing rugulate (LM & SEM), rugulae have microechinate supra-sculpturing, high density of microechinae between rugulae, microechinae diameter ca. 0.1 µm.

**Clade Malvids**

**Order Malvales**

**Family Malvaceae** Jussieu

**Genus *Florissantia*** Knowlton

***Florissantia* sp. 1 (**Plate 16, Figure D-F)

Description: Pollen, monad, shape oblate, rounded triangular in polar view, equatorial diameter 32-35 µm wide (LM); semitectate, exine 1.5-2.0 µm thick, nexine thinner than sexine, brevicolporate (3), nexine slightly thickend around endopori (LM); sculpturing reticulate (LM & SEM), brochii decrease in size toward the equator.

Remarks: This type of pollen shows affinity to the Sterculiaceae-type pollen described in

Leopold & Clay-Poole. Wingate & Nichols (2001) described a similar pollen type as *Bombacacidites* sp. aff. *B. reticulatus.* Manchester (1994) processed fossil stamen of two *Florissantia* species, *F. speirii* and *F. ashvillii*, and obtained pollen with high affinity to this pollen type.
In the North American fossil record, from southern Alaska to central Colorado, the presence of the genus *Florissantia* can be verified from middle Eocene to early Oligocene (Manchester, 1992).

**Malvaceae gen. et spec. indet. 1** (Plate 16, Figure G-I)

*Description:* Pollen, monad, shape oblate, outline rounded triangular to circular in polar view, equatorial diameter 23-26 µm wide (LM); semitectate, exine 1.0-1.5 µm thick, nexine thinner than sexine, brevicolporate (3), nexine slightly thickend around endopori (LM); sculpturing scabrate (LM), microreticulate, perforate fossulate (SEM).

Remarks: This pollen shares similarities with the *Bombacacidites*-type pollen known from Florissant (Wingate & Nichols, 2001; Plate 7, Fig. 6-7).

**Malvaceae gen. et spec. indet. 2** (Plate 16, Figure J-L)

*Description:* Pollen, monad, shape spheroidal to oblate, pollen outline circular, pollen diameter 52-58 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM), pantoporate, pori diameter 3-6 µm, sexine slightly thickend around endopori (LM); sculpturing echinate (LM & SEM), microbaculate, microverrucate (SEM), echinae base diameter 1.5-2.0 µm, echinae length 2.5-3.5 µm.

Remarks: This pollen type corresponds with the *Malvacipollis* sp. C type described in Wingate & Nichols (2001; Plate 9, Figure 3). Wingate & Nichols (2001) described four different types of *Malvacipollis* from Florissant.
Earliest appearance of fossil Malvaceae leaves and pollen are known from the middle-late Palaeocene, Cerrejón Formation, Colombia (Carvallo, et al. 2011).
The herbs, shrubs and trees of this family have a cosmopolitan distribution.

**Malvaceae gen. et spec. indet. 3** (Plate 17, Figure A-C)

Description: Pollen, monad, shape oblate to spheroidal, pollen outline circular, pollen diameter 43-49 µm (LM), eutectate, exine 1.0-1.5 µm thick, nexine thinner than sexine, pantoporate, pori diameter 2-4 µm (LM), sexine slightly thickend around endopori (LM), sculpturing is echinate (LM & SEM),microechinate, microrugulate, perforate (SEM), echinae base diameter 1.0-1.5 µm, echinae length 2.0-2.5 µm (SEM).

**Malvaceae gen. et spec. indet. 4** (Plate 17, Figure D-F)

Description: Pollen, monad, shape spheroidal to oblate, pollen outline circular to elliptic, pollen diameter 38-43 µm wide (LM); eutectate, exine 1.0-1.5 µm thick, pantoporate, pori diameter 1-3 µm (SEM); sculpturing echinate (LM & SEM), rugulate to microrugulate, fossulate perforate, echinae base diameter 1.0-1.5 µm, echinae length 1.5-2.0 µm.

**Malvaceae gen. et spec. indet. 5** (Plate 17, Figure G-I)

Description: Pollen, monad, shape spheroidal to oblate, outline circular in polar view, equatorial diameter 37-42 µm wide (LM); eutectate, exine 1.0-1.5 µm thick, stephanoporate, pori diameter 3.5-4.5 µm (SEM); sculpturing echinate (LM & SEM), perforate (SEM), echinae base diameter 0.5-1.0 µm, echinae length 1.5-2.0 µm.

Remarks: This pollen type corresponds with the *Malvacipollis* sp. D type described in Wingate & Nichols (2001; Plate 9, Figure. 4).

**Malvaceae gen. et spec. indet. 6** (Plate 17, Figure J-L)

Description: Pollen, monad, shape spheroidal to oblate, pollen outline circular to elliptic, pollen diameter 68-77 µm wide (LM); eutectate, exine 1.0-1.5 µm thick (LM & SEM), pantoporate; sculpturing echinate (LM & SEM), microverrucate, perforate (SEM), echinae base diameter 2.0-2.5 µm, echinae base perforate fossulate, echinae length 3.5-4.5 µm (SEM).

Remarks: This pollen type corresponds with the *Malvacipollis* sp. B type described in Wingate & Nichols (2001; Plate 9, Figure. 2).

**Family Thymelaeaceae** Jussieu

**Genus *Daphne*** Linné

***Daphne* sp.** (Plate 18, Figure A-C)

Description: Pollen, monad, shape spheroidal, pollen outline circular, equatorial diameter 30-35 µm wide (LM); semitectate, exine 1.0-1.5 µm thick, nexine thinner than sexine, pantoaperturate; sculpturing reticulate (LM), echinae with a triangular base on muri are forming a croton pattern, echinae show characteristic microrugulate sculpturing.

Remarks: From Florissant fossil leaves of *Daphne septentrionalis* (MacGinitie, 1953; Manchester, 2001) are known.
The genus *Daphne* consists of 95 species, its evergreen to deciduous shrubs and subshrubs have a Eurasian distribution.

**Thymelaeaceae gen. et spec. indet.** (Plate 18, Figure D-F)

Description: Pollen, monad, shape spheroidal, pollen outline circular, equatorial diameter 24-28 µm wide (LM); semitectate, exine 1.5-2.0 µm thick, nexine thinner than sexine, pantoaperturate, sculpturing reticulate (LM), short columellae, echinae on muri are forming a croton pattern (SEM)

Remarks: This type of pollen shows affinity to pollen of the species *Thymelaea*.
This family of herbs, shrubs, liane and trees consists of ca. 50 genera with 891 species and has a global distribution.

**Order Myrtales**

**Family Onagraceae** Jussieu

**Onagraceae *Epilobium*-type pollen 1** (Plate 18, Figure D-F)

Description: Pollen, monad, shape oblate, convex triangular, equatorial diameter 65-85 µm wide (LM); eutectate, exine 2.0-2.5 µm thick (LM), nexine as thick as sexine, tri-pororate, aperture diameter 5-7 µm, apertures with annulus; sculpturing scabrate (LM), microverrucate (SEM), viscin threads rope-like

Remarks: Leopold & Claypoole (2001) described this pollen type as *Semeiandra* cf. *grandiflora*, Wingate & Nichols (2001) described this pollen type as *Corsinipollenites parviangulu*s. This pollen shares similarities (rope-like viscin threads, surface sculpturing) with the pollen of the genus *Epilobium*.
From Florissant a single fossil of an Onagraceous flower (Manchester, 2001) and two pollen types (Leopold & Clay-Poole 2001; Wingate & Nichols 2001; *Corsinipollenites oculus-noctis parvus* & *C. parviangulus*) are known. These two types show a similar surface and viscin thread sculpturing, the only discerning features are size and tubular protoberances surrounding the apertures.
Today Onagaceae with *Epilobium*-type pollen have a cosmopolitan distribution. Earliest Onagaceae pollen is known from Late Cretaceous of northern South and southern North America (Martin, 2003).

**Onagraceae *Epilobium*-type pollen 2** (Plate 18, Figure J-M)

Description: Pollen, monad, shape oblate, polar axis 50-55 µm long (LM), equatorial diameter 60-65 µm wide (LM); eutectate, exine 1.5-2.0 µm thick (LM), nexine as thick as sexine, triporate, aperture diameter 5-7 µm, apertures with prolonged annulus; sculpturing scabrate (LM), microverrucate (SEM), viscin threads segmented to rope-like

Remarks: Leopold & Clay-Poole (2001) compared this pollen type with *Xylonagra* pollen; Wingate & Nichols (2001) described this pollen type as *Corsinipollenites oculus-noctis parvus*.

**Order Sapindales**

**Family Sapindaceae** Jussieu

**Genus *Acer* Linné**

***Acer* sp. 1** (Plate 19, Figure A-C)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 39-41 µm long (LM); eutectate, exine ca. 1.5 µm thick, nexine and sexine have the same thickness, tricolpate; sculpturing striate (LM & SEM), perforate, fossulate muri 0.2-0.4 µm wide, striae branching and intertwining.

Remarks: Manchester (2001) confirmed three *Acer* species from leaf and fruit fossils, *Acer florissantii* (leaves), *A. mcginitiei* (fruits) and *A. oregonianum* (leaves & fruits), from Florissant. Leopold & Clay-Poole (2001) described Sapindaceae-type pollen and Wingate & Nichols (2001) described two types of *Aceripollenites*. Fruits and leaves of a different Spindaceae, *Dipteronia insignis*, also have been reported from Florissant (Manchester, 2001).

In North American *Acer* has an excellent fossil record since the Eocene, Oligocene and the later Neogene based on fruits and leaves (Wolfe & Tanai, 1987).

Today the genus *Acer* consists of approximately 124-128 species and is mainly native to the Northern Hemisphere, with 10 species native to North America. In Eurasia and North America *Acer* preferes the temperate climate zone, additionally it is found in Mediterranean, warm temperate, climates of North Africa, Southern Europe and the North American west coast. Under the tropical climate of South-East Asia *Acer* also thrives on Java (Indonesia) where it has its most southern appearance (Van Gelderen et al., 1994).

***Acer* sp. 2** (Plate 19, Figure D-F)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 46-50 µm long (LM), equatorial diameter 30-32 µm wide (LM); eutectate, exine 1.0-1.5 µm thick, nexine and sexine have the same thickness, tricolpate; sculpturing striate (LM & SEM), fossulate, perforate (SEM), strie are running parallel to the polar axis, striae smooth, striae width 0.3-0.5 µm.

***Acer* sp. 3** (Plate 19, Figure G-I)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 50-54 μm long (LM), equatorial diameter 30-34 μm wide (LM); eutectate, exine 0.5-1 μm thick, tricolpate; sculpturing scabrate (LM), rugulate, fossulate, perforate (SEM).

Remarks: This type of pollen shows affinity to *Acer negundo* pollen. A n*egundo*-like fruit, *Acer mcginitiei* (former *A. heterodentatum*), was reported from Florissant. (Wolfe & Tanai, 1987).

**Family Anacardiaceae** R. Brown

**Anacardiaceae gen. et spec. indet.** (Plate 19, Figure J-L)

Description: Pollen, monad, shape spheroidal, outline circular in polar view, equatorial diameter 34-36 μm wide (LM); semitectate, exine 1.5-2.0 μm thick, nexine thinner than sexine, tricolporate, colpus membrane microechinate; sculpturing scabrate (LM),microreticulate (SEM), muri with microechinae as suprasculpture, muri 0.4-0.6 μm wide.
Remarks: This pollen shows affinities to pollen of *Pistacia*. Fossils of Anacardiaceae, *Cotinus*, *Rhus* and *Schmaltzia*; are known from Florissant (Manchester, 2001).
From the Eocene, Oligocene and Neogene of North America multiple fossil leaves, flowers and seeds are known (e.g. Graham, 2011; Clarno Formation, middle Eocene - Wheeler & Manchester, 2002; John Day Formation, Oligocene – Meyer & Manchester, 1997).
The Anacardiaceae consist of 81 genera with 873 species and show cosmopolitan distribution in tropical and temperate climates (e.g. Stevens, 2001 et seq.).

**Family Rutaceae** Jussieu

**Rutaceae gen. et spec. indet.** (Plate 20, Figure A-C)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 26-28 μm long (LM), equatorial diameter 14-16 μm wide (LM); semitectate, exine 1.0-1.5 μm thick, nexine thinner than sexine, tricolporate; sculpturing reticulate (LM), striatoreticulate (SEM).

Remarks: This pollen corresponds with Rutaceae-type pollen described by Leopold &

Clay-Poole (2001) from Florissant.

The first distinct appearance of this family in the North American fossil record are seeds of *Zanthoxylum*, from the late Eocene, lower John Day Formation, Oregon, USA (Manchester & McIntosh, 2007).

Today the Rutaceae consist of 161 genera with 2070 species and range from herbs to trees. This family thrives from tropical to temperate climates on all continents.

**Clade Asterids**

**Order Cornales**

**Cornaceae (Alangiaceae)** Berchthold & Presl

**Genus *Alangium*** Lamarck

***Alangium* sp.** (Plate 20, Figure D-F)

Description: Pollen, monad, shape spheroidal, circular lobate in polar view, equatorial diameter 34-40 µm wide (LM); semitectate, exine 2-3 µm thick (LM), nexine thinner than sexine, tricolporate; sculpturing reticulate (LM & SEM), lumen decrease in size the areas surrounding colpi, freestanding coumellae visible (SEM).

Remarks: In the North American fossil record Alangium is known from middle Eocene, Clarno Formation, Oregon, USA (Manchester, 1994).

Today the deciduous trees and shrubs of *Alangium* consist of approximately 21 species and show an African, Australian and South-East Asian distribution.

**Order Ericales**

**Family Ebenaceae** Gücke

**Genus *Diospyros*** Linné

***Diospyros* sp.** (Plate 20, Figure G-I)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 42-46 µm long (LM), equatorial diameter 30-34 µm wide (LM); eutectate, exine 0.5-1.0 µm thick, tricolporate; sculpturing scabrate (LM), microrugulate, fossulate (SEM).

Remarks: In the North American fossil record several *Diospyros* species are known from early Eocene Wilcox Formation, Tennessee, USA (Berry, 1916; Berry, 1930), but this floras are in need of revision. Definitive *Diospyros* macro-fossils are known from late Miocene, Mint Canyon Flora, California, USA (Axelrod, 1940).
The genus *Diospyros* includes over 500 species of trees and shrubs. Its main distribution is pan-tropical in wet to seasonally dry lowland areas with only a few species extending into temperate climates and montane elevations/regions.

**Family Ericaceae** Jussieu

**Ericaceae gen et spec. indet.** (Plate 20, Figure J-L)

Description: Pollen, tetrade, shape spheroidal, outline of monade circular, outline of tetrade triangular in polar view, equatorial diameter 35-38 µm wide (LM); eutectate, exine 1.0-1.5 µm thick, nexine thinner than sexine, tricolporate, colpi 17-19 µm long, aperture membrane is microechinate (SEM); sculpturing scabrate (LM), in central mesopolpium areas microverrucate and microrugulate, at polar areas and around apertures perforate, fossulate.

Remarks: From Florissant Ericaceae-type pollen have been reported (Leopold & Clay-Poole, 2001; Wingate & Nichols, 2001, *Ericipites*).
In the North American fossil record several Ericaceae are known since the middle Eocene (e. g. Graham, 2011et sequ.).
The Ericaceae include ca. 126 genera with close to 4000 species, ranging from herbs to trees. This family shows a cosmopolitan distribution with rare lowland tropic occurrences.

**Clade Euasterids I (Lamiids)**

**Order Garryales**

**Family Eucommiaceae** Engler

**Genus *Eucommia*** Oliver

***Eucommia* sp.** (Plate 21, Figure D-F)

Description: Pollen, monad, shape prolate, triangular-lobate in polar view, elliptic in equatorial view, polar axis 20-24 µm long (LM), equatorial diameter 15-16 µm wide (LM); eutectate, exine 1.5-2.0 µm thick (LM), nexine and sexine have the same thickness, tricolporate to tricolporidate, colpus length 15-18 µm (LM); sculpturing psilate (LM), microechinate, perforate (SEM)

Remarks: Fossil *Eucommia* seeds (Manchester, 2001) and pollen (Leopold & Clay-Poole, 2001) are known from Florissant.
The Paleogene and Neogene fossil record of *Eucommia* shows a wide Northern Hemispheric distribution with occurrences in Africa as well (Ferguson et al., 1997).
Today the monotypic family of Eucommiaceae with its extant species *Eucommia ulmoides* is restricted to central China. This deciduous trees are resistant to drought and thrive on well drained soils.

**Order Gentianales**

**Family Apocynaceae** Jussieu

***Tabernaemontana*** Linné

***Tabernaemontana sp.*** (Plate 21, Figure G-I)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 20-22 µm long (LM), equatorial diameter 16-18 µm wide (LM); eutectate, exine 1.0-1.5 µm, nexine thinner than sexine, tricolporate, endoaperture rectangular elongated; sculpturing scabrate (LM), perforate (SEM), perforations decrease around the apertures.

Remarks: The pollen wall sculpturing and structure of this pollen type shows high affinities with the pollen of *Tabernaemontana* (Van Campo et al., 1979).
From Florissant Apocynaceae seeds were confirmed by Manchester (2001) and *Tabernaemontana*-type pollen was reported by Leopold (2001).
Today the 15 genera and 150 species of Tabernaemontaneae have a pan-tropical distribution.

**Order Lamiales**

**Family Lamiaceae** Martynov

**Lamiaceae gen. et spec. indet.** (Plate 21, Figure J-L)

Descripion: Pollen, monad, shape prolate to spheroidal, triangular in polar view, outline elliptic to circular in equatorial view, polar axis 24-26 µm long (LM), equatorial diameter 20-22 µm wide (LM); semitectate, exine 1.5-2.0 µm thick (LM), nexine and sexine have the same thickness, tricolpate; sculpturing scabrate (LM), microbireticulate (SEM)

Remarks: In the fossil record of America fossil fruits of Lamiaceae are known from the late Eocene, Tonsoi Flora of Panama (Herrera et al., 2012).

This cosmopolitan family consists of 236 genera with 7173 species, mainly herbs with some tree and vine exceptions.

**Family Oleaceae** Hoffmannsegg & Link

**Genus *Fraxinus*** Linné

***Fraxinus* sp.** (Plate 22, Figure A-C)

Description: Pollen, monad, shape prolate, outline circular to lobate in polar view, outline elliptic in equatorial view, polar axis 23-25 µm long (LM), equatorial diameter 18-20 µm wide (LM); semitectate, exine 1.0-1.5 µm thick, nexine thinner than sexine, tricolporate; sculpturing reticulate (LM), heterobrochate reticulate (SEM), muri 0.5-0.8 µm wide and segmented.

Remarks: Probable *Fraxinus*-type pollen, *Fraxinoipollenites medius* (Wingate & Nichols, 2001; Plate 4, Figure. 5) is known from Florissant.

Oleaceaen-type leaves and fruits are known from middle Eocene, Claiborne Group, Tennessee, USA (Call & Dilcher, 1992; Dilcher & Lott, 2005), definite samaras and fruits of *Fraxinus* prove its presence since the Oligocene (see Graham, 2011).

Today 45-65 species of *Fraxinus* can be discerned. This mainly deciduous trees and rarly shrubs thrive in the temperate to subtropic climates of the Northern Hemisphere.

**Clade Euasterids II (Campanulids)**

**Order Asterales**

**Family Asteraceae** Berchtold & J. Presl

**Tribus Senecioneae** Cassini

**Senecioneae gen. et spec. indet.** (Plate 22, Figure D-F)

Description: Pollen, monad, shape spheroidal, pollen outline circular, pollen diameter 15-17 µm wide (LM); eutectate, exine 1.5-2.0 µm thick, tricolporate; sculpturing echinate (LM & SEM), echinae base 1.5-2.0 µm diameter (LM), numerous perforations between echinae and at the base of the echinae, the base of the echinae is slightly rugulate, the rugulae orientation is to the apex of the echinus they surround (SEM)

Remarks: Wingate & Nichols (2001) probably described a different morphotype of Aster-acea-type pollen from Florissant. The here described pollen has strong affinities to the Senecioneae tribus.

Early Asteraceae macro-fossils are known from Palaeocene/Eocene of South Africa and Eocene of Patagonia, South America (e.g. Graham, 2011 et seq.).

The cosmopolitan Asteraceae family consists of 1620 genera, 23.600 species and ranges from herbs, shrubs, vines to trees.

**Order Dipsacales**

**Family Adoxaceae** Ernst Meyer

**Genus *Viburnum*** Linné

***Viburnum* sp.** (Plate 22, Figure G-L)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 50-54 µm long (LM), equatorial diameter 44-46 µm wide (LM); semitectate, exine 2.0-2.5 µm thick, nexine thinner than sexine, tricolporate; sculpturing is reticulate (LM & SEM), reticulate sculpturing decreasing in the area surrounding the colpi.

Remarks: Leopold & Clay-Poole (2001) reported *Viburnum*-pollen from Florissant.

From the middle Eocene, Thunder Mountain Flora, fossil leaves are the earliest confirm-ation of this genus (Axelrod, 1998).

The deciduous to evergreen genus *Viburnum* includes 175 species of mainly shrubs and some trees. Today *Viburnum* is native to temperate and tropical montane regions of Eurasia North, Central, and South America.

**Family Caprifoliaceae** Jussieu

**Genus *Lonicera*** Linné

***Lonicera* sp.** (Plate 21, Figure A-C)

Description: Pollen, monad, shape oblate, outline circular to convex triangular in polar view, equatorial diameter 37-42 µm wide(LM); eutectate, exine 1.0-1.5 µm thick, nexine thinner than sexine, brevitricolporate; sculpturing scabrate (LM), echinate to microechin-ate, perforate (SEM), echinae base diameter 0.4-0.5 µm (SEM)

Remarks: Caprifoliaceae-type fruit (Manchester, 2001) and pollen (Wingate & Nichols, 2001; *Lonicerapollis*) is known from Florissant.

This evergreen and deciduous genus includes approximately 180 species ranging from shrubs to trees. Today *Lonicera* thrives in temperate to tropic climate of the Northern Hemisphere.

## 4.5. Incertae sedis

**Indet. 1** (Plate 23, Figure A-C)

Description: Pollen, monad, shape spheroidal, pollen outline circular, pollen diameter 25-30 µm wide (LM); eutectate, exine more than 1.0-1.5 µm thick, triporate; sculpturing echinate (LM & SEM), between echinae microverrucate, microechinate, perforate (SEM), echinae base diameter 1.0-1.5 µm, echinae length 2.5-3.0 µm (SEM)

**Indet. 2** (Plate 23, Figure D-F)

Description: Pollen, monad, shape prolate, ellipsoid in equatorial view, circular lobate in polar view, polar axis 20-22 µm long (LM), equatorial diameter 20-24 µm wide (LM);

semitectate, exine 1.0-1.5 μm, nexine thinner than sexine, tricolpate, colpus membrane microrugulate (SEM); sculpturing microreticulate (LM & SEM), muri are running at graded levels.

**Indet. 3** (Plate 23, Figure G-I)

Description: Pollen, monad, shape prolate to spheroidal, outline cicular in equatorial view, polar axis 39-41 μm long (LM), equatorial diameter 36-38 μm wide (LM); eutectate, exine 1.5-2.0 μm thick, nexine thinner than sexine, tricolporate; sculpturing striate (LM), strie ribbed (SEM).

Remarks: A similar striate pollen type was described by Wingate & Nichols (2001; Plate 6, Figure 14; Tricolporate sp. D).

**Indet. 4** (Plate 23, Figure J-L)

Description: Pollen, monad, shape spheroidal, pollen outline circular, pollen diameter 20-25 μm wide (LM); eutectate, exine 1.0-1.5 μm thick, inaperturate; sculpturing echinate (LM & SEM), rugulate, microverrucate, perforate (SEM), echinae base diameter 0.5-0.8 μm, echinae length 1.5-2 μm (SEM)

**Indet. 5** (Plate 24, Figure A-C)

Description: Pollen, monad, shape prolate, outline elliptic in equatorial view, polar axis 20-26 μm long (LM), equatorial diameter 20-22 μm wide (LM); eutectate, exine 0.5-1.0 μm thick, nexine thinner than sexine, tricolporate, bridge in the porus area present (LM & SEM); sculpturing scabrate (LM), rugulate, fossulate to perforate (SEM), supra-sculpturing microrugulate.

**Indet. 6** (Plate 24, Figure D-F)

Description: Pollen, monad, shape oblate, outline triangular in polar view, equatorial diameter 36-40 μm (LM), eutectate, exine 0.8-1 μm thick, brevitricolporate, sculpturing scabrate (LM), verrucate, fossulate (SEM).

**Indet. 7** (Plate 24, Figure G-I)

Description: Pollen, monad, shape oblate, outline triangular in polar view, equatorial diameter 36-40 µm wide (LM); exine 0.5-1 µm thick, eutectate, tricolpate, colpi length one third of the pollen diameter, scuplturing scabrate (LM), microrugulate, fossulate (SEM).

Remarks: Both Indet. 5 and 6 pollen types show high affinity in outline and sculpturing to the North American Cretaceous *Proteacidites*-type. All encountered specimen of this types showed a poor state of preservation.

**Indet. 8** (Plate 24, Figure J-L)

Description: Pollen, monad, shape oblate, outline triangular in polar view, equatorial diameter 44-54 µm wide (LM); trichotomosulcate; sculpturing reticulate (LM & SEM), smooth muri 0.5-1 µm wide.

Remarks: A similar reticulate pollen type was described by Wingate & Nichols (2001; Plate 9, Figure 13 & 14; Triporate sp.).

# 5. Results

The investigated sediment sample from the Florissant Formation comprises a diverse palynomorph community as reported in Leopold & Clay-Poole (2001) and Wingate & Nichols (2001). Ninty-one different taxa were identified, eigth spore taxa of Bryophyte and Pteridophyte origin, nine pollen taxa of gymnosperm and seventy-four pollen taxa of angiosperm origin.

An assignment on family level was only possible in one of the eight spore taxa. All nine gymnosperm pollen taxa could be discerned to genus level. Sixty-six angiosperm taxa

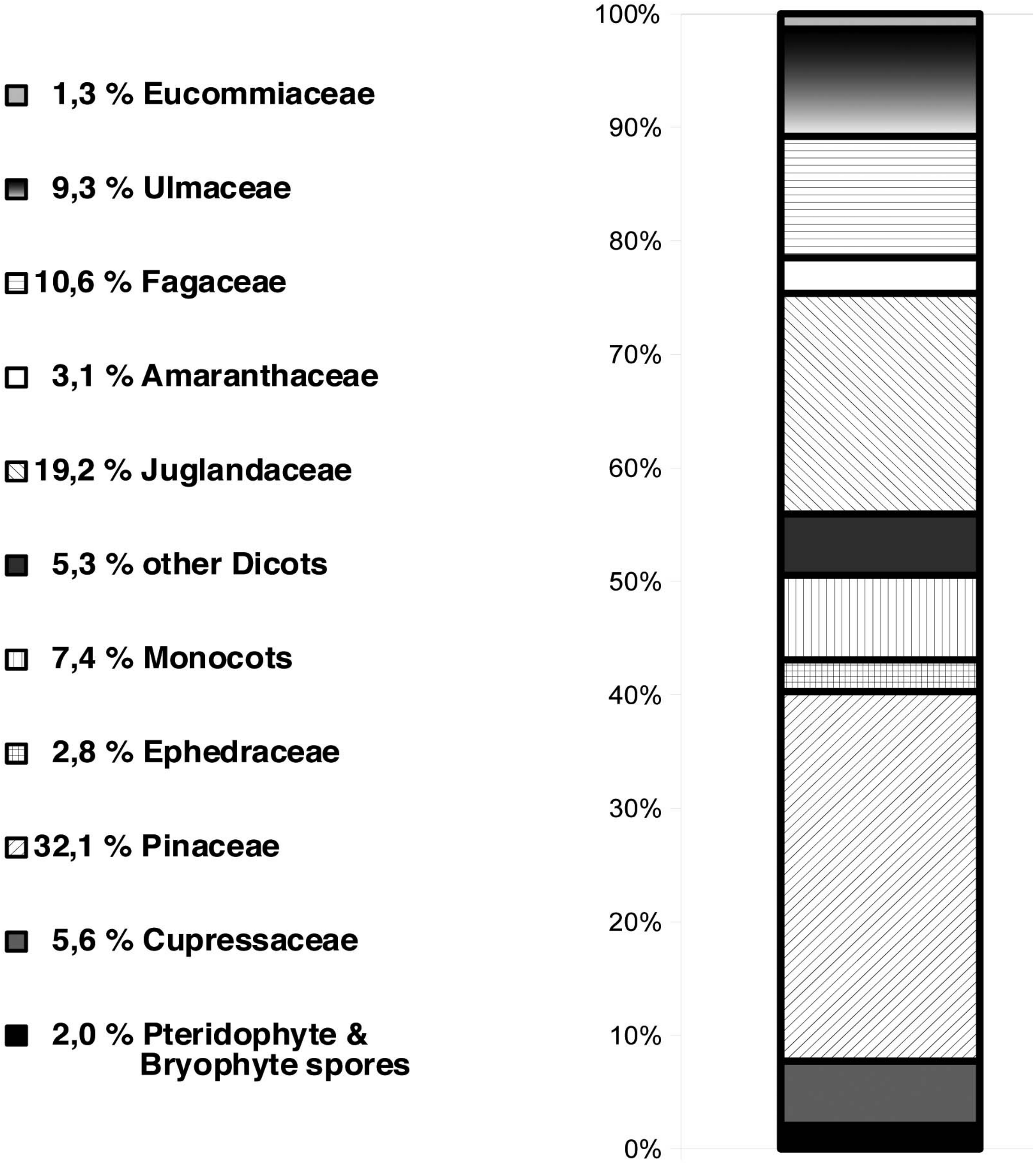


**Figure 3.** Relative spore and pollen abundance

were assigned to a family of which thirty-five could be discerned to genus level, eight angiosperm taxa could not be allocated to a family.

Fungal spores and freshwater cysts have been observed but have not been subject of further examination.

| Class/Clade/Family | Genus | Info | Makrofossils | Pollen | Source |
|---|---|---|---|---|---|
| **Ginkopsida** | | | | | |
| Ginkgoaceae | *Ginkgo* | | | x | |
| **Coniferopsida incl. Gnetales** | | | | | |
| Cupressaceae | *Chamaecyparis* | | C, L | | 3 |
| | *Sequoia* | | C, B, W | x | 1, 2, 3 |
| Taxaceae | *Torreya* | | L | | 3 |
| Pinaceae | *Abies* | | S | x | 1, 2, 3 |
| | *Cathaya* | | | x | |
| | *Picea* | | S | x | 1, 2, 3 |
| | *Pinus Strobus* | 2 spp. | C, S, L | x | 1, 2, 3 |
| | *Pinus Pinus* | 3 spp. | C, S, L | x | 1, 2, 3 |
| | *Tsuga* | | | x | 1, 2 |
| Ephedraceae | *Ephedra* | 2 species | B | x | 1, 2, 3 |
| **Angiosperms** | | | | | |
| Nympheaceae | | | | x | 1, 2 |
| **Magnoliids** | | | | | |
| Lauraceae | indet. | 2 types | L | | 3 |
| **Monocots** | | | | | |
| Potamogetonaceae | *Potamogeton* | | L, Fr | | 3 |
| Dioscoreaceae | *Discrorea* | | Fr | | 3 |
| Liliaceae | | | | x | 1, 2 |
| Smilacaceae | *Smilax*? | | L | | 3 |
| **Commelinids** | | | | | |
| Arececeae | indet. | | L | x | 1, 2, 3 |
| Cyperaceae | *Cyperacites* | | L | | 2, 3 |
| Poaceae | | | | x | 1, 2 |
| | *Stipa* | | Fr | x | 3 |
| Typhaceae | *Sparganium* | | | x | 1, 2 |
| | *Typha* | | L | x | 1, 2, 3 |
| **Eudicots** | | | | | |
| Buxaceae | | | | x | 2 |
| Platanaceae | *Platanus* | | L | x | 1, 2?, 3 |
| Menispermaceae | | | - | x | |
| Berberidaceae | *Mahonia* | 2-3 species | L | | 3 |
| Ranunculaceae | | | - | x | 2? |
| Trochodendraceae | *Tetracentron* | | - | x | |

Macrofossils: L-leave, Ll-leavelet, B-branch, C-cone, Fr-fruit, S-seed, W-wood, Fl-Flower
Sources: 1-Leopold & Clay-Poole (2001); 2-Wingate & Nichols (2001); 3-Manchester (2001); 4-Wheeler (2001)
?-uncertain or poor perservation; †-extinct

**Table 1.1.**

| Class/Clade/Family | Genus | Info | Makrofossils | Pollen | Source |
|---|---|---|---|---|---|
| **Core Eudicots** | | | | | |
| Amaranthaceae | | 3-4 spp. | - | x | 1, 2 |
| Cercidiphyllaceae | | | | x | 2 |
| Grossulariaceae | *Ribes* | | L | | 3 |
| Hamamelidaceae | | 2 species | | x | 2?, 3? |
| Polygonaceae | | | | x | 2 |
| **Rosids** | | | | | |
| Vitaceae | *Vitis?* | | L | x | 3 |
| | *Parthenocissus* | | L | | 3 |
| **Eurosids** I | | | | | |
| Fabaceae | indet. | 4 species | Ll | x | 2, 3 |
| | *Cercis* | | L, Fr | | 3 |
| | *Ceasalpina* | | Ll | x | 2, 3 |
| | *Prosopis* | | L | | 3 |
| | *Robinia* | | L, W | | 3, 4 |
| | *Vicia* | | L | | 3 |
| Betulaceae | *Paracarpinus/Asterocarpinus*† | | Fr, L | x | 3 |
| | *Alnus* | | | x | 2 |
| | *Betula* | | | x | 2 |
| | *Ostrea/Carpinus* | | | x | 1 |
| Fagaceae | *Castanea*? | | Fl | x | 3 |
| | Fagopsis | | L, Fl, Fr | | 3 |
| | *Lithocarpus* | | | x | |
| | *Quercus* | 9 ssp. | L, Fr | x | 1, 2, 3 |
| Juglandaceae | *Carya* | | L, Ll, Fl, Fr | x | 1, 2, 3 |
| | *Cyclocarya* | | | x | 1 |
| | *Engelhardia* | 2 spp. | | x | 1, 2 |
| | *Juglans* | | S? | x | 1, 2, 3 |
| Rhoipteleaceae | | | | x | 1, 2 |
| Salicaceae | *Populus* | | L, Fr | | 3 |
| | *Salix* | 4 spp. | L | x | 1, 2, 3 |
| Euphorbiaceae | *Euphorbia* | | | x | 1, 2, 3 |
| Elaeagnaceae | | | | x | 1, 2 |
| Cannabaceae | *Humulus* | | L | | 3 |
| Rosaceae | indet. | 4 species | | x | 1, 2, 3 |
| | *Amelanchier* | | L | | 3 |
| | *Cerocarpus* | | L, Fr | | 3 |
| | *Crataegus* | 3 species | L | x | 2, 3 |
| | *Malus* | | L | | 3 |
| | *Rosa* | | L | | 3 |
| | *Rubus* | | L | | 3 |
| | *Vauquelinia* | 2 species | L | | 3 |
| Ulmaceae | | | W | x | 1, 2, 4 |
| | *Celtis* | | L | | 3 |
| | *Cedrelospermum*† | | L, S | x | 3 |
| | *Ulmus* | | L, F | x | 1, 2, 3 |

Macrofossils: L-leave, Ll-leavelet, B-branch, C-cone, Fr-fruit, S-seed, W-wood, Fl-Flower
Sources: 1-Leopold & Clay-Poole (2001); 2-Wingate & Nichols (2001); 3-Manchester (2001); 4-Wheeler (2001)
?-uncertain or poor perservation; †-extinct

**Table 1.2**

| Class/Clade/Family | Genus | Info | Makrofossils | Pollen | Source |
|---|---|---|---|---|---|
| **Malvids** | | | | | |
| Malvaceae | indet. | at least 6 types | | x | 2 |
| | *Florissantia*† | | Fl, Fr | x | 1, 2, 3 |
| | *Tilia*? | | L | x | 2, 3 |
| Thymeleaceae | indet. | | | x | |
| | *Daphne* | | L | x | 2, 3 |
| Onagraceae | indet. | | Fl | x | 1, 2, 3 |
| Sapindaceae | | | | x | 1, 2, 3 |
| | *Acer* | 3 spp. | F, L | x | 1, 2, 3 |
| | *Athyana* | | L | | 3 |
| | *Dipteronia* | | Fr, L? | | 3 |
| | *Koelreuteria* | | Fr, L?, W | | 1, 3, 4 |
| Simaroubaceae | *Ailanthus* | | Fr | | 2?, 3 |
| Meliaceae | *Cedrela* or *Toona* | | S | x? | 2, 3 |
| Anacardiaceae | indet. | | | x | |
| | *Cotinus* | | L | | 3 |
| | *Rhus* | 3 spp. | L | | 3 |
| | *Schmaltzia* | | L | | 3 |
| Rutaceae | | | S? | x | 1, 3 |
| **Asterids** | | | | | |
| Cornaceae | *Alangium* | | | x | |
| Hydrangeaceae | | | L, Fl | | 3 |
| Ebenaceae | *Diospyros* | | | x | |
| Ericaceae | | | | x | 1, 2 |
| **Euasterids I (Lamiids)** | | | | | |
| Apocynaceae | indet. | | S | | 3 |
| | *Tabernaemontana* | | | x | 1 |
| Eucommiaceae | *Eucommia* | | Fr | x | 1, 2, 3 |
| Lamiaceae | | | | x | |
| Oleaceae | *Osmanthus*? | | L, Fr | x | 1, 3 |
| | *Fraxinus* | | | x | 2 |
| **Euasterids II (Campanulids)** | | | | | |
| Asteraceae | | | | x | 1, 2 |
| Adoxaceae | Sambuccus | | L | | 1, 2, 3 |
| | *Viburnum* | | | x | 1 |
| Caprifoliaceae | *Diplodiptela* | | Fr | | 3 |
| | *Lonicera* | | | x | 2 |
| Araliaceae | | | Fr | | 3 |

Macrofossils: L-leave, Ll-leavelet, B-branch, C-cone, Fr-fruit, S-seed, W-wood, Fl-Flower
Sources: 1-Leopold & Clay-Poole (2001); 2-Wingate & Nichols (2001); 3-Manchester (2001); 4-Wheeler (2001)
?-uncertain or poor perservation; †-extinct

**Table 1.3**

Bisaccate Pinaceae (*Pinus, Abies*, *Picea* and *Cathaya*) are the most common pollen in the sample. The most abundant angiosperm pollen can be allocated to Juglandaceae (*Carya*, *Engelhardia* and *Juglans*), Fagaceae (diverse *Quercus* species, *Lithocarpus and Castanaea*), Ulmaceae (*Ulmus* and *Cedrelospermum)* and several Monocots (mainly *Typha* and *Sparganium*). For relative spore and pollen abundances see Figure 3.

A compilation of gymnosperm and angiosperm macro- and micro-fossil taxa known from the Florissant Formation can be found in Tables 1.1. to 1.3.

# 6. Discussion

The families and morphotypes previously reported in the works of Leopold & Clay-Poole (2001) and Wingate & Nichols (2001) of Pinaceae, Ephedraceae, Arecaceae, Poaceae, Typhaceae, Buxaceae, Ranunculaceae, Amaranthaceae (formerly Chenopodiaceae), Hamamelidaceae, Vitaceae, Betulaceae, Fagaceae, Juglandaceae, Salicaceae, Euphorbiaceae, Rosaceae, Ulmaceae, Malvaceae (formerly Sterculiaceae and Bombacaceae), Thymeleaceae, Onagraceae, Sapindaceae (formerly Aceraceae), Anacardiaceae, Rutaceae, Ericaceae, Apocynaceae, Eucommiaceae, Oleaceae, Asteraceae and Caprifoliaceae could also be verified by this investigation.

Palynomorphs of *Pediastrum*, *Bothryococcus*, *Pinus Pinus* (diploxylon-type), Nymphaeceae, Liliaceae, Polygonaceae, Fabaceae, Rhoipteleaceae, Simaroubaceae, Eleagnaceae and Meliaceae were not observed in the present study, although the presence of these palynomorphs has been reported in previous works on the Florissant Formation (Leopold & Clay-Poole, 2001; Wingate & Nichols, 2001).

In addition to the already extensive fossil pollen record of the Florissant Formation, *Gingko*, *Cathaya*, Menispermaceae, Trochodendraceae (*Tetracentron*), Corneaceae (*Alangium*), Ebenaceae (*Diospyros*), Lamiaceae and *Lithocarpus* have been identified for the first time.

Pollen of families and genera already reported from Florissant´s macro-fossil record, such as Anacardiaceae, Vitaceae and *Cedrelospermum* could also be verified in the pollen record. The presence of *Castanea*-pollen could provide important information regarding the uncertain taxonomic assignment of a possible fossil *Castanea*-leaf (Manchester, 2001) more likely.

Due to the single grain method and the SEM´s higher magnification and resolution it was possible to identify and verify the presence of three *Acer* pollen types (three species known from macro fossils; Manchester, 2001) and five *Quercus* pollen types (nine species known from macro fossils; Manchester, 2001).

Since Wingate & Nichols (2001) conducted investigations only under light microscope, some pollen could not be identified or certainly allocated to a taxonomic group. Using the single grain method the taxonomic status and verification of some pollen could be clarified (Ranunculaceae, Hamamelidaceae, Rosaceae and *Fraxinus*). The previously (Leopold & Clay-Poole,2001; Wingate & Nichols, 2001) suspected presence of Myrtaceae, Sapotaceae and Proteaceae could not be verified and should be omitted from the Florissant flora.

Leopold & Clay-Poole (2001; Plate 1, Figures 2, 3, 5 & 6) determined *Selaginella*-type spores. As similar spores from this sample (Plate 2, Figures D-I) do not show micro- and supra-sculpturing attributed to the *Selaginella*-type of spores, the designation to the group *Selaginella* can not be confirmed here.

The anemophilous pollination strategy of *Ginkgo*, the rare presence of its pollen and the absence of macro-fossil occurrence in the Florissant sediments suggest that these trees Florissant palaeo-lake.

Wingate & Nichols (2001) reported the presence *Podocarpidites*-type pollen. This type of pollen occurred in the present sample as well. Due to its microechinate supra-sculpturing it shows remarkable similarity to *Cathaya*-pollen. It has to be considered that in this sample, as well as in the entire Florissant formation, the *Podocarpidites*-type could represent an aberrant form of bisaccate Pinaceae pollen in general. Both, *Podocarpus* and *Cathaya* are part of the Eocene North American fossil record, a fossil stem and leaf compressions of *Podocarpus* from the early Eocene of Tennessee (Dilcher, 1969) and *Cathaya*-pollen from Eocene Axel Heiberg island (Liu & Basinger, 2000) have previously been reported. Considering the palynological evidence, the presence of *Podocarpus* in the near vicinity of the Florissant palaeolake is questionable.

Leopold et al. (2008) compared the buxaceous pollen type, known from Wingate & Nichols (2001; Plate 8, Figure 21) with pollen from *Pachysandra* and *Sarcococca.* The suprascultpure of the observed buxaceous pollen type (Plate 6 G-I) shows that the designation to this two species can be ruled out.

The diverse and exceptionally well-preserved macro- and microflora of the Florissant Formation provide a unique glimpse at the brink of global climatic change, the Eocene-Oligocene boundary.

The application of the single grain technique produced additional taxa and could clarify uncertain allocations to families and genera of the west-central North American Eocene palaeo-environment and flora. The additional and more accurately determined families and genera will provide a more accurate the palaeo-climate reconstruction. Dispite the amount of additional information gained through this method, questions of palaeo-elevation still remain a source of discussion.

A further investigation of a complete cross-section of the Florissant Formation comprising the single grain method would definitely bring additional insightful information to the already extensive amount of gathered scientific work.

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# 9. Plates

## Plate 1.

Figure A: Bryophyta fam. gen. et spec. indet LM
Figure B: Bryophyta fam. gen. et spec. indet SEM
Figure C: Bryophyte fam. gen. et spec. indet SEM; surface detail

Figure D: Pteridophyte fam. gen. et spec. indet 1 LM; polar view
Figure E: Pteridophyte fam. gen. et spec. indet 1 SEM; proximal view
Figure F: Pteridophyte fam. gen. et spec. indet 1 SEM; surface detail

Figure G: Pteridophyta fam. gen. et spec. indet 2 LM; polar view
Figure H: Pteridophyta fam. gen. et spec. indet 2 SEM; proximal view
Figure I: Pteridophyte fam. gen. et spec. indet 2 SEM; surface detail

Figure J: Pteridophyta fam. gen. et spec. indet 3 LM; polar view
Figure K: Pteridophyta fam. gen. et spec. indet 3 SEM; proximal view
Figure L: Pteridophyta fam. gen. et spec. indet 3 SEM; surface detail

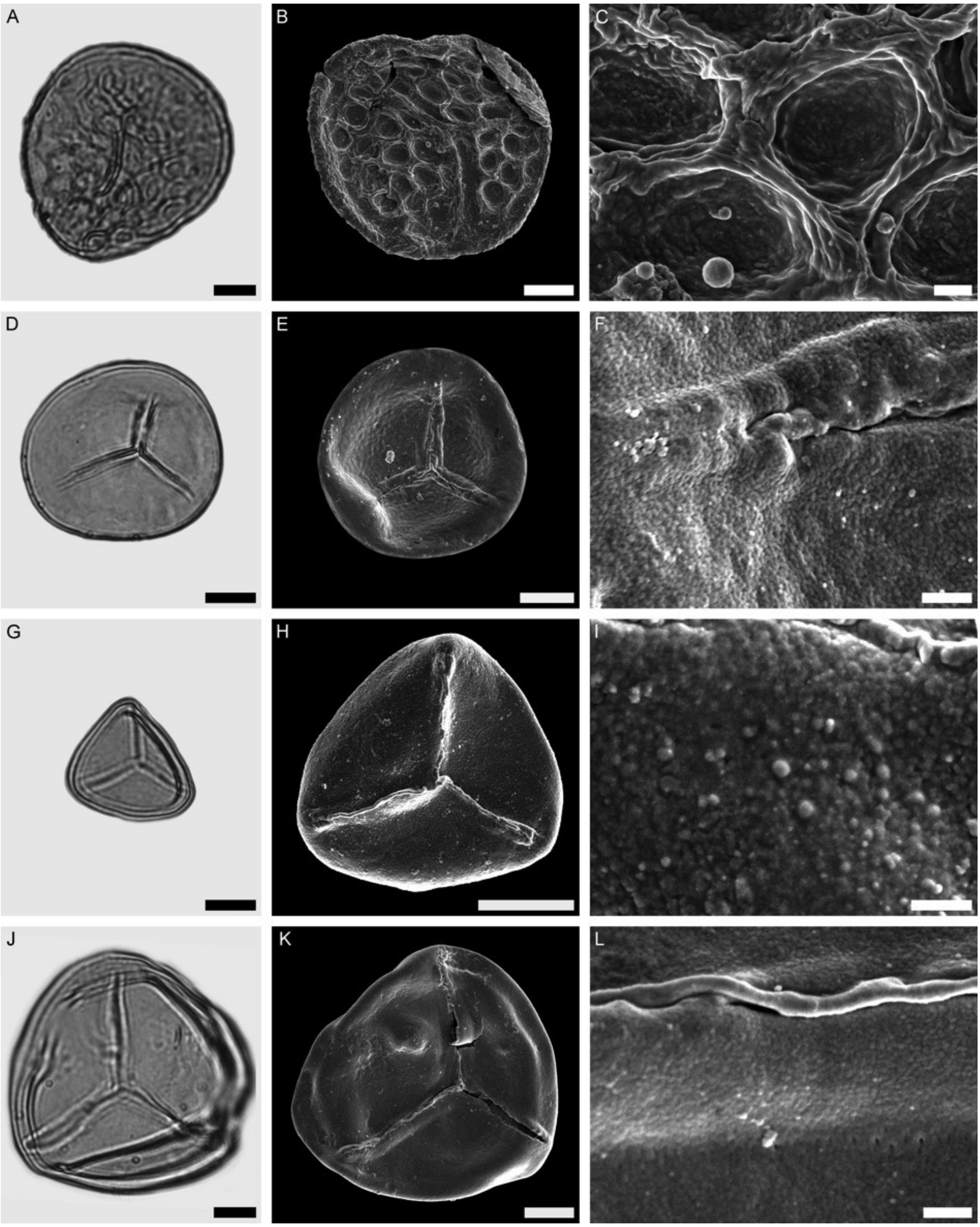


**Plate 1.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 2.

Figure A: Pteridophyta fam. gen. et spec. indet 4 LM; polar view
Figure B: Pteridophyta fam. gen. et spec. indet 4 SEM; proximal view
Figure C: Pteridophyte fam. gen. et spec. indet 4 SEM; surface detail

Figure D: Pteridophyta fam. gen. et spec. indet 5 LM; polar view
Figure E: Pteridophyta fam. gen. et spec. indet 5 SEM; proximal view
Figure F: Pteridophyta fam. gen. et spec. indet 5 SEM; surface detail

Figure G: Pteridophyta fam. gen. et spec. indet 6 LM; polar view
Figure H: Pteridophyta fam. gen. et spec. indet 6 SEM; proximal view
Figure I: Pteridophyta fam. gen. et spec. indet 6 SEM; surface detail

Figure J: Polypodiaceae gen. et sp. indet LM; equatorial view
Figure K: Polypodiaceae gen. et sp. indet SEM; equatorial view
Figure L: Polypodiaceae gen. et sp. indet SEM; surface detail

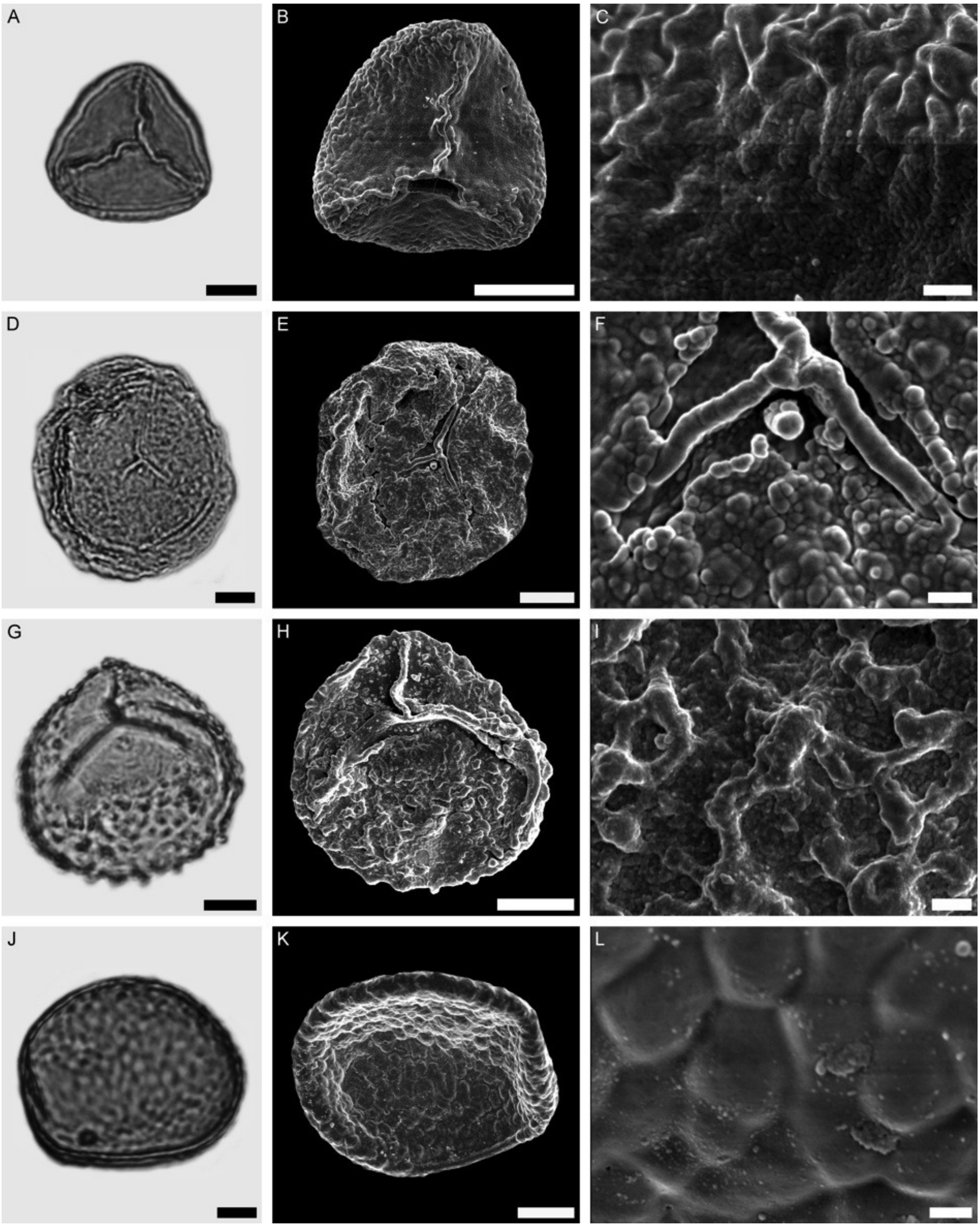


**Plate 2.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 3.

Figure A: *Sequoia* sp. LM; (left) fissurate & (right) afissurate
Figure B: *Sequoia* sp. SEM; (left) fissurate & (right) afissurate
Figure C: *Sequoia* sp.SEM; fissurate pollen surface detail
Figure D: *Sequoia* sp. SEM; afissurate pollen surface detail

Figure E: *Abies* sp. LM; equatorial view
Figure F: *Abies* sp. SEM; equatorial view
Figure G: *Abies* sp. SEM; saccus surface detail
Figure H: *Abies* sp. SEM; corpus surface detail

Figure I: *Cathaya* sp. LM; polar view
Figure J: *Cathaya* sp. SEM; equatorial view
Figure K: *Cathaya* sp. SEM; saccus surface detail
Figure L: *Cathaya* sp. SEM; leptoma surface detail

Figure M: *Cathaya* sp. LM; aberrant pollen, “Podocrapidites type”; polar view
Figure N: *Cathaya* sp. SEM; aberrant pollen, “Podocrapidites type”; equatorial view
Figure O: *Cathaya* sp. SEM; aberrant pollen, “Podocrapidites type”; saccus surface detail
Figure P: *Cathaya* sp. SEM; aberrant pollen, “Podocrapidites type”; corpus surface detail

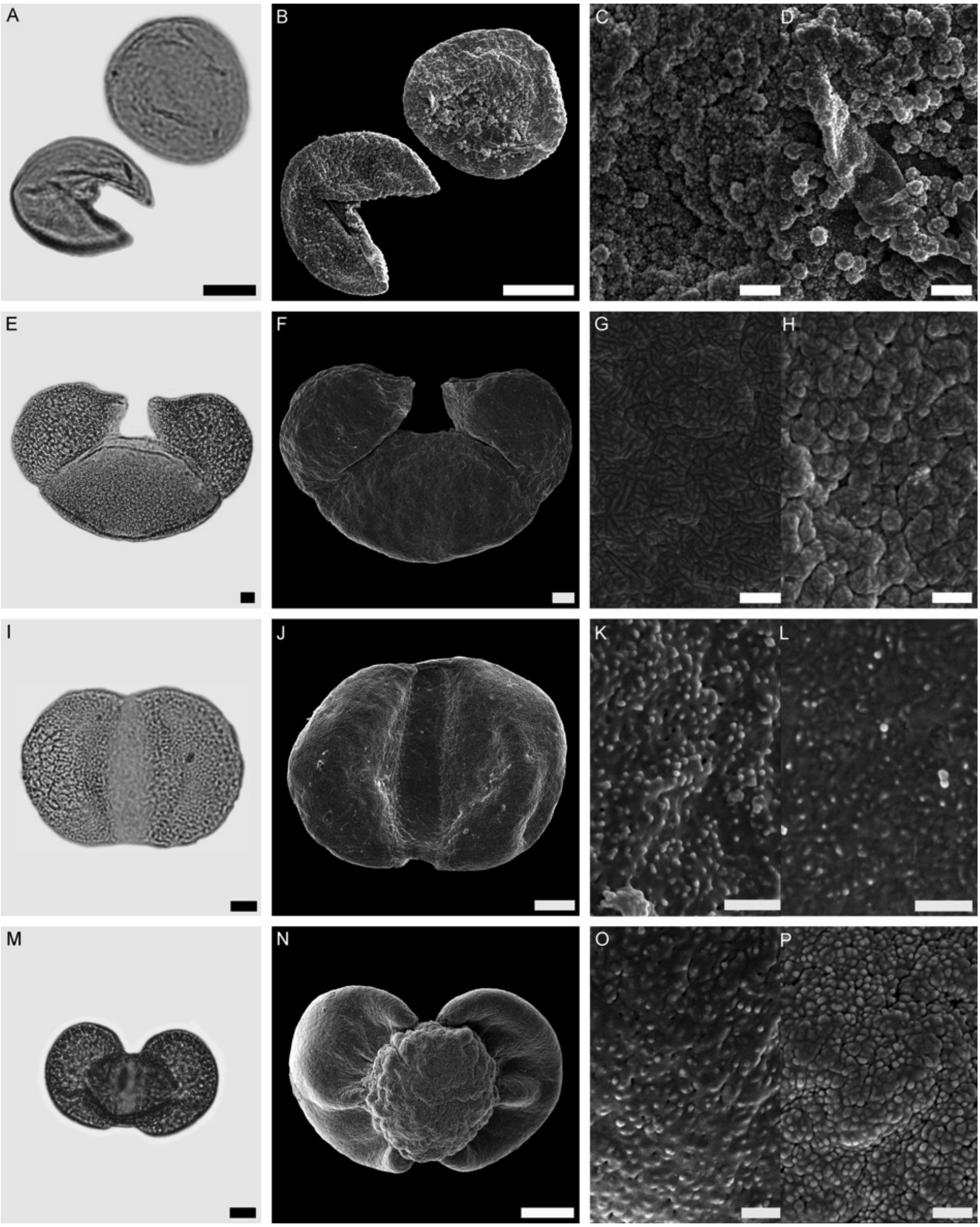


**Plate 3.**

Scale bar 10 µm in Figures A, B, E, F, I, J, M & N
Scale bar 1 µm in Figures C, D, G, H, K, L, O & P

## Plate 4.

Figure A: *Picea* sp. LM; equatorial view
Figure B: *Picea* sp. SEM; equatorial view
Figure C: *Picea* sp. SEM; saccus surface detail
Figure D: *Picea* sp. SEM; corpus surface detail

Figure E: *Pinus* subgenus *Strobus* sp. LM; equatorial view
Figure F: *Pinus* subgenus *Strobus* sp. SEM; equatorial view
Figure G: *Pinus* subgenus *Strobus* sp. SEM; saccus surface detail
Figure H: *Pinus* subgenus *Strobus* sp. SEM; corpus surface detail

Figure I: *Tsuga* sp. LM; polar view
Figure J: *Tsuga* sp. SEM; proximal view
Figure K: *Tsuga* sp. SEM; distal saccus surface detail
Figure L: *Tsuga* sp. SEM; proximal leptoma surface detail

Figure M: *Ephedra* sp. 1 LM; equatorial view
Figure N: *Ephedra* sp. 1 SEM; equatorial view
Figure O: *Ephedra* sp. 1 SEM; surface detail

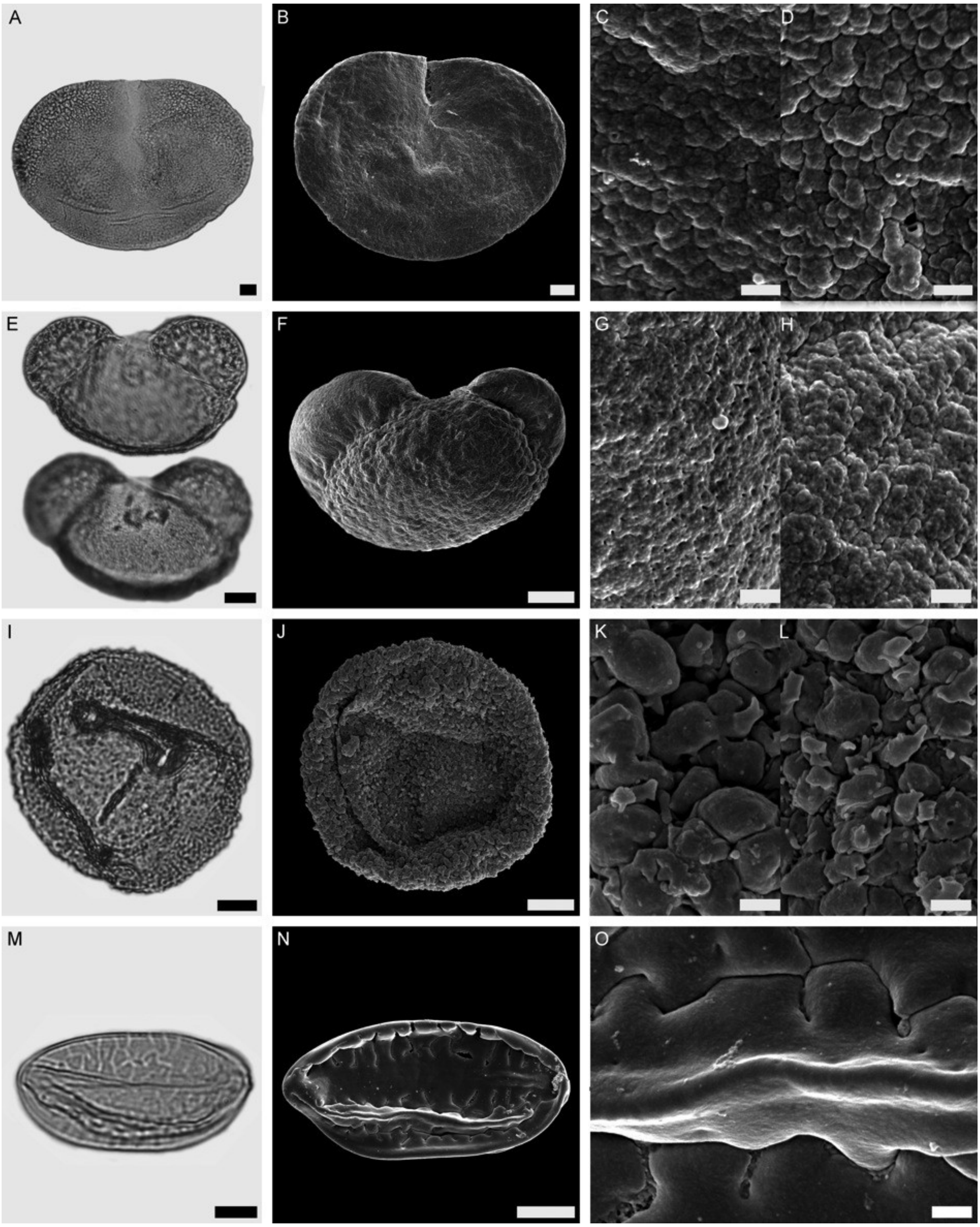


**Plate 4.**

Scale bar 10 μm in Figures A, B, E, F, I, J, M & N
Scale bar 1 μm in Figures C, D, G, H, K, L & O

## Plate 5.

Figure A: *Ephedra* sp. 2 LM; equatorial view
Figure B: *Ephedra* sp. 2 SEM; equatorial view
Figure C: *Ephedra* sp. 2 SEM; surface detail

Figure D: *Gingko* sp. LM
Figure E: *Gingko* sp. SEM
Figure F: *Gingko* sp. SEM; surface detail

Figure G: Arecaceae gen et spec. indet. LM
Figure H: Arecaceae gen et spec. indet. SEM
Figure I: Arecaceae gen et spec. indet. SEM; surface detail

Figure J: Poaceae cf. *Stipa* LM; polar view
Figure K: Poaceae cf. *Stipa* SEM
Figure L: Poaceae cf. *Stipa* SEM; surface detail

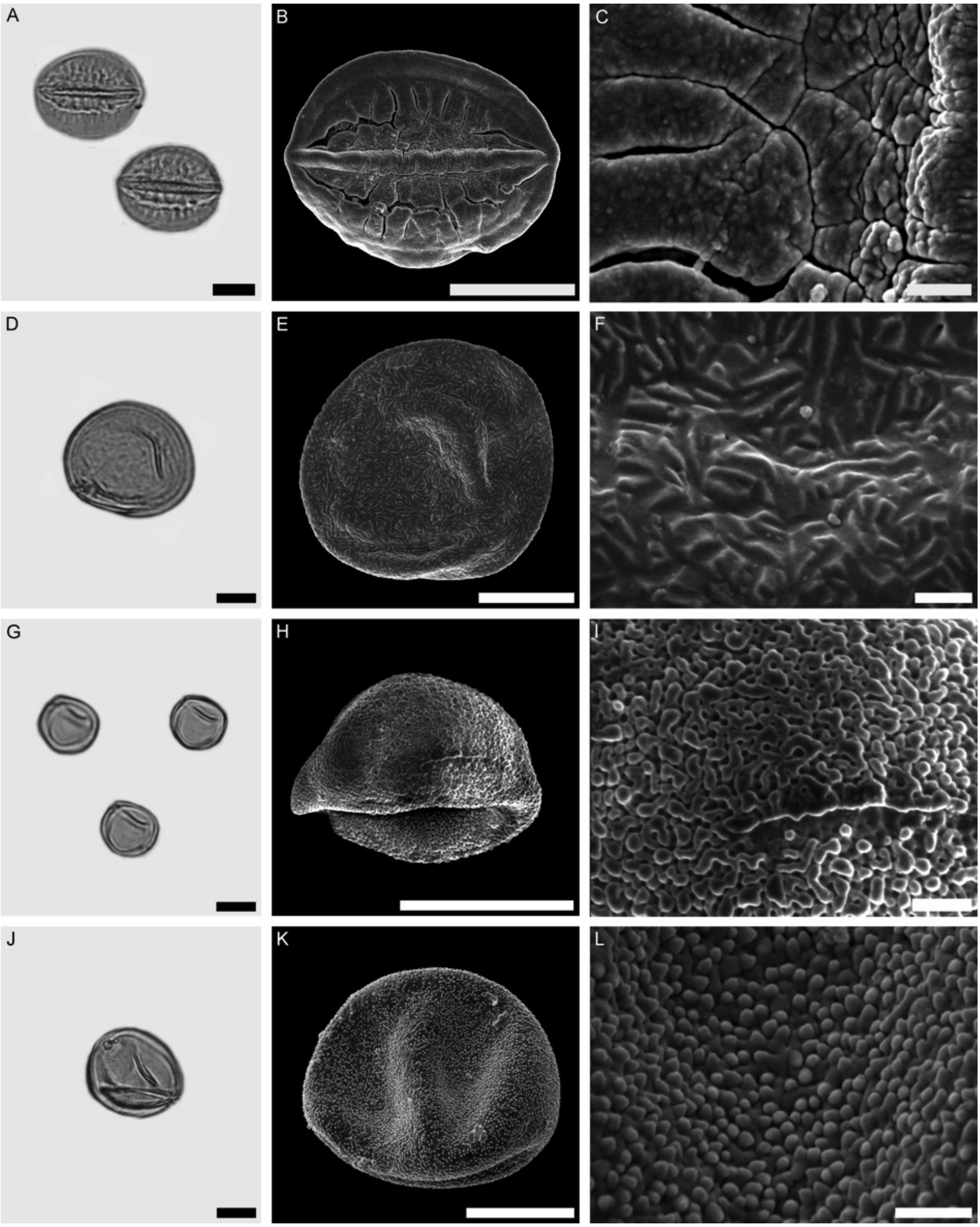


**Plate 5.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 6.

Figure A: *Typha* sp. LM
Figure B: *Typha* sp. SEM
Figure C: *Typha* sp. SEM; surface detail

Figure D: *Sparganium* sp. LM
Figure E: *Sparganium* sp. SEM
Figure F: *Sparganium* sp. SEM; surface detail

Figure G: Buxaceae gen. et spec. indet. LM
Figure H: Buxaceae gen. et spec. indet. SEM
Figure I: Buxaceae gen. et spec. indet. SEM; surface detail

Figure J: *Platanus* sp. LM; polar view
Figure K: *Platanus* sp. SEM; polar view
Figure L: *Platanus* sp. SEM; surface detail

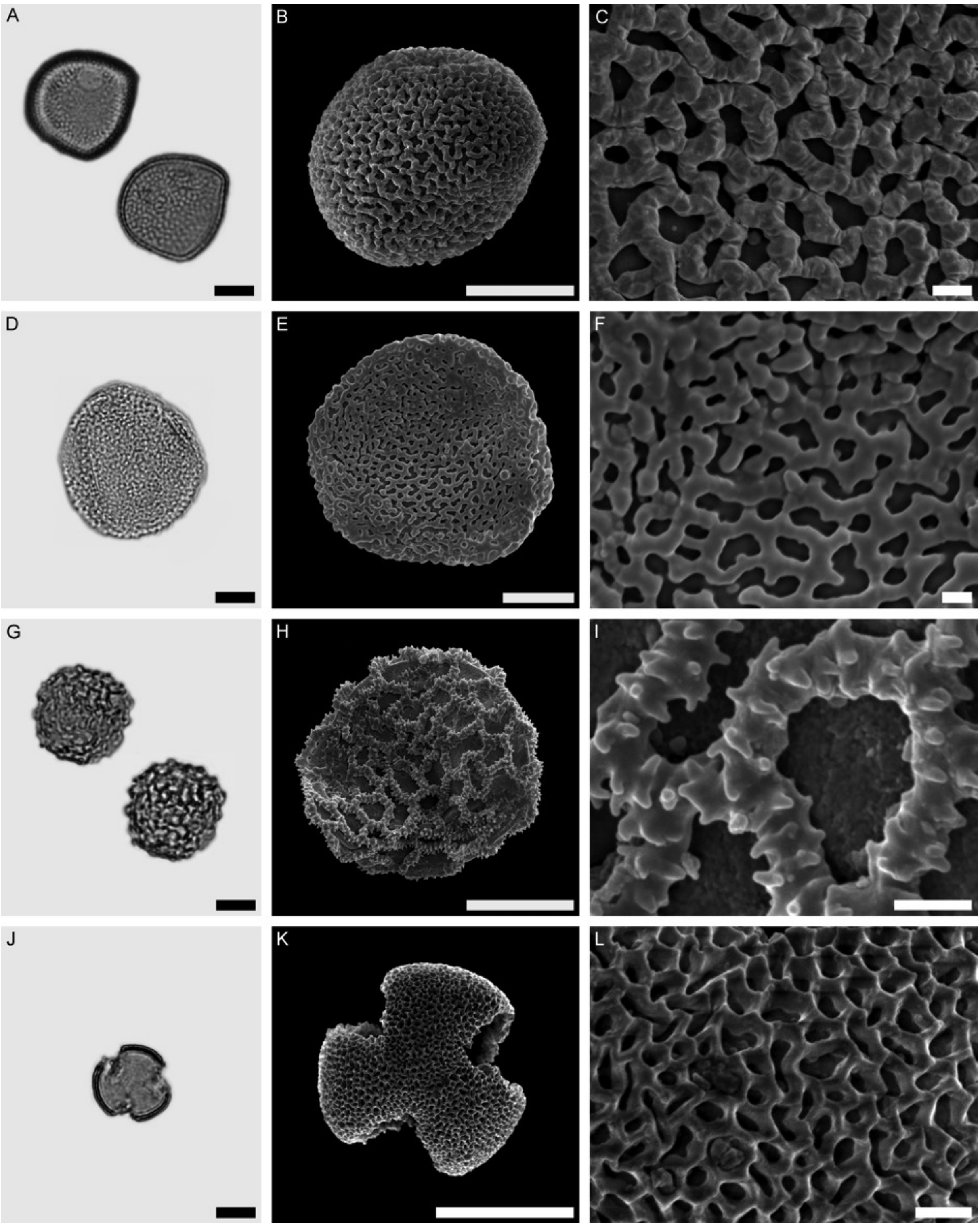


**Plate 6.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 7.

Figure A: Menispermaceae gen. et spec. indet. LM
Figure B: Menispermaceae gen. et spec. indet. SEM
Figure C: Menispermaceae gen. et spec. indet. SEM; surface detail

Figure D: Ranunculaceae gen. et spec. Indet. LM; polar view
Figure E: Ranunculaceae gen. et spec. Indet. SEM; polar view
Figure F: Ranunculaceae gen. et spec. Indet. SEM; surface detail

Figure G: *Tetracentron* sp. LM; equatorial view
Figure H: *Tetracentron* sp. SEM; equatorial view
Figure I: *Tetracentron* sp. SEM; surface detail

Figure J: Chenopodiadae gen. et spec. indet. 1 LM
Figure K: Chenopodiadae gen. et spec. indet. 1 SEM
Figure L: Chenopodiadae gen. et spec. indet. 1 SEM; surface detail

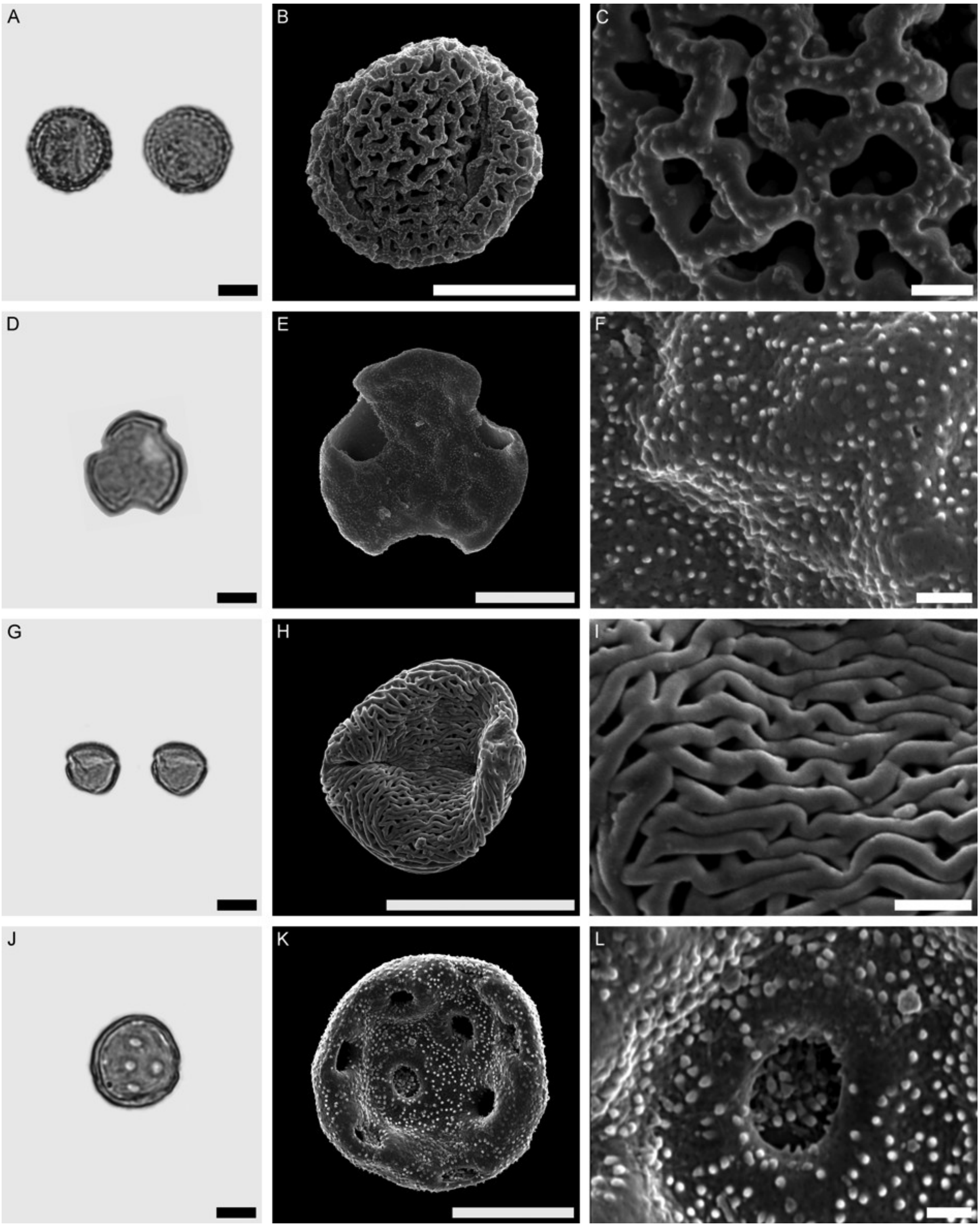


**Plate 7.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 8.

Figure A: Chenopodiadae gen. et spec. indet. 2 LM
Figure B: Chenopodiadae gen. et spec. indet. 2 SEM
Figure C: Chenopodiadae gen. et spec. indet. 2 SEM; surface detail

Figure D: Chenopodiadae gen. et spec. indet. 3 LM
Figure E: Chenopodiadae gen. et spec. indet. 3 SEM
Figure F: Chenopodiadae gen. et spec. indet. 3 SEM; surface detail

Figure G: Chenopodiadae gen. et spec. indet. 4 LM
Figure H: Chenopodiadae gen. et spec. indet. 4 SEM
Figure I: Chenopodiadae gen. et spec. indet. 4 SEM; surface detail

Figure J: Hamamelidaceae gen. et spec. indet. 1 LM
Figure K: Hamamelidaceae gen. et spec. indet. 1 SEM
Figure L: Hamamelidaceae gen. et spec. indet. 1 SEM; surface detail

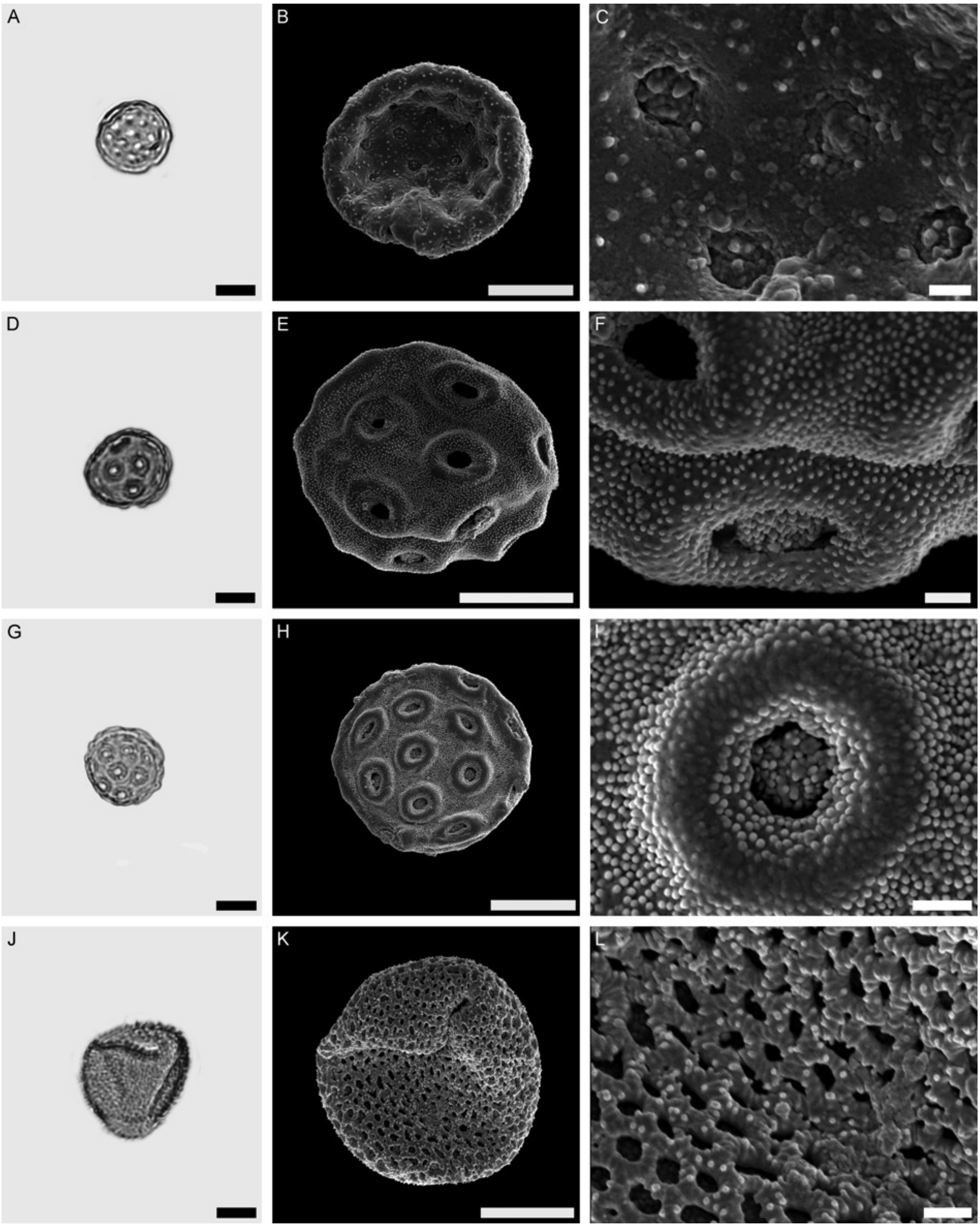


**Plate 8.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 9.

| | |
|---|---|
| Figure A: | Hamamelidaceae gen. et spec. indet. 2 LM; equatorial view |
| Figure B: | Hamamelidaceae gen. et spec. indet. 2 SEM; equatorial view |
| Figure C: | Hamamelidaceae gen. et spec. indet. 2 SEM; surface detail |
| Figure D: | Vitaceae gen. et spec. indet. 1 LM; equatorial view |
| Figure E: | Vitaceae gen. et spec. indet. 1 SEM; equatorial view |
| Figure F: | Vitaceae gen. et spec. indet. 1 SEM; surface detail |
| Figure G: | Vitaceae gen. et spec. indet. 2 LM; equatorial view |
| Figure H: | Vitaceae gen. et spec. indet. 2 SEM; equatorial view |
| Figure I: | Vitaceae gen. et spec. indet. 2 SEM; surface detail |
| Figure J: | *Betula* sp. LM; polar & equatorial view |
| Figure K: | *Betula* sp. SEM; polar view |
| Figure L: | *Betula* sp. SEM; surface detail |

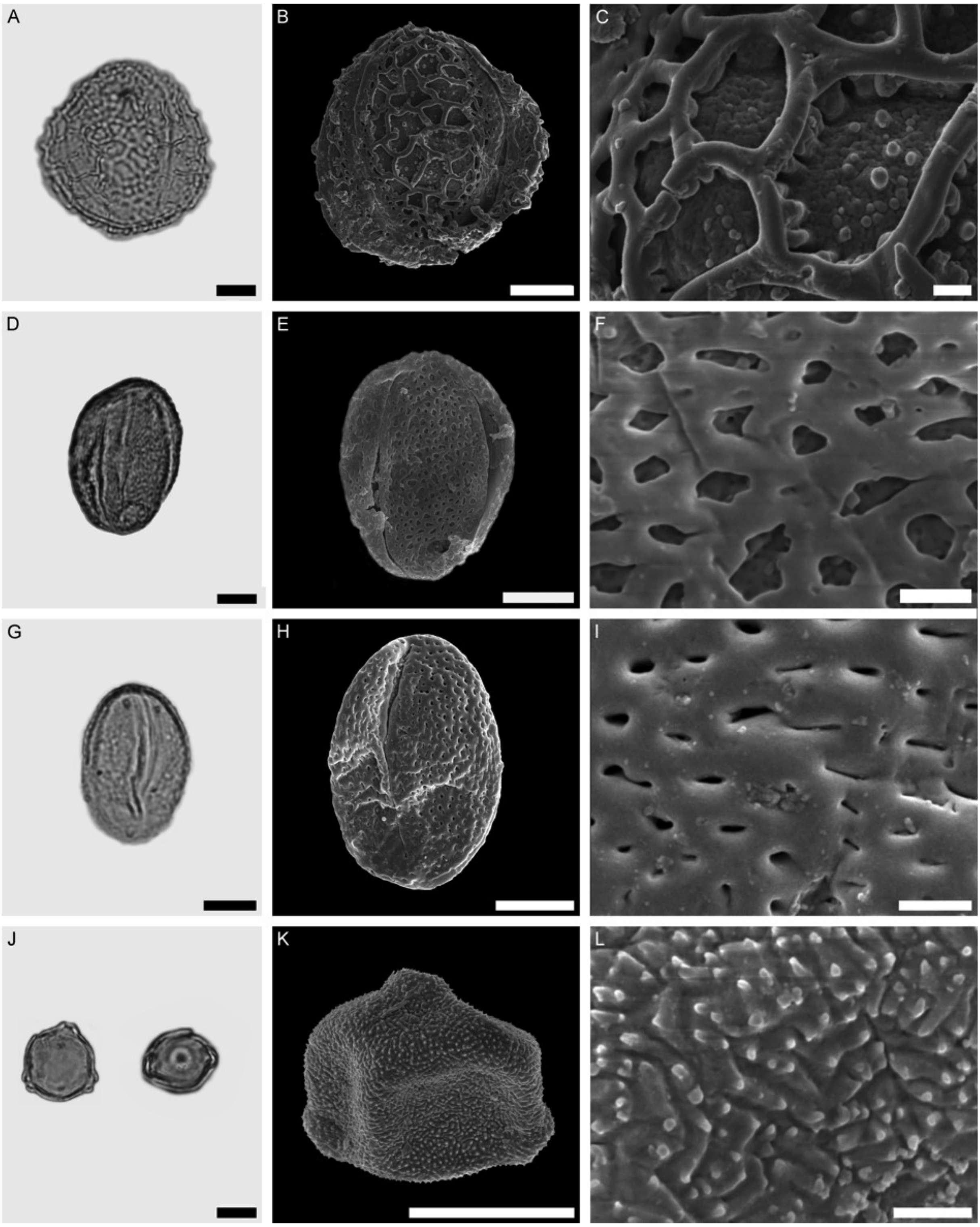


**Plate 9.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 10.

Figure A: *Castanea* sp. LM; equatorial view
Figure B: *Castanea* sp. SEM; equatorial view
Figure C: *Castanea* sp. SEM; surface detail

Figure D: *Lithocarpus* sp. LM; equatorial view
Figure E: *Lithocarpus* sp. SEM; equatorial view
Figure F: *Lithocarpus* sp. SEM; surface detail

Figure G: *Quercus* sp. 1 Cyclobalanopsis-type LM; polar view
Figure H: *Quercus* sp. 1 Cyclobalanopsis-type SEM; polar view
Figure I: *Quercus* sp. 1 Cyclobalanopsis-type SEM; surface detail

Figure J: *Quercus* sp. 2 Protobalanus-type LM; polar (left) & equatorial (right) view
Figure K: *Quercus* sp. 2 Protobalanus-type SEM; equatorial view
Figure L: *Quercus* sp. 2 Protobalanus-type SEM; surface detail

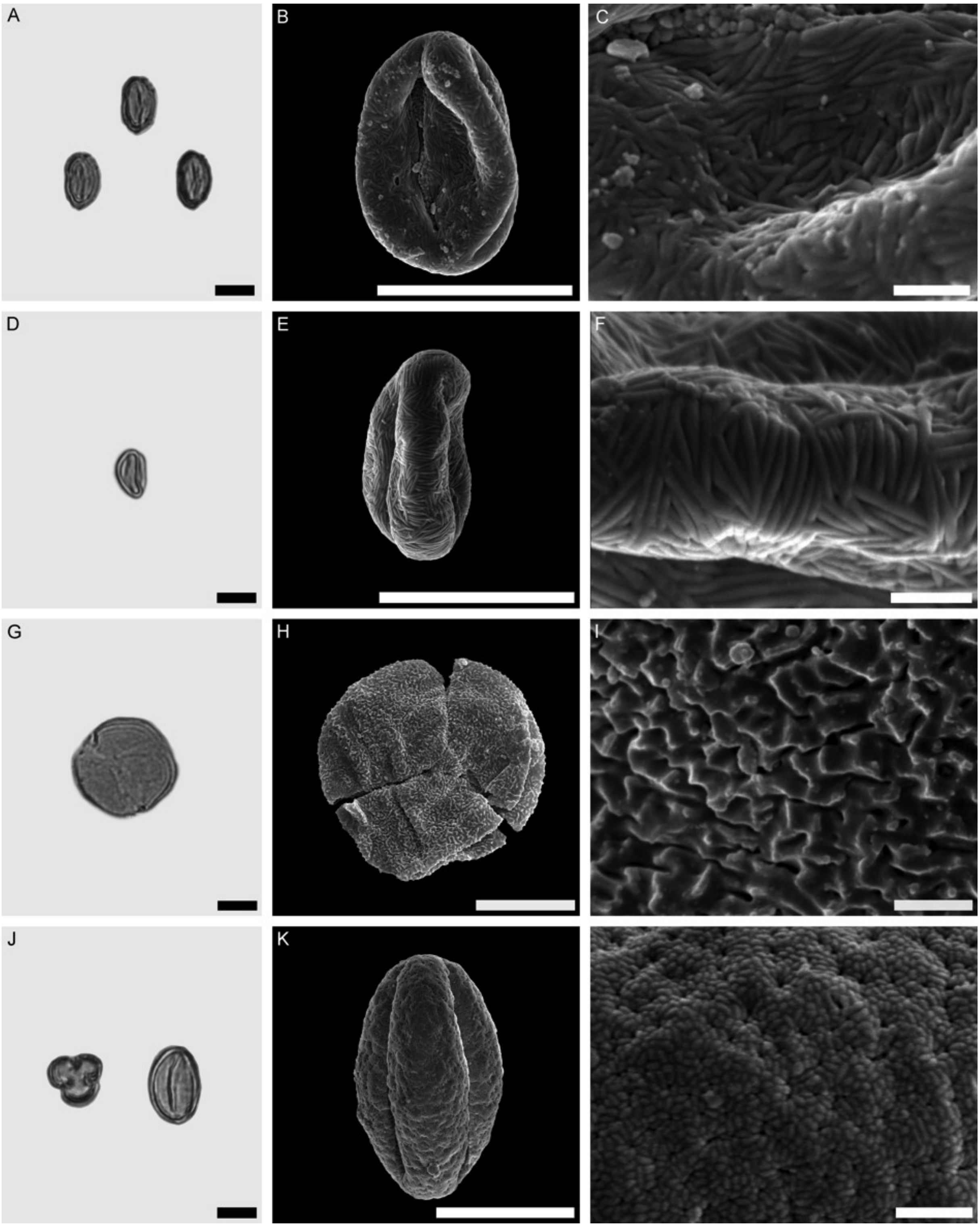


**Plate 10.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 11.

Figure A: *Quercus* sp. 3 LM; Protobalanus-type; equatorial view
Figure B: *Quercus* sp. 3 SEM; Protobalanus-type; equatorial view
Figure C: *Quercus* sp. 3 SEM; Protobalanus-type; surface detail

Figure D: *Quercus* sp. 4 Lobate-type LM; equatorial (left) & polar (right) view
Figure E: *Quercus* sp. 4 Lobate-type SEM; equatorial view
Figure F: *Quercus* sp. 4 Lobate-type SEM; surface detail

Figure G: *Quercus* sp. 5 Lobate type LM; equatorial view
Figure H: *Quercus* sp. 5 Lobate type SEM; equatorial view
Figure I: *Quercus* sp. 5 Lobate type SEM; surface detail

Figure J: *Carya* sp. LM; polar view;
Figure K: *Carya* sp. SEM; distal (left) & proximal (right) view
Figure L: *Carya* sp. SEM; surface detail

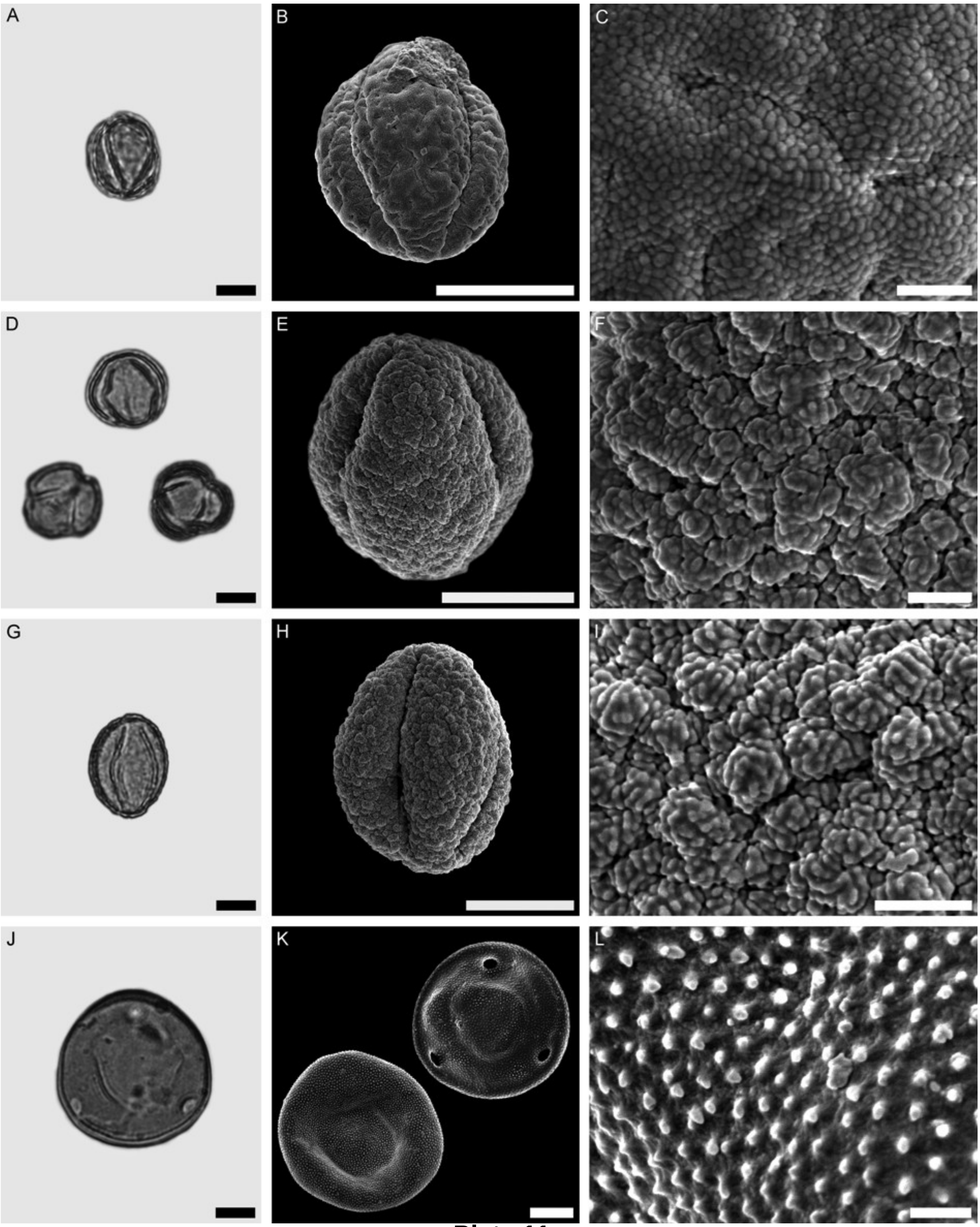


**Plate 11.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 12.

Figure A: *Engelhardia* sp. LM; polar view
Figure B: *Engelhardia* sp. SEM; polar view
Figure C: *Engelhardia* sp. SEM; surface detail

Figure D: *Engelhardia* aff. *Palaeocarya* LM; polar view
Figure E: *Engelhardia* aff. *Palaeocarya* SEM; polar view
Figure F: *Engelhardia* aff. *Palaeocarya* SEM; surface detail

Figure G: *Juglans* sp. LM; equatorial view
Figure H: *Juglans* sp. SEM; equatorial view
Figure I: *Juglans* sp. SEM; surface detail

Figure J: *Salix* sp. LM; equatorial view
Figure K: *Salix* sp. SEM; equatorial view
Figure L: *Salix* sp. SEM; surface detail

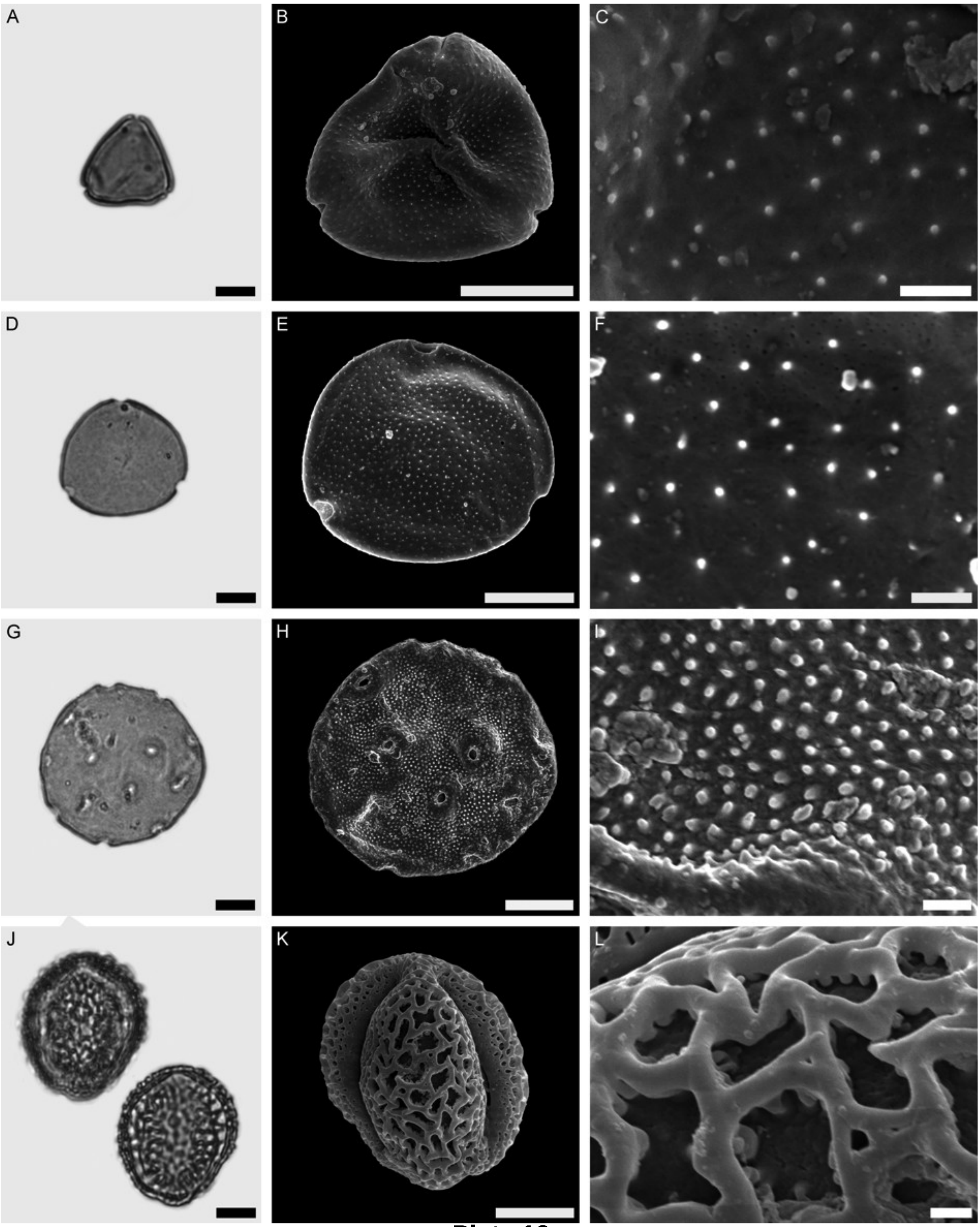


**Plate 12.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 13.

Figure A: Euphorbiaceae gen. et spec. indet. 1 LM; equatorial view
Figure B: Euphorbiaceae gen. et spec. indet. 1 SEM; equatorial view
Figure C: Euphorbiaceae gen. et spec. indet. 1 SEM; surface detail

Figure D: Euphorbiaceae gen. et spec. indet. 2 LM; polar view
Figure E: Euphorbiaceae gen. et spec. indet. 2 SEM; polar view
Figure F: Euphorbiaceae gen. et spec. indet. 2 SEM; surface detail

Figure G: *Crataegus* sp. LM; equatorial view
Figure H: *Crataegus* sp. SEM; equatorial view
Figure I: *Crataegus* sp. SEM; surface detail

Figure J: Rosaceae gen. et spec. indet. 1 LM; equatorial view
Figure K: Rosaceae gen. et spec. indet. 1 SEM; equatorial view
Figure L: Rosaceae gen. et spec. indet. 1 SEM; surface detail

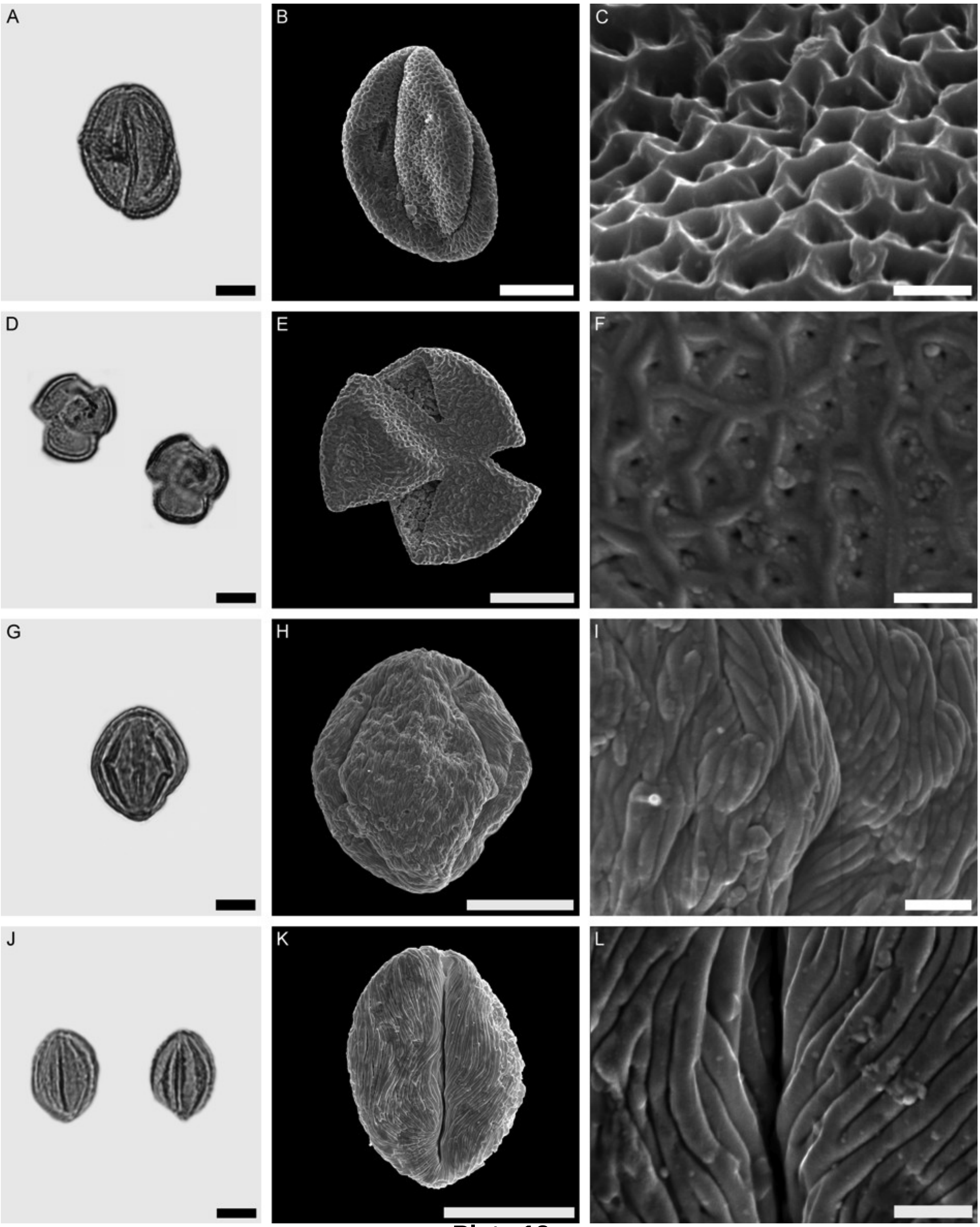


**Plate 13.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 14.

Figure A: Rosaceae gen. et spec. indet. 2 LM; equatorial view
Figure B: Rosaceae gen. et spec. indet. 2 SEM; equatorial view
Figure C: Rosaceae gen. et spec. indet. 2 SEM; surface detail

Figure D: Rosaceae gen. et spec. indet. 3 LM; equatorial view
Figure E: Rosaceae gen. et spec. indet. 3 SEM; equatorial view
Figure F: Rosaceae gen. et spec. indet. 3 SEM; surface detail

Figure G: Rosaceae gen. et spec. indet. 4 LM; equatorial view
Figure H: Rosaceae gen. et spec. indet. 4 SEM; equatorial view
Figure I: Rosaceae gen. et spec. indet. 4 SEM; surface detail

Figure J: *Cedrelospermum* sp. 1 LM; polar view
Figure K: *Cedrelospermum* sp. 1 SEM; polar view
Figure L: *Cedrelospermum* sp. 1 SEM; surface detail

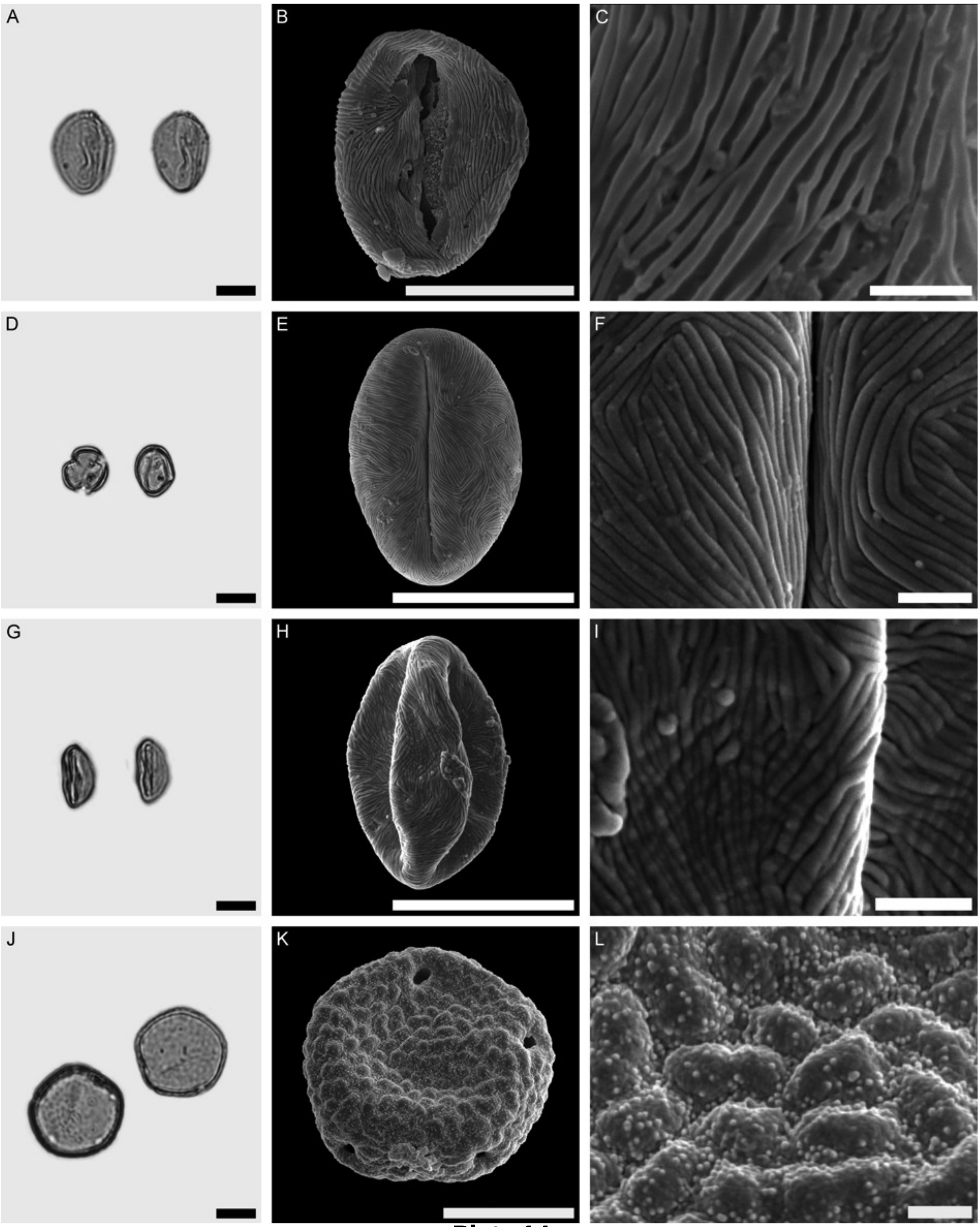


**Plate 14.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 15.

Figure A: *Cedrelospermum* sp. 2 LM; polar view
Figure B: *Cedrelospermum* sp. 2 SEM; polar view
Figure C: *Cedrelospermum* sp. 2 SEM; surface detail

Figure D: *Ulmus* sp. 1 LM; polar view
Figure E: *Ulmus* sp. 1 SEM; polar view
Figure F: *Ulmus* sp. 1 SEM; surface detail

Figure G: *Ulmus* sp. 2 LM; polar view
Figure H: *Ulmus* sp. 2 SEM; polar view
Figure I: *Ulmus* sp. 2 SEM; surface detail

Figure J: *Ulmus* sp. 3 LM; polar view
Figure K: *Ulmus* sp. 3 SEM; polar view
Figure L: *Ulmus* sp. 3 SEM; surface detail

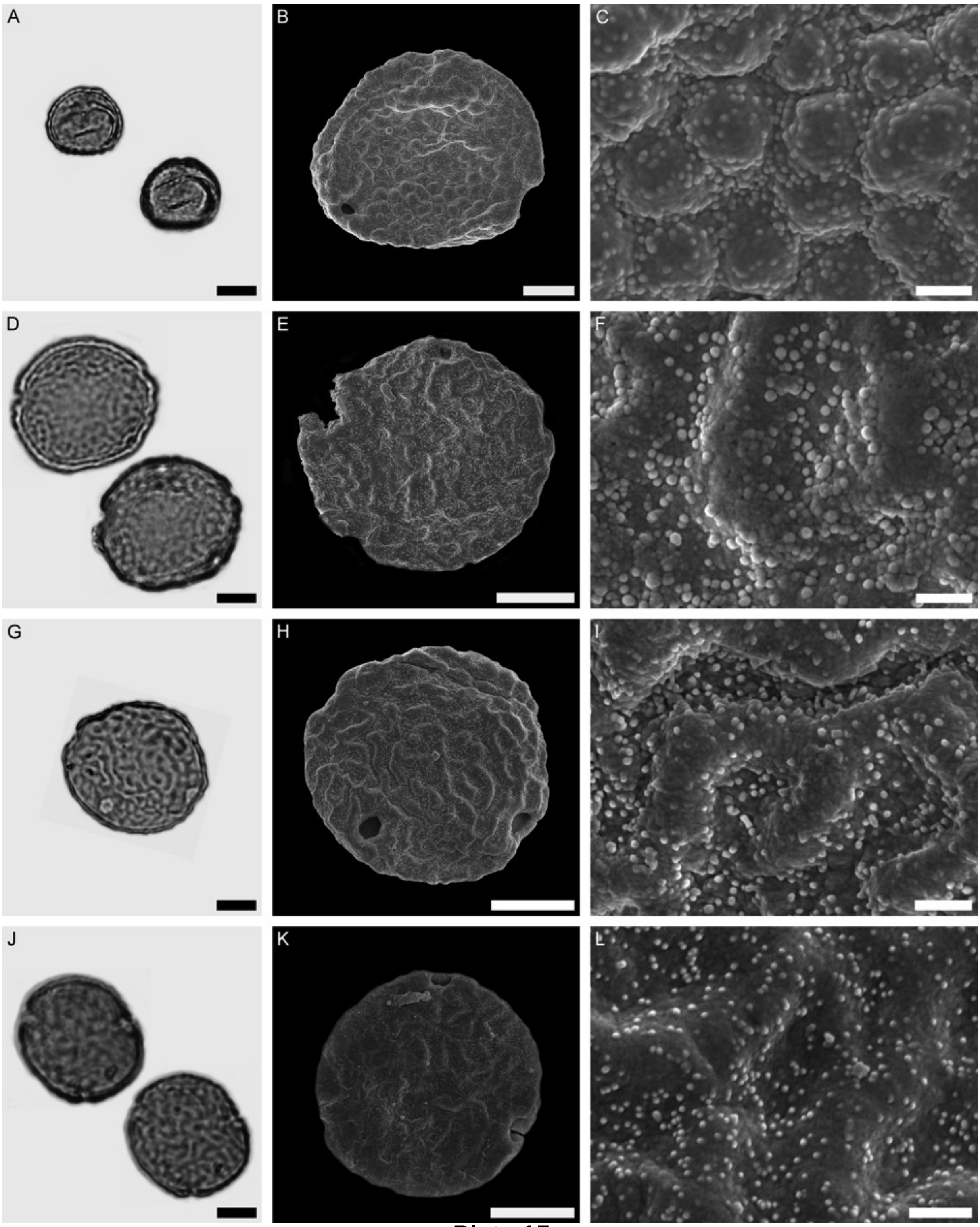


**Plate 15.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 16.

Figures A: Ulmaceae gen. et spec. indet LM; polar view
Figures B: Ulmaceae gen. et spec. indet SEM; polar view
Figures C: Ulmaceae gen. et spec. indet SEM; surface detail

Figures D: *Florissantia* sp. 1 LM; polar view
Figures E: *Florissantia* sp. 1 SEM; polar view
Figures F: *Florissantia* sp. 1 SEM; surface detail

Figures G: Malvaceae gen. et spec. indet. 1 LM; equatorial view
Figures H: Malvaceae gen. et spec. indet. 1 SEM; equatorial view
Figures I: Malvaceae gen. et spec. indet. 1 SEM; surface detail

Figures J: Malvaceae gen. et spec. indet. 2 LM
Figures K: Malvaceae gen. et spec. indet. 2 SEM
Figures L: Malvaceae gen. et spec. indet. 2 SEM; surface detail

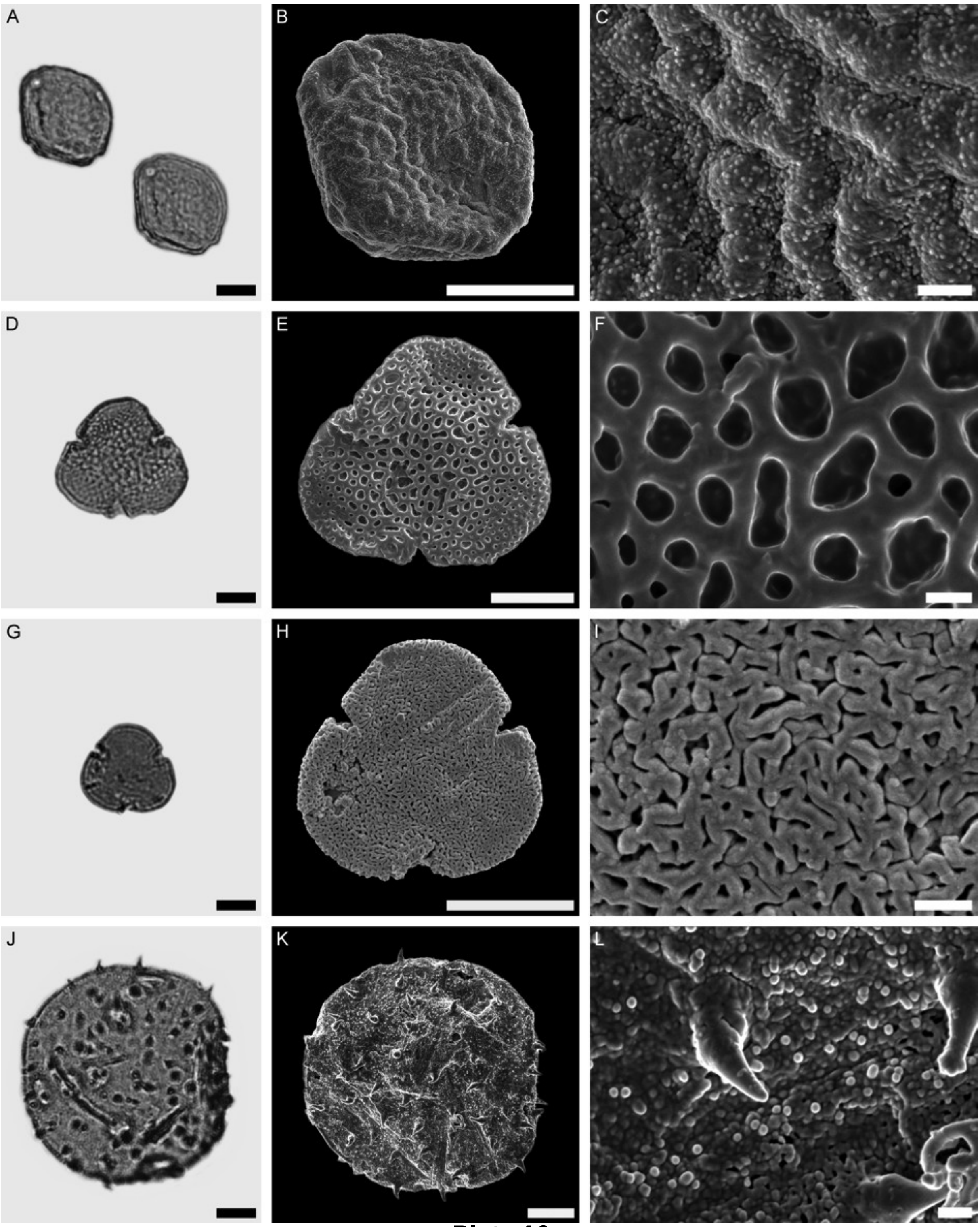


**Plate 16.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 17.

Figures A: Malvaceae gen. et spec. indet. 3 LM
Figures B: Malvaceae gen. et spec. indet. 3 SEM
Figures C: Malvaceae gen. et spec. indet. 3 SEM

Figures D: Malvaceae gen. et spec. indet. 4 LM
Figures E: Malvaceae gen. et spec. indet. 4 SEM
Figures F: Malvaceae gen. et spec. indet. 4 SEM; surface detail

Figures G: Malvaceae gen. et spec. indet. 5 LM; polar view
Figures H: Malvaceae gen. et spec. indet. 5 SEM; polar view
Figures I: Malvaceae gen. et spec. indet. 5 SEM; surface detail

Figures J: Malvaceae gen. et spec. indet. 6 LM
Figures K: Malvaceae gen. et spec. indet. 6 SEM
Figures L: Malvaceae gen. et spec. indet. 6 SEM; surface detail

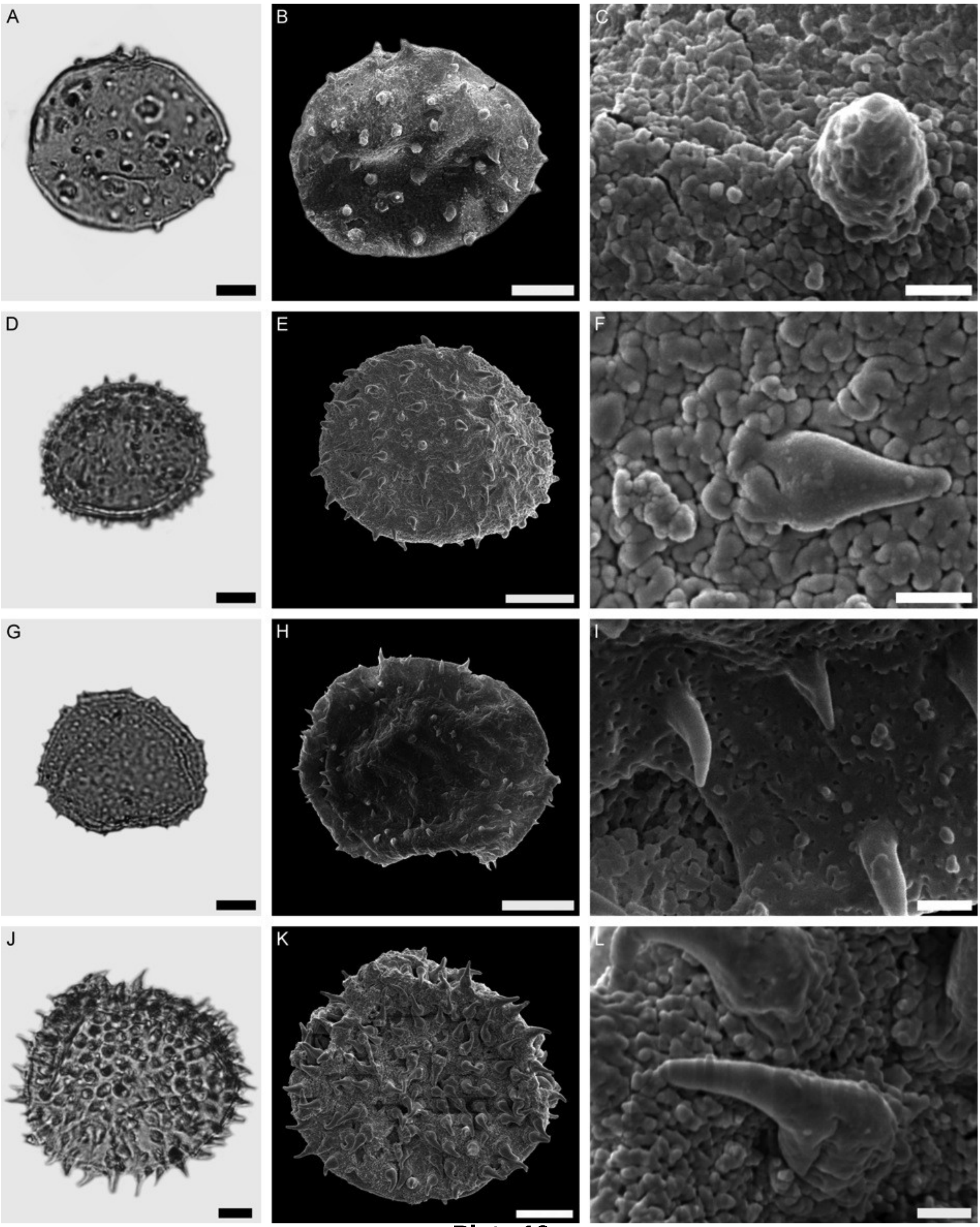


**Plate 12.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 18.

Figures A: *Daphne* sp. LM
Figures B: *Daphne* sp. SEM
Figures C: *Daphne* sp. SEM; surface detail

Figures D: Thymelaeaceae gen. et spec. indet. LM
Figures E: Thymelaeaceae gen. et spec. indet. SEM
Figures F: Thymelaeaceae gen. et spec. indet. SEM; surface detail

Figures G: Onagraceae *Epilobium*-type pollen 1 LM; polar view
Figures H: Onagraceae *Epilobium*-type pollen 1 SEM; polar view
Figures I: Onagraceae *Epilobium*-type pollen 1 SEM; viscin thread detail

Figures J: Onagraceae *Epilobium*-type pollen 2 LM; equatorial view
Figures K: Onagraceae *Epilobium*-type pollen 2 SEM; equatorial view
Figures L: Onagraceae *Epilobium*-type pollen 2 SEM; surface detail
Figures M: Onagraceae *Epilobium*-type pollen 2 SEM; viscin thread detail

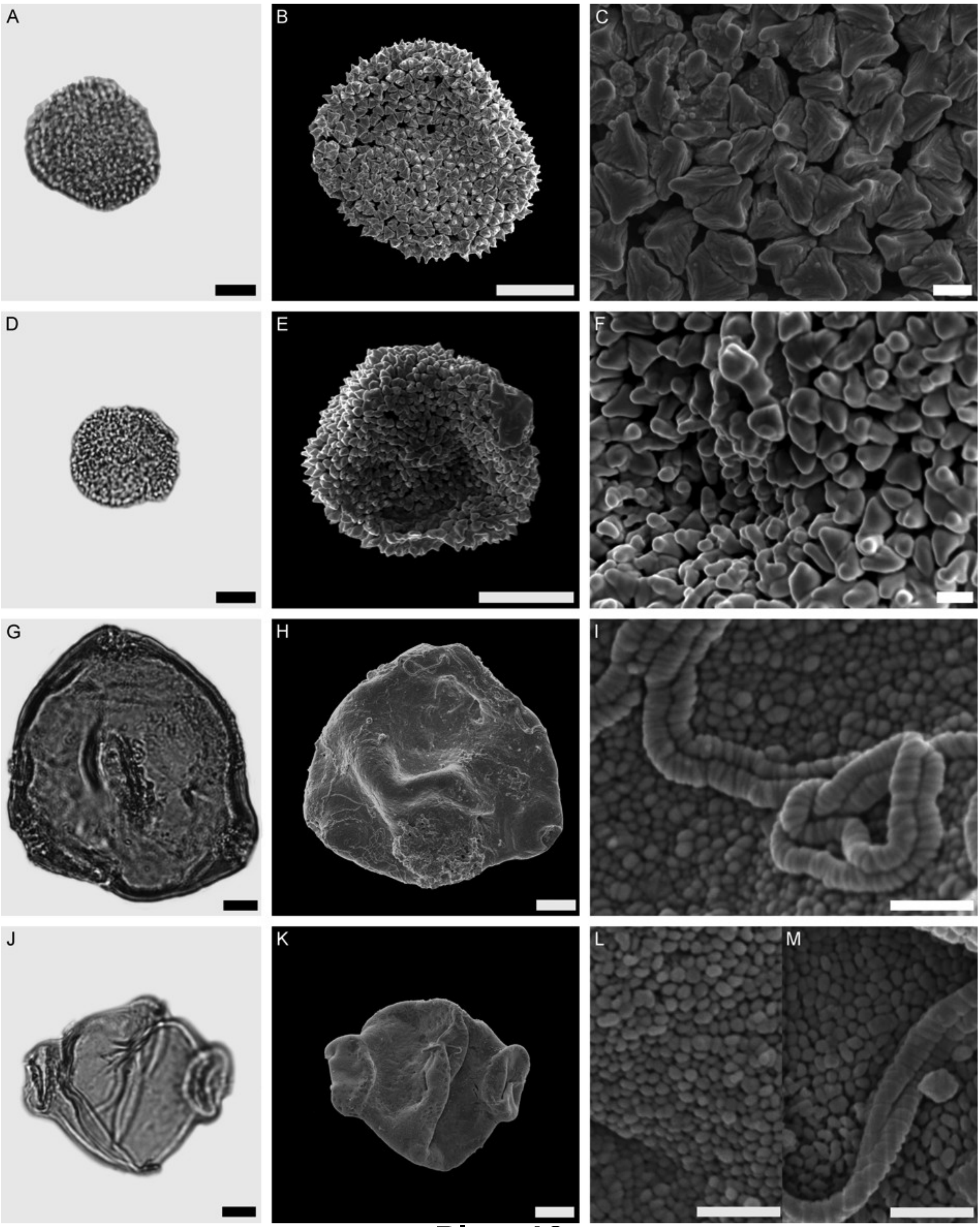


**Plate 18.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I, L & M

## Plate 19.

Figures A: *Acer* sp. 1 LM
Figures B: *Acer* sp. 1 SEM
Figures C: *Acer* sp. 1 SEM; surface detail

Figures D: *Acer* sp. 2 LM; equatorial view
Figures E: *Acer* sp. 2 SEM; equatorial view
Figures F: *Acer* sp. 2 SEM; surface detail

Figures G: *Acer* sp. 3 LM; equatorial view
Figures H: *Acer* sp. 3 SEM; equatorial view
Figures I: *Acer* sp. 3 SEM; surface detail

Figures J: Anacardiaceae gen. et spec. indet. LM; polar view
Figures K: Anacardiaceae gen. et spec. indet. SEM; polar view
Figures L: Anacardiaceae gen. et spec. indet. SEM; surface detail

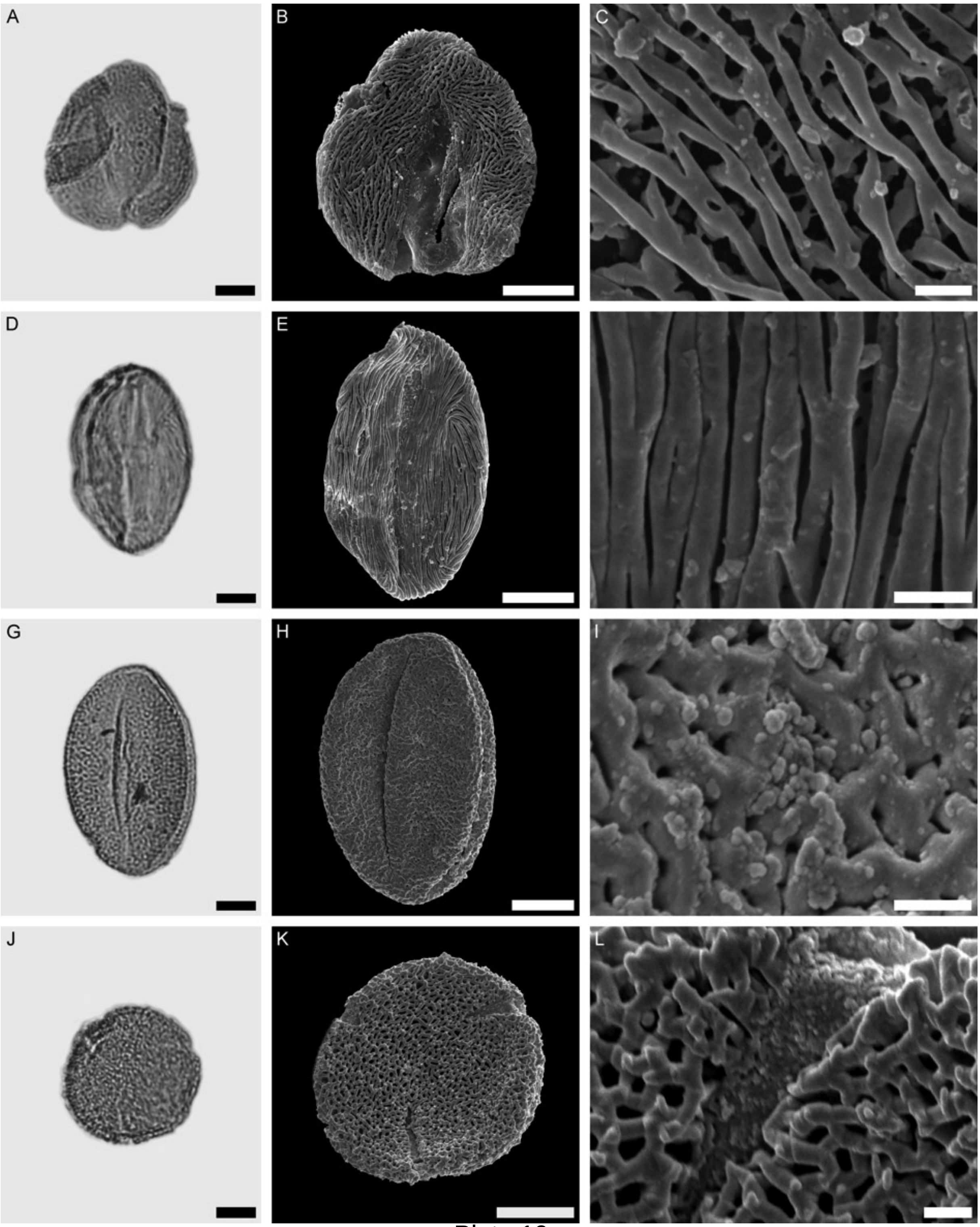


Plate 19.

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 20.

Figures A: Rutaceae gen. et spec. indet. LM; equatorial view
Figures B: Rutaceae gen. et spec. indet. SEM; equatorial view
Figures C: Rutaceae gen. et spec. indet. SEM; surface detail

Figures D: *Alangium* sp. LM; polar view
Figures E: *Alangium* sp. SEM; polar view
Figures F: *Alangium* sp. SEM; surface detail

Figures G: *Diospyros* sp. LM; equatorial view
Figures H: *Diospyros* sp. SEM; equatorial view
Figures I: *Diospyros* sp. SEM; surface detail

Figures J: Ericaceae gen et spec. indet. LM
Figures K: Ericaceae gen et spec. indet. SEM
Figures L: Ericaceae gen et spec. indet. SEM; surface detail

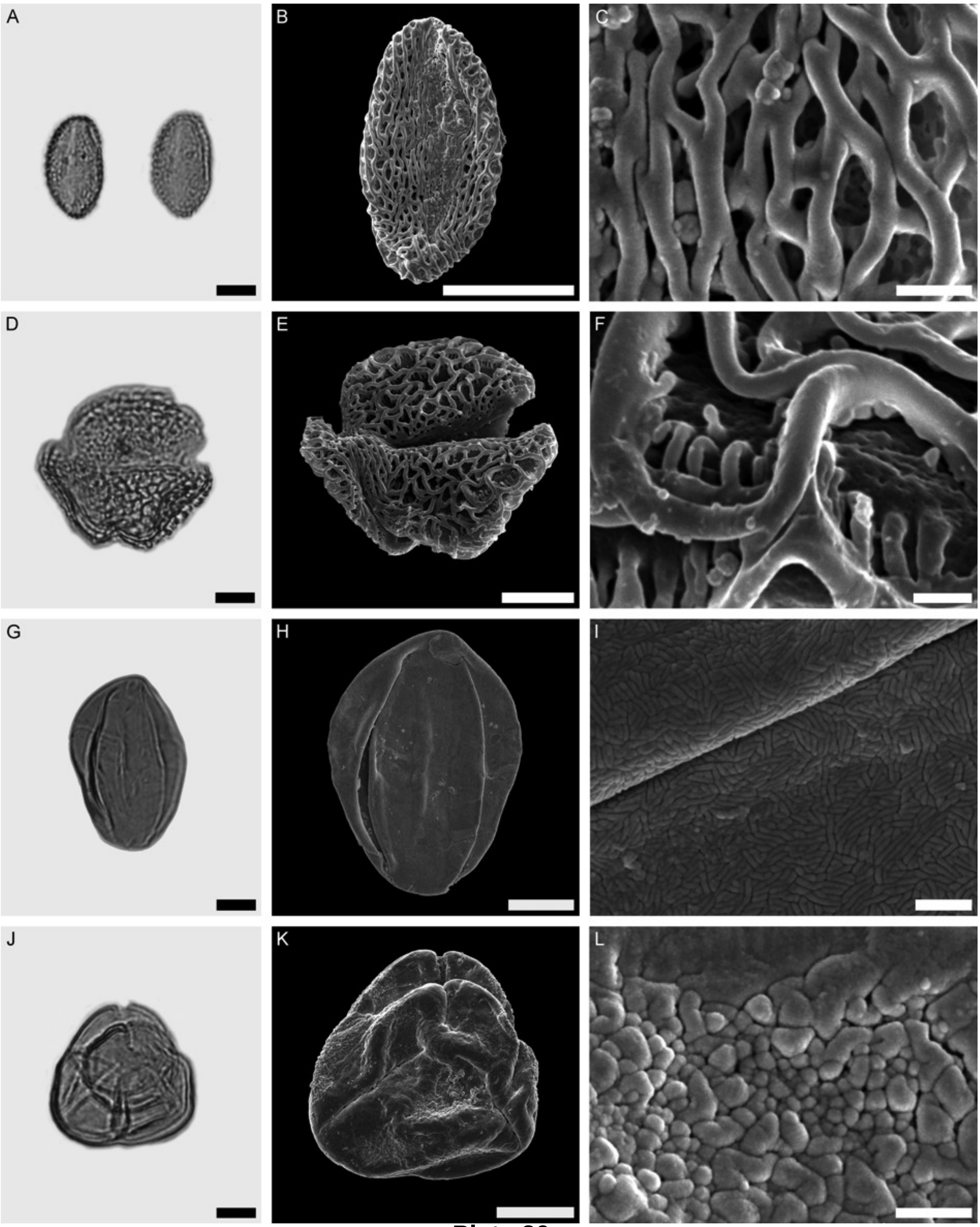


**Plate 20.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 21.

Figures A: *Lonicera* sp. LM; polar view
Figures B: *Lonicera* sp. SEM; polar view
Figures C: *Lonicera* sp. SEM; surface detail

Figures D: *Eucommia* sp. LM; polar (left) & equatorial (right) view
Figures E: *Eucommia* sp. SEM; equatorial view
Figures F: *Eucommia* sp. SEM; surface detail

Figures G: *Tabernaemontana* sp. LM; equatorial view
Figures H: *Tabernaemontana* sp. SEM; equatorial view
Figures I: *Tabernaemontana* sp. SEM; surface detail

Figures J: Lamiaceae gen. et spec. indet. 1 LM; polar (left) & equatorial (right) view
Figures K: Lamiaceae gen. et spec. indet. 1 SEM; equatorial view
Figures L: Lamiaceae gen. et spec. indet. 1 SEM; surface detail

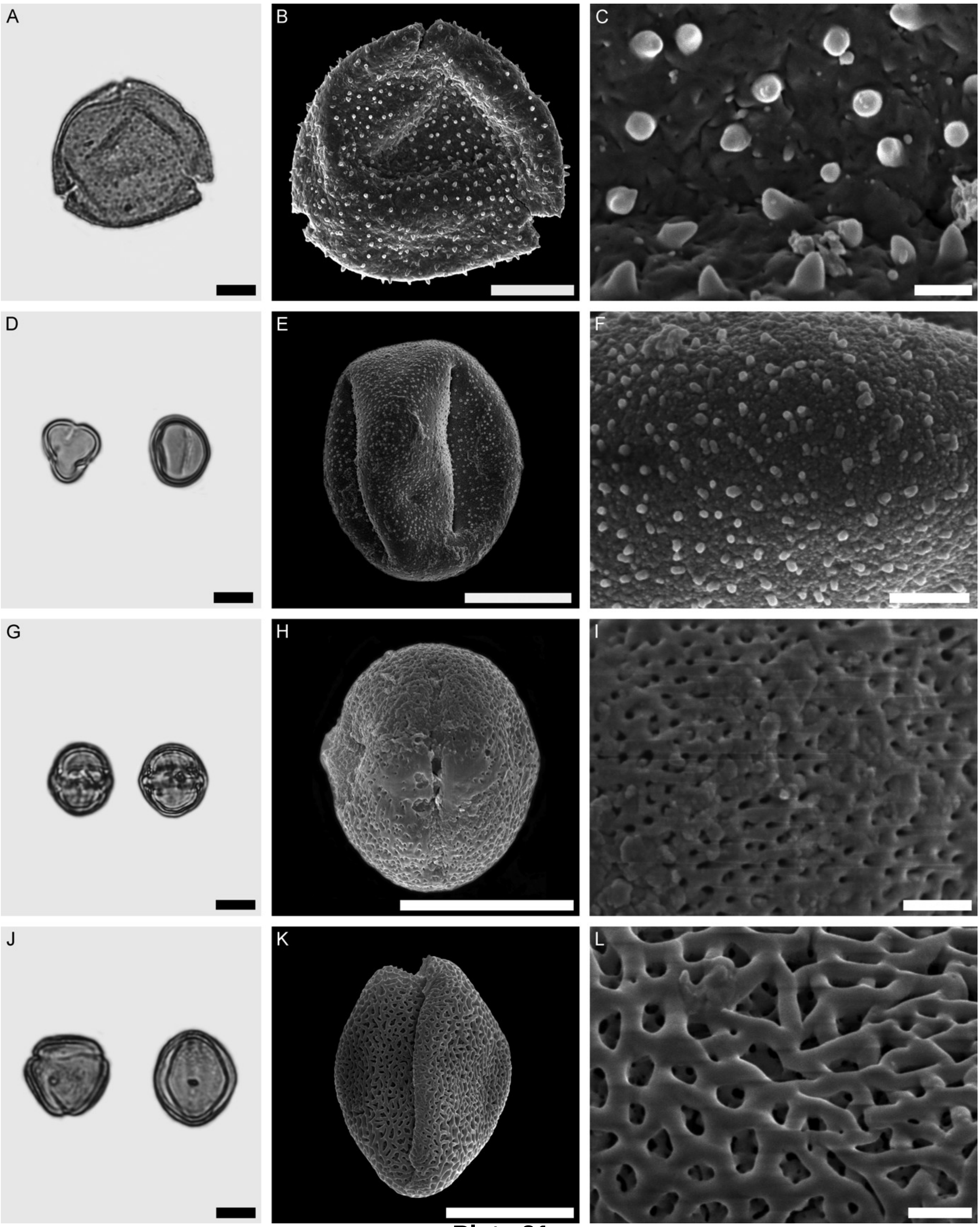


**Plate 21.**

Scale bar 10 µm in Figures A, B, D, E, G, H, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 22.

Figures A: *Fraxinus* sp. LM; polar (left) & equatorial (right) view
Figures B: *Fraxinus* sp. SEM; equatorial view
Figures C: *Fraxinus* sp. SEM; surface detail

Figures D: *Senecioneae* gen. et spec. indet. LM; polar view
Figures E: *Senecioneae* gen. et spec. indet. SEM; polar view
Figures F: *Senecioneae* gen. et spec. indet. SEM; surface detail

Figures G: *Viburnum* tetrade LM
Figures H: *Viburnum* tetrade SEM
Figures I: *Viburnum* sp. SEM; equatorial view

Figures J: *Viburnum* sp. LM; equatorial view
Figures K: *Viburnum* sp. SEM; equatorial view
Figures L: *Viburnum* sp. SEM; surface detail

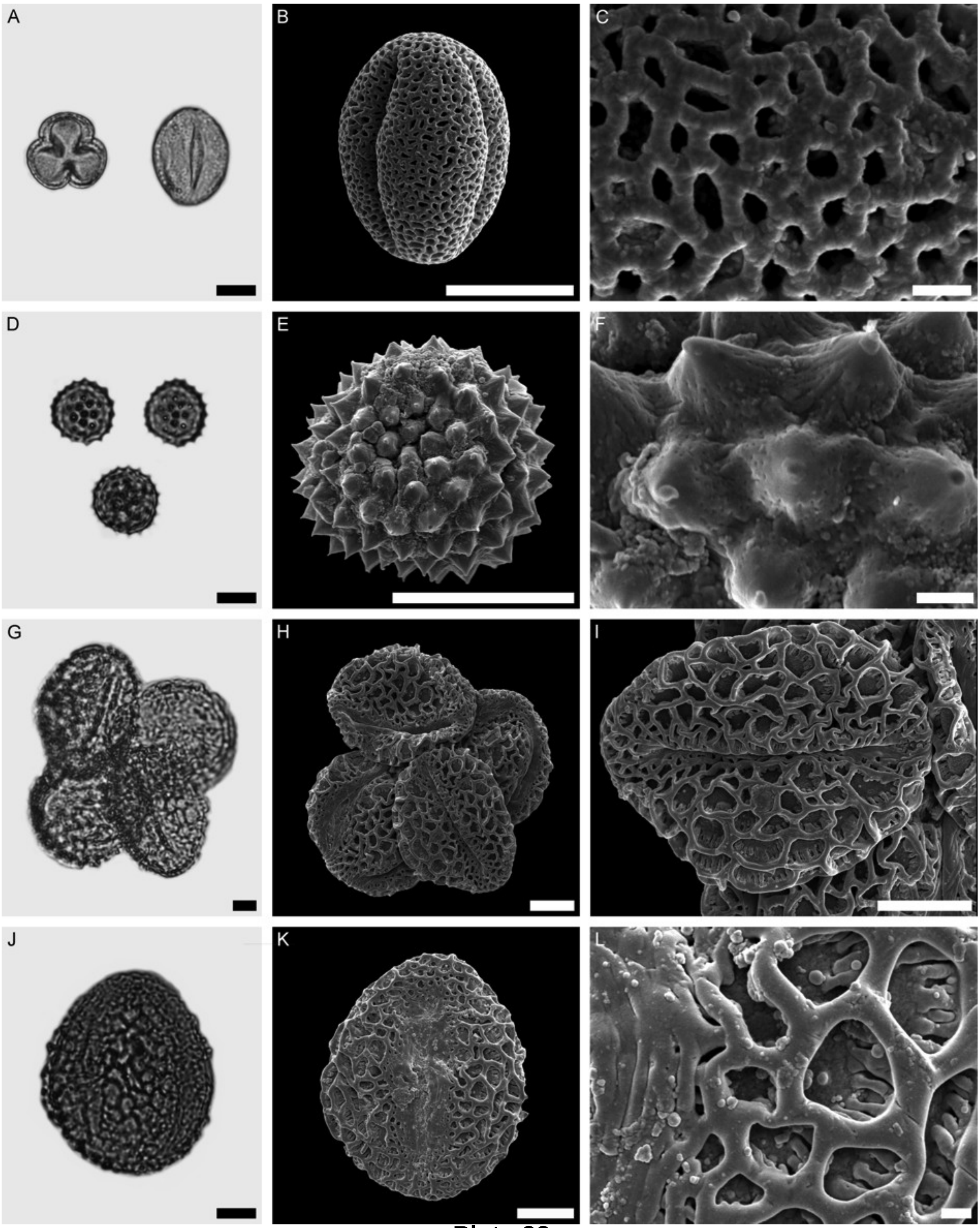


**Plate 22.**

Scale bar 10 µm in Figures A, B, D, E, G, H, I, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 23:

Figures A: Indet. 1 LM
Figures B: Indet. 1 SEM
Figures C: Indet. 1 SEM; surface detail

Figures D: Indet. 2 LM
Figures E: Indet. 2 SEM
Figures F: Indet. 2 SEM; surface detail

Figures G: Indet. 3 LM; equatorial view
Figures H: Indet. 3 SEM; equatorial view
Figures I: Indet. 3 SEM; surface detail

Figures J: Indet. 4 LM
Figures K: Indet. 4 SEM
Figures L: Indet. 4 SEM; surface detail

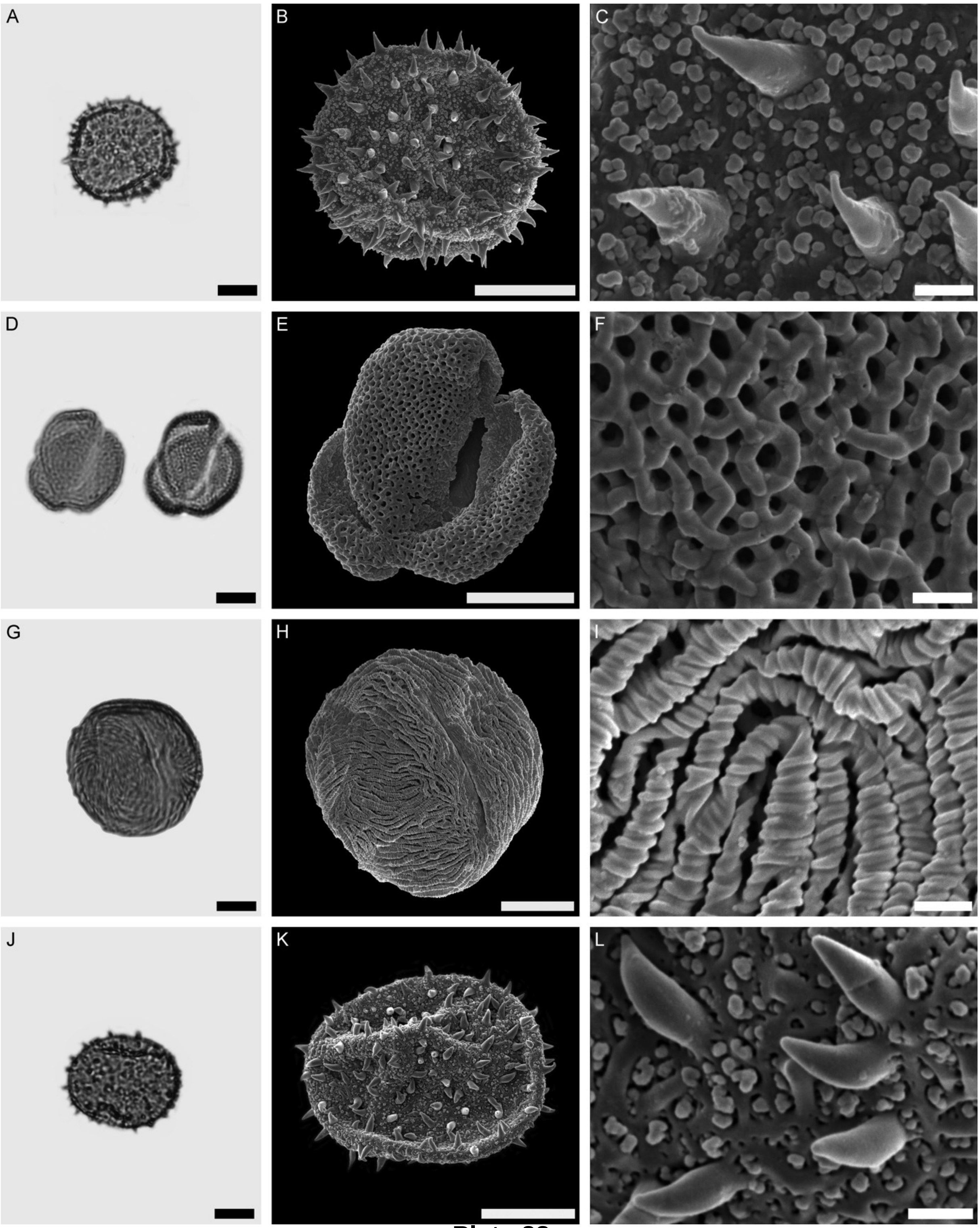


**Plate 23.**

Scale bar 10 µm in Figures A, B, D, E, G, H, I, J & K
Scale bar 1 µm in Figures C, F, I & L

## Plate 24.

| | |
|---|---|
| Figures A: | Indet. 5 LM; equatorial view |
| Figures B: | Indet. 5 SEM; polar view |
| Figures C: | Indet. 5 SEM; surface detail |
| | |
| Figures D: | Indet. 6 LM; polar view |
| Figures E: | Indet. 6 SEM; polar view |
| Figures F: | Indet. 6 SEM; surface detail |
| | |
| Figures G: | Indet. 7 LM; polar view |
| Figures H: | Indet. 7 SEM; polar view |
| Figures I: | Indet. 7 SEM; surface detail |
| | |
| Figures J: | Indet. 8 LM; polar view |
| Figures K: | Indet. 8 SEM; polar view |
| Figures L: | Indet. 8 SEM; surface detail |

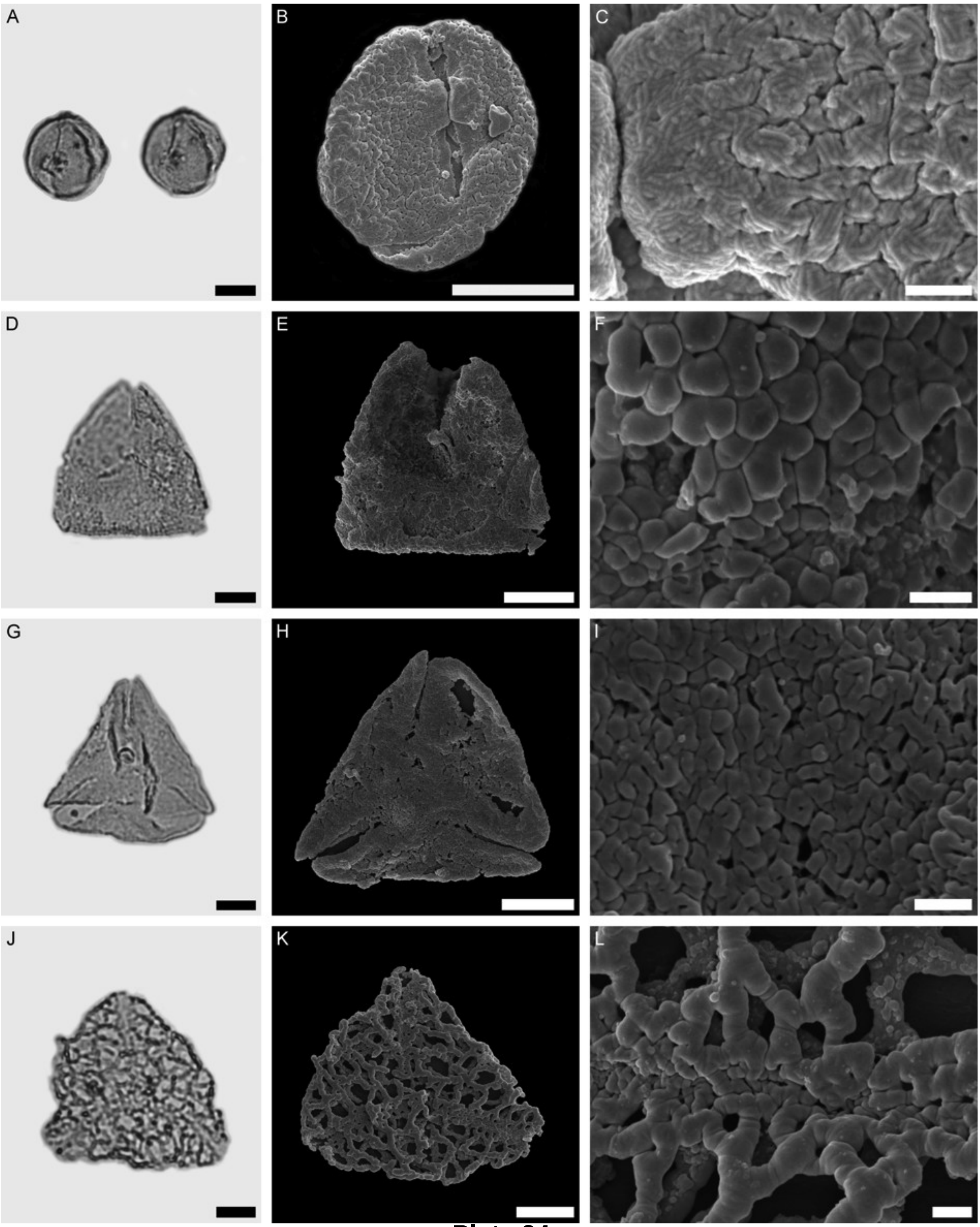


**Plate 24.**

Scale bar 10 µm in Figures A, B, D, E, G, H, I, J & K
Scale bar 1 µm in Figures C, F, I & L

# Appendix

## Curriculum Vitae

| | |
|---|---|
| Name: | Johannes Bouchal |
| Nationalität: | Österreich |
| | |
| 1986-1990 | Volksschule in Göllersdorf |
| 1990-1994 | Hauptschule in Göllersdorf |
| 1994-1999 | Höhere Lehranstalt für Tourismus (HLT) in Retz |
| 1999 | Maturaabschluß an der HLT in Retz |
| 2000-2001 | Präsenzdienst in Langenlebarn |
| | |
| 2001 | Inskription an der Universität Wien (Biologie A 437) |
| 2004-2006 & 2013 | Anstellung als Tutor unterschiedlicher Lehrveranstaltungen (paläontologische Übungen I, biologische Einführungs übungen I, Einführung in die Paläontologie |
| 2010-2013 | Diverse Arbeitsverträge für das NHM in Wien |
| 2011 | Spezialisierung „Diplomstudium Paläontologie“ (Stkz. 443) |
| 2011 | Arbeitsbeginn an der Diplomarbeit „The microflora of the latest Eocene (Priabonian) Florissant Formation, a |
| com | bined method approach” Diplomarbeitsbetreuer: Prof. Reinhard Zetter |
| | |
| **Abstracts** | EGU 2012, Poster Präsentation |
| | Bouchal, J. M. 2012 High resolution taxonomic study of the late Eocene (~34 Ma) Florissant palynoflora, Colorado USA Geophysical Research Abstracts Vol. 14, |
| EGU2012- | 13830-1, 2012 EGU General Assembly 2012 |