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Palynomorphs from a Recent Soil Covered with a Savanna-Like Vegetation in Caxiuanã, Pará, Brazilian Amazon

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Abstract - Palynomorphs from seven soil sediment samples obtained along a transect of a savanna-like area located next to the bay of Caxiuanã, state of Pará, Brazil, were described and illustrated in 139 light micrographs. The taxa comprise Algae, spores of Fungi, Bryophyta, Pteridophyta and pollen grains of Angiosperms. Data of palynomorph places of deposition and Angiosperms habitus and ecological ranges were presented.

Keywords - palynomorphs, Caxiuanã, Amazon region, savanna.

INTRODUCTION

Climatic changes that occurred during the Quaternary period in the Amazon region have largely been analyzed in order to get a support for environmental evolution (Absy *et al.*, 1991). Palynology is an important tool in this respect.

The National Forest of Caxiuanã is a large area under protection, located in the Amazon forest of the state of Pará, Northern Brazil, comprising the hydrographic basin of the rivers Caxiuanã and Anapu (Lisboa *et al.*, 1997). The last river is the most important in the region and takes a south/north direction. It was formed together with some bays during the Quaternary period by neotectonic processes (Kern & Costa, 1997). One of these is the bay of Caxiuanã. An area for developing research projects, the "Estação Científica Ferreira Penna, ECFPn", is limited by this bay and the river Caxiuanã and administrated by the Museum Paraense Emílio Goeldi, Belém, Pará (Fig. 1).

Barth *et al.* (1997) have analyzed the pollen spectra of seven samples of soil sediments collected along a transect crossing a patch of a savanna-like vegetation located at the western side of the bay of Caxiuanã in the municipality of Melgaço, state of Pará. The forest around this area presents shrubs in contact with the surrounding forest (of the "várzea" type) and a savanna-like central core (Fig. 2). The results obtained certified the human influence as responsible for recent alterations of the vegetation, also in today inhabited places. On the other hand the richness of

algae, mosses and fungi was emphasized in relation to the oscilation of the water level of the bay and the bad drained soil (Ferreira *et al.*, 1997).

In the present paper it is intended to describe the morphology of the most important and most frequent palynomorphs isolated from the soil sediments and to evaluate their identity in relation to the actual plant species occurring in this area.

MATERIAL AND METHODS

Six samples of the soil were taken along a transect and one sample in addition in an open grassland patch (Fig. 2) in the same area. The transect starts at the western margin of the bay of Caxiuanã and finished near to the first waterarm ("igapó") located parallel to the margin of the bay. Each sample was composed of 25 mixed smaller samples. The soil is a sandy clay and the samples were prepared according to the purposed standard methodology (Ybert *et al.*, 1992), consisting of chemical treatments using KOH, HF and HCl, including acetolysis and a zinc chloride gradient.

Description of pollen grain morphology follows the nomenclature purposed in Punt *et al.* (1994). Pollen grain size classes (small, medium, large) are in accordance to Erdtman (1952) and pollen grain dimensions are presented by bars in the plates. Pollen grain magnification was maintained constant, except in few cases when indicated in separate. Plant families, genera and species identification was based upon data from literature (Carreira *et al.*, 1997; Hooghiemstra

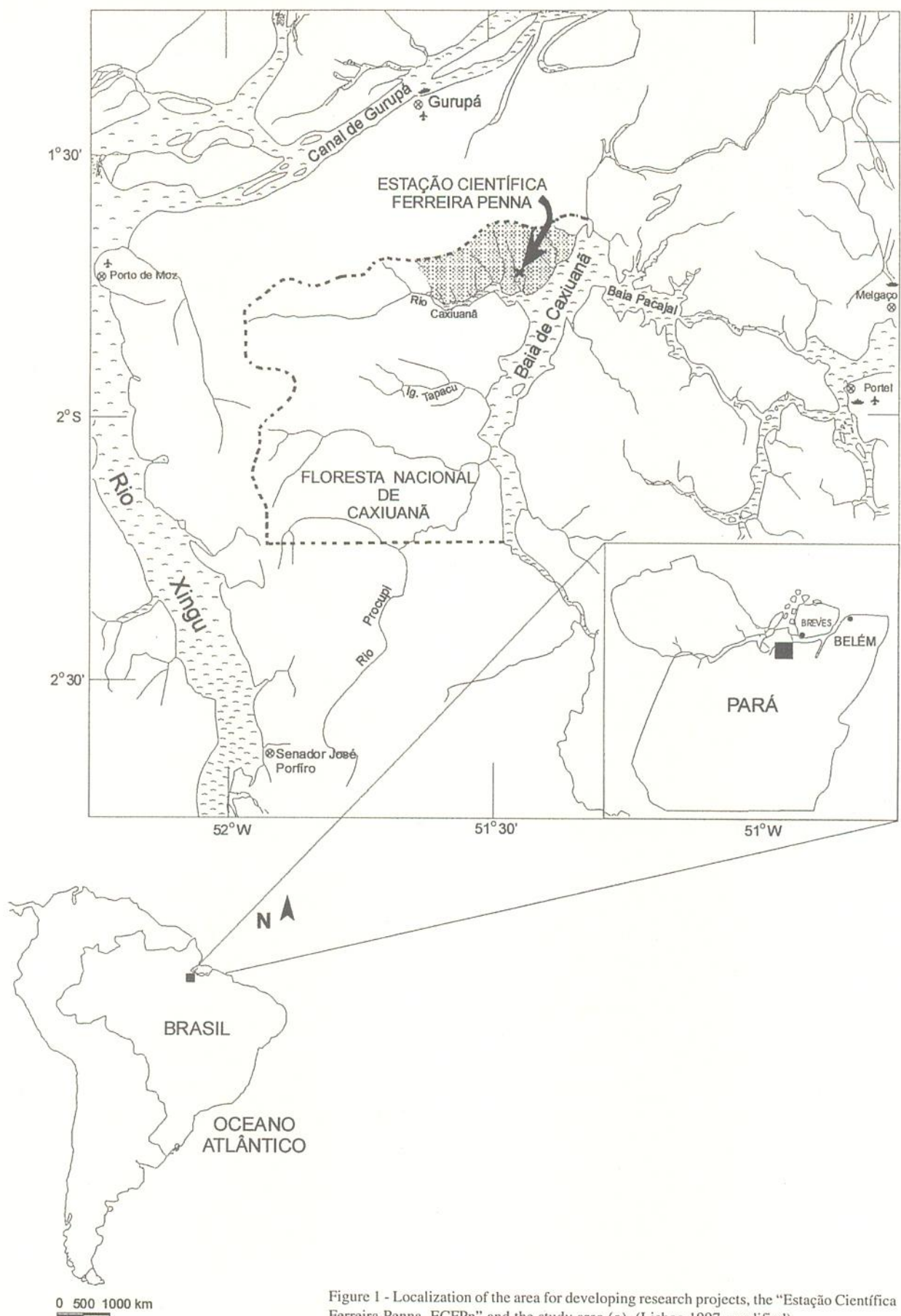
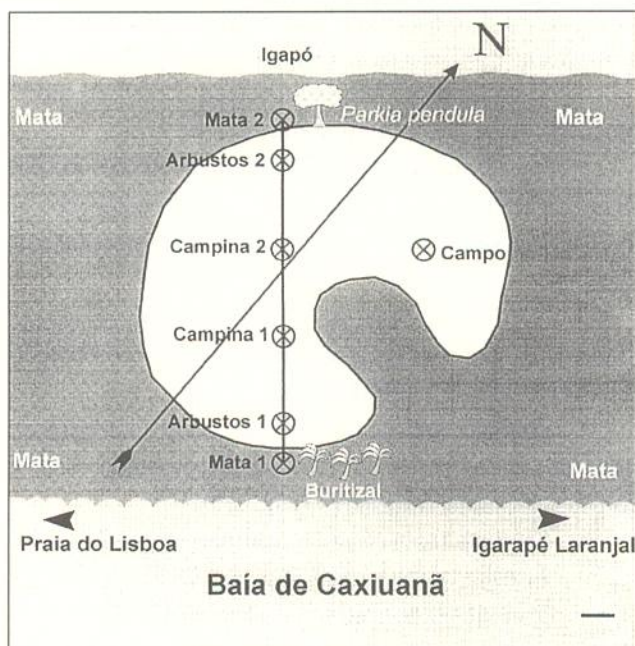


Figure 1 - Localization of the area for developing research projects, the "Estação Científica Ferreira Penna, ECFPn" and the study area (o). (Lisboa 1997, modified)



1984; Garcia, 1997; Neves & Lorscheitter, 1992, 1995; Luizi-Ponzo *et al.*, 1997; Roubik & Moreno, 1991; van Geel & van der Hammen, 1978) and the reference

collection of the Laboratory of Palynology of the Federal University of Rio de Janeiro.

RESULTS

The samples of the transect are named in sequence, starting next to the margin of the bay, as “mata-1” (forest-1), “arbustos-1” (shrubs-1), “campina-1” (savanna-1), “campina-2” (savanna-2), “arbustos-2” (shrubs-2) and “mata-2” (forest-2), in accordance to the type of vegetation below they were collected. One sample of the open grassland patch is named “campo” (grassland) (Fig. 2).

Erosion of pollen grain and spore sporoderms was observed in all soil samples. Failing conditions of preservation may be responsible for a low pollen content in samples, nevertheless a high diversity of taxa, in special of Bryophyta was detected (Fig. 3).

The descriptions of palynomorphs are presented in accordance to the alphabetical ordering of family names. In addition are mentioned the corresponding soil samples and the plant habitus. The illustrations are referred first to the plate number and in sequence to the figure number. Magnifications are indicated by bar values.

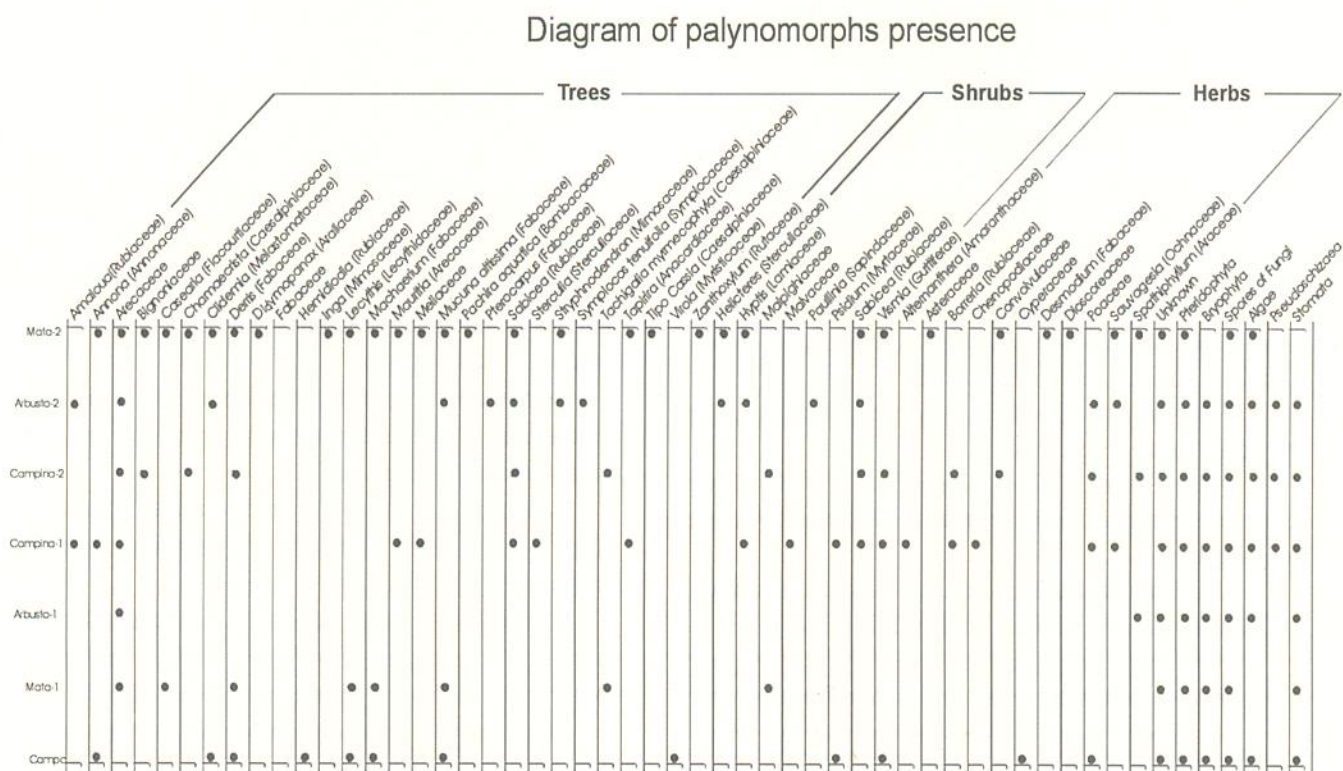


Figure 3 - Diagram of palynomorphs presence (elaborated using the Tilia program).

Morphological descriptions and ecological ranges:

ALGAE (Plate 1)

Found in all samples, except in mata-1, frequently in the open area of campo.

Algae (?) (Figs. 1/1,2). Elongated, bilaterally symmetric, colorless cell presenting one longitudinal and well determined rim.

Algae (?) (Fig. 1/5). Rounded, light brown cell presenting a curved apertural rim.

Chlorophyceae: cf. *Spirogyra* (Figs. 1/3,4). Elongated, colorless cells, containing each a round inclusion body.

Zygnemataceae: probably *Mougeotia* type (Figs. 1/9,10). Typical structured (polygonal) cells, light brownish.

Zygnemataceae: *Zygnema* type (Fig. 1/11). Rounded, perforated cell, brownish colored.

Zygnemataceae: cf. *Debarya*. (Fig. 5/47): zygospore. Rounded, colorless cell presenting a granulate surface ornamentation.

Pseudoschizaea. (Figs. 1/12-18). Typical structured colorless cells, presenting concentrically disposed ridges on both faces and of taxonomic *insertae sedis*.

FUNGI and PALYNOMORPHS (Plate 2)

Found in all samples. Spores are dark brown (black), brown, orange, yellow colored or colorless.

Typical structured polygonal cells, dark brown with smooth surfaces (Figs. 1/6-8).

Glomaceae: *Rhizophagus* (Figs. 2/1,2,16 and 4/26). Light yellow or brownish round cells presenting a short neck as in Figs. 2/2 and 4/26, or a longer filament, as in Figs. 2/1 and 2/16.

Rounded dark spores presenting irregularly distributed dark surface granules as in Figs. 2/3 and 2/9 or little verrucae as in Fig. 2/12.

Brown round poliforated spore; pores aspidotes and equidistant (Figs. 2/4,5).

Dematiaceae: *Tetraploa*. (Fig. 2/6). Brownish spore composed of four segments starting from one side only.

Little round dark spores, with a smooth (above) or finely structured surface (below) (Fig. 2/7)

Cluster of fungal spores (Fig. 2/8). Large group of dark brown cells that never detach one from another.

Sordariaceae: *Gelasinospora* (Fig. 2/10). Elongated brown spore with regularly distributed small perforations.

Two brown fungal cells (Fig. 2/11) that open at their extremities (*Diploploa*?).

Dematiaceae: *Nigrospora* (Fig. 2/13). Rounded black spore with a not outstanding slit.

Lycoperdaceae: *Lycoperdon* (Fig. 2/14). Collorless, fuzzy coated round spore without apertures; at the right side of the figure a dark epidermis cell of Poaceae.

Typical aspect of a sample from mata-2, presenting dark and light stained smooth spores, beside brownish organic material (Fig. 2/15).

Typical aspect of a sample from arbustos-2, presenting a spore of *Rhizophagus* and small carbonized plant fragments (Fig. 2/16).

Stomata from campina samples (Figs. 2/17,18).

Fitolite of Poaceae (Figs. 2/14,19).

Pice of plant epidermis (Fig. 2/20).

BRYOPHYTA (Plate 3-5)

Found in all samples, preferentially in more humid places, less inside "mata". Presenting more than 1700 species in Caxiuanã (Dr. Regina Lisboa, personal communication), no bibliographic data of spore morphology, except Luiz-Ponzo *et al.* (1997) are available. The moss spores detected are in general colourless, light colored, rarely brownish. Spores are presented following the sequence of the transect.

Mata-1: small spore with a large round aperture and a thick undulated perine (Fig. 3/1).

Mata-1: medium sized spore with a granulate perine (Fig. 5/42).

Mata-1: medium sized spore with a smooth perine surface (Fig. 5/43).

Mata-1: a large spore with fuzzely structured broad perine and a large rounded and smooth bordered aperture (Figs. 5/45,46).

Arbustos-1: rounded medium sized spore with a large round aperture and a finely granulated perine; Dicranaceae type (Figs. 3/7,8).

Arbustos-1: elipsoidal medium sized spore with a large pear-formed aperture and a psilate perine; Dicranaceae type (Figs. 3/10, 11).

Arbustos-1: large dark brownish rounded spore presenting large ridges of perine or insulae and a large smooth bordered round aperture (Figs. 5/49,50).

Campina-1: medium sized spore with a large polygonal aperture and small irregularly disposed processes in the perine (Fig. 3/9).

Campina-1: subtriangular, medium sized hialine spore with a trilete aperture and a psilate perine; Anthocerotaceae: *Phaeoceros* type (Fig. 3/12).

Campina-1: small spore with a round aperture and a finely undulated perine (Figs. 3/15, 16).

Campina-1: small to medium sized spore with a round aperture and a very thin finely undulated perine; Dicranaceae: *Holomitrium* type (Fig. 3/17).

Campina-1: small spore with a round aperture and thin perine processes; Dicranaceae: *Campylopus* type (Fig. 3/18).

Campina-1: small spores with a round aperture and perine ridges forming polygonal lumina (Figs. 3/19,20).

Campina-1: small spore with a heart-shaped aperture and a thin psilate perine (Fig. 4/21).

Campina-1: small spore with a well determined round aperture and a psilate perine of variable thickness (Fig. 4/22).

Campina-1: medium sized oval spore with a same shaped well delimited large aperture and a very thin psilate perine (Fig. 4/25).

Campina-1: small to medium sized round spore with a large round aperture and a thin sporoderm (Fig. 4/30).

Campina-1: very small round spore with a round aperture and fine long perine processes (Bruchiaceae?) (Figs. 4/32,33).

Campina-1: similar spore as in Figs. 7-8; Dicranaceae type (Figs. 4/34,36).

Campina-1: a large spore presenting a thin and contrasted exine surrounded by a transparent strongly undulated perine with numerous transversal ridges like columella (Fig. 5/48).

Campina-2: medium sized spore with a great round aperture and a fuzzy structured perine (Figs. 3/13,14).

Campina-2: small to medium sized round spore with a small polygonal shaped rim of the aperture and a thin sporoderm (Fig. 4/31).

Campina-2: similar spore as in Figs. 3/10-11; Dicranaceae type (Fig. 4/35).

Campina-2: large spore surrounded by a broad transparent undulated perine (Figs. 5/37,38).

Campina-2: similar spore as in Figs. 10-11; Dicranaceae type (Fig. 5/39).

Campina-2: medium sized spore presenting an irregular formed aperture and a finely granulated perine (Figs. 5/40,41).

Campina-2: a larger spore than of Fig. 31, but also presenting a strong structured rim around the aperture (Fig. 5/44).

Arbustos-2: small spore with a irregularly formed large aperture and a finely structured perine with thin branched processes (Fig. 3/2).

Arbustos-2: medium sized spore with a large round aperture and a granulate perine (Figs. 3/3,4 and 5/42).

Arbustos-2: easily deformed spore of medium size with a very thin, granulated perine (Fig. 3/5).

Arbustos-2: large spore with a round aperture and a thin irregularly structured perine (Fig. 3/6).

Campo: survey of a soil sample showing numerous dark-burned organic fragments, a fuzzy coated moss spore and a *Rhizophagus* spore (Fig. 4/26).

Campo: small spore with a large aperture and pilum like regularly ordered perine processes (Figs. 4/27,28).

Campo: small spore with an elongated aperture and a psilate thin perine (Fig. 4/29).

PTERIDOPHYTA (Plate 6)

Spores of Pteridophyta are not frequent in the soil sediments and a few types of spores were detected in all samples examined. No preference of habitat could be defined.

Selaginellaceae: *Selaginella* type 1 (Figs. 6/1-4). Large spores, trilete, presenting a typical structured perine of irregularly distributed long transversal processes and muri of variable thickness and length; small and large lumina are located one beside the other. Herbaceous. Spores were found in sample of arbustos-2.

Selaginellaceae: *Selaginella* type 2 (Fig. 6/5). Medium to large spores, trilete, presenting a spiculate perine. Herbaceous. Spores were found in sample of arbustos-2.

Dryopteridaceae: *Elaphoglossum* (Figs. 4/23,24). Medium sized elipsoidal spore with a same shaped large aperture and typical joined ridges of psilate perine at the distal polar are. Herbaceous. Spores were found in sample of campina-1.

Dryopteridaceae: *Dryopteris* (Figs. 6/6,7). Large spores, monolete, the perine presenting different sized flat insulae. Herbaceous. Spores were found in sample of campo.

Polypodiaceae: type 1 (Fig. 6/8).

Large spore, monolete, with a characteristically verrucate perine.

Herbaceous. Spores were found in sample of mata-1 and campina-2.

Polypodiaceae: type 2 (Fig. 6/9).

Medium sized spore, trilete, with a characteristically verrucate perine.

Herbaceous. Spores were found in sample of arbustos-1.

ANGIOSPERMS (Plate 7-12)

Pollen grains were found in all samples, most frequently in sample of mata-2, and less frequently next to the water line. They are in general well preserved, showing that no distant pollen transport have occurred. Pollen grain identification was executed considering the list of species published in Lisboa *et al.* (1997), Ferreira *et al.* (1997), some pollen description in Carreira *et al.* (1997) and personal observations.

Amaranthaceae: *Alternanthera* (Fig. 7/1)

Pollen grains of small size, 12-porate, presenting a large reticulum where each lumen corresponds to a pore; muri provided with spinules. Ectexine larger than endexine.

Herbaceous. Pollen grains were found only in sample campina-1.

Anacardiaceae: *Tapirira guianensis* Aubl.

(Figs. 7/2-4, 11/120-122)

Pollen grains of medium size, prolate, 3-colporate, presenting a fine striate surface. Ectexine larger than endexine.

Small trees. Pollen grains were found in samples of campina-1 and arbustos-2.

Annonaceae: *Annona paludosa* Aubl. (Figs. 7/6-8)

Pollen grains assembled in polyads, but in soil samples monads were recognized only; polyads are irregularly formed; pollen grains are of large size, inaperturate, presenting a pilate ornamentation. Ectexine is thicker than endexine.

Trees. Pollen grains were found in samples of mata-2, campina-1 and campo.

Apocynaceae (?) (Fig. 10/70)

Pollen grains of medium size, prolate, 8-zonocporate, endoapertures lalongate, psilate.

Pollen grains were found only in sample of mata-2.

Apocynaceae (?) (Figs. 10/88-90)

Pollen grains small to medium size, prolate, 3-colporate, endoapertures lalongate, zonorate, psilate, colourless.

Pollen grains were found only in sample of arbustos-2.

Araceae: *Spathiphyllum* (Figs. 7/11,12)

Pollen grains of medium to large size, inaperturate, presenting a strongly striated ornamentation. Sexine thicker at the polar areas.

Herbaceous. Pollen grains were found in sample of arbustos-1, campina-2 and mata-2.

Araliaceae: *Didymopanax morototonii* (Aubl.)

Decne. et Planch. (Figs. 7/9,10)

Pollen grains of medium size, oblate spheroidal to spheroidal, 3-colporate, colpi invaginate, surface reticulate.

Trees. Pollen grains were found only in sample mata-2.

Arecaceae: *Astrocaryum murumuru* Mart.

(Figs. 12/137, 138)

Pollen grains large, flattened, trichotomocolpate, perforate-reticulate.

Trees. Pollen grains were found in sample of mata-1.

Arecaceae: *Euterpe oleracea* Mart. pollen type

(Figs. 7/13,14,17)

Pollen grains of medium to large size, 1-colpate, presenting a finely granulate surface.

Trees. Pollen grains were found in all samples, except in campo.

Arecaceae: *Mauritia vinifera* Mart. (Fig. 7/16)

Pollen grains of medium to large size, 1-aperturate, presenting a thick exine covered with sparsely distributed big spines.

Trees. Pollen grains were found in samples of campina-1 and mata-2. This palm species is very frequent in the area of mata-1, but pollen grains were not found in the soil there.

Arecaceae: not identified (Fig. 7/15)

Large pollen grains, 1-aperturate, sexine (without spines) thicker than nexine. Spines mamilliforme. Pollen grains were found only in sample mata-1.

Arecaceae: not identified (Fig. 12/139)

Pollen grain medium sizes, flattened, trichotomocolpate, reticulate.

Trees. Pollen grains were found in sample of mata-1.

Bignoniaceae: *Jacaranda copaia* (Aubl.) D.

Don (Fig. 8/22)

Pollen grains of medium to large size, suboblate, 3-

colporate, endoaperture large and scarcely defined, psilate. Trees. Pollen grains were found in samples of campina-2, mata-2 and mata-1.

Bombacaceae: *Pachira aquatica* (Aubl.) K. Schum. (Figs. 8/23,24)

Pollen grains of medium size, oblate, 3-colporate, planaperturate, reticulate, heterobrochate. Lumina smaller at the angles.

Very common trees in the region, but not referred to the savanna area. Pollen grains were found only in sample of mata-2.

Caesalpinaceae: *Chamaecrista lucens* Pittier (Figs. 11/100, 11/105, 11/118, 119)

Pollen grains small, subprolate, 3-colporate, endoapertures scarcely defined, reticulate.

Trees. Pollen grains were found in samples of campina-2 and mata-2.

Caesalpinaceae: *Tachygalia myrmecophyla* Ducke (Figs. 9/36-39)

Pollen grains small, prolate to subprolate, 3-colporate, longicolate, reticulate, heterobrochate.

Trees. Pollen grains were found in samples of mata-1 and campina-2.

Chenopodiaceae: pollen type *Amaranthus*/Chenopodiaceae (Fig. 8/25)

Pollen grains small, spheroidal, pantoporate, reticulate. Herbaceous. Pollen grains were found only in sample of campina-1.

Clusiaceae: *Rheedia* (Figs. 9/35 and 11/104)

Pollen grains small, spheroidal, 3-colporate, colpi short and broad, reticulate.

Trees. Two species were related in the forest area: *R. acuminata* Planch. et Triana e *R. gardneriana* Miers ex Pl. & Tr., but not referred to the savanna area. Pollen grains were found only in sample of mata-2.

Clusiaceae: *Vismia* (Figs. 8/20,21)

Pollen grains of small to medium size, prolate spheroidal, 3-colporate, colpi invaginate, surface reticulate. Sexine thicker than nexine.

Very common shrubs. Two species were related in the forest area: *V. baccifera* Reichart. and *V. cayennensis* Pers. Pollen grains were found in samples of campina-1, campina-2, mata-2 and campo.

Convolvulaceae: not identified (Figs. 8/27-29)

Pollen grains of medium size, spheroidal, pantocolpate, spiculate. Sexine thicker than nexine.

Herbaceous. Pollen grains were found in samples of campina-2 and mata-2.

Cyperaceae: not identified (Fig. 8/26)

Pollen grains of medium size, spheroidal, inaperturate, psilate.

Herbaceous. Pollen grains were found only in sample of campo.

Dioscoreaceae: *Dioscorea* (Figs. 8/30-32)

Pollen grains small, flattened, 1-colpate, spiculate.

Herbaceous. Pollen grains were found only in sample mata-2.

Fabaceae: *Derris cf. amazonica* Killip pollen type (Figs. 9/55-60, 62-65)

Pollen grains small, prolate spheroidal, 3-colporate, endoaperture alongate, psilate.

Trees. Pollen grains were found in samples of mata-1, campina-2, mata-2 and campo.

Fabaceae: *Desmodium barbatum* Griseb. (Figs. 9/48,49)

Pollen grains of medium size, spheroidal, 3-colporate, endoaperture alongate, surface insulate.

Trees. Pollen grains were found only in samples of mata-2.

Fabaceae: *Machaerium quinata* Sandw. pollen type (Figs. 9/51,52)

Pollen grains small, spheroidal, 3-colporate, endoapertures scarcely defined, reticulate; sexine thicker at mesocolpia.

Trees. Pollen grains were found in samples of mata-1, mata-2 and campo.

Fabaceae: *Mucuna altissima* DC. (Figs. 9/50 and 12/128)

Pollen grains large, prolate, 3-colporate, endoapertures scarcely defined, reticulate.

Trees related to the flooded areas, but not referred to the savanna area. Pollen grains were found in samples of arbustos-2, mata-2, mata-1 and campo.

Fabaceae: *Pterocarpus amazonicus* Hub. (Figs. 9/46,47)

Pollen grains of medium size, prolate, 3-colporate, colpi equatorially constricted, endoapertures scarcely defined, reticulate.

Trees. Pollen grains were found only in samples of arbustos-2.

Fabaceae: not identified (Fig. 9/61)

Pollen grains small, spheroidal, 3-colporate, endoaperture alongate, psilate. Pollen grain constitution is less rigid than in the formerly described pollen type. Pollen grains were found only in samples of campina-2.

Fabaceae: not identified (Figs. 9/68,69)
Pollen grains small, prolate spheroidal, 3-colporate, endoapertures scarcely defined, reticulate.
Pollen grains were found only in samples of campo.

Fabaceae: not identified (Figs.12/125-127)
Pollen grains of medium size, spheroidal, 3-colporate, reticulate.
Pollen grains were found only in samples of campina-2.

Flacourtiaceae: *Casearia cf. arborea* Urb. (Figs. 8/33,34)
Pollen grains small, prolate, longicolpate with narrow and lalongate endoapertures, pilate.
Trees. Pollen grains were found in samples of mata-1 and mata-2.

Lamiaceae: *Hyptis*-like (Figs. 11/112)
Pollen grains of medium size, prolate spheroidal, 6-colpate, psilate
Shrubs. Pollen grains were found in samples of campina-1, arbustos-2 and mata-2.

Lecythidaceae: type 1 (Figs. 11/113,114)
Pollen grains small, spheroidal, 3-colporate, colpi invaginate, psilate, presenting a thick exine
Trees. Pollen grains were found in samples of mata-2.

Lecythidaceae: type 2 (Figs. 11/115-117)
Pollen grains small, spheroidal, 3-colporate, finely ornamentate.
Trees. Pollen grains were found in samples of mata-1. For the savanna area was indicated only the species *Lecythis cf. lurida* (Miers) Mori. The family is well represented in the forest, comprising several genera.

Malpighiaceae: *Byrsonima aff. crassifolia* (L.) Kunth. (Figs. 12/134-136)
Pollen grains small, spheroidal, 3-colporate, endoapertures lalongate, psilate.
Trees. Pollen grains were found only in sample of campina-2.

Malpighiaceae: *Tetrapteris*-like (Figs. 12/132, 133)
Pollen grains large, spheroidal, pantocolporate, endoapertures circular, psilate, presenting a thick nexine. Shrubs, low climbing. Pollen grains were found in samples of mata-1 and campina-2.

Melastomataceae: *Clidemia hirta* Don. (Figs. 10/73,74)
Pollen grains small, subprolate to prolate, 3-colporate, 3-pseudocolpate, psilate; exine colourless.
Trees. Pollen grains were found in samples of arbustos-2 and campo.

Melastomataceae: *Miconia alata* Schrank ex DC. (Figs. 10/71,72)
Pollen grains small, subprolate to prolate, 3-colporate, 3-pseudocolpate, psilate.
Trees. Pollen grains were found in samples of mata-2 and campo.

Meliaceae: *Carapa guianensis* Aubl. (Figs. 10/75-78)
Pollen grains of medium size, oblate, 3-colporate, ornamentation smooth, LO-type.
Trees. Pollen grains were found only in sample of campina-1.

Meliaceae: *Cedrella fissilis* Vell. (Figs. 10/79,80)
Pollen grains of medium size, prolate, 3-colporate, colpi and lalongate endoapertures equatorially constricted, psilate.
Trees. Pollen grains were found only in sample of mata-2.

Mimosaceae: pollen type of *Mimosa verrucosa* Benth. (Figs. 9/40,41)
Tetragonal tetrads, small, psilate.
Shrubs. Pollen grains were found only in sample of arbustos-2.

Mimosaceae: *Inga* (Figs. 9/42,43)
Polyads of large size; pollen grains converging to a virtual central point of the polyad. Surface finely granulate.
Tree. Pollen grains were found only in sample of mata-2.

Mimosaceae: *Stryphnodendron* (Figs. 9/44,45)
Polyads of 12 pollen grains, of small size, psilate.
Trees. Two species were related in the forest area: *S. paniculatum* Ducke and *S. pulcherrimum* (Willd.) Hochr., but not referred to the savanna area. Pollen grains were found only in samples of arbustos-2 and mata-2.

Myristicaceae: *Virola surinamensis* Warb. (Figs. 10/83,84)
Pollen grains small, trapezoidal, 1-colpate, reticulate.
Trees. Pollen grains were found only in sample of campo.

Myrsinaceae-like (Figs. 11/109, 110)
Pollen grains small to medium size, prolate spheroidal, 4-colpate, reticulate.
Pollen grains were found only in sample of campo.

Myrtaceae: *Psidium guineense* Swartz (smooth leaves) (Fig. 10/81)

Pollen grains of medium size, oblate, 3-colporate, granulate.

Shrubs and small trees; this species shall be introduced by men. Pollen grains were found in sample of arbustos-1.

Myrtaceae: *Psidium guineense* Swartz (hairy leaves) (Fig. 10/82)

Pollen grains small, oblate, 3-colporate, psilate.

Shrubs and small trees; this species shall be introduced by men. Pollen grains were found in sample of campo.

Poaceae: *Panicum rudgei* Roem. et Schult. (Fig. 12/131)

Pollen grain of medium size, spheroidal, 1-porate, psilate.

Herbaceous. Pollen grains were found in sample of campina-2.

Poaceae: type 1 (Fig. 10/85)

Pollen grain small to medium size, spheroidal, 1-porate, finely granulate.

Herbaceous. Pollen grains were found in sample of campina-1.

Poaceae: type 2 (Figs. 10/86, 87)

Pollen grain small, spheroidal, 1-porate, psilate.

Herbaceous. Pollen grains were found in sample of arbustos-2.

Poaceae: type 3 (Figs. 12/130)

Pollen grain of medium size, spheroidal, 1-porate, granulate.

Herbaceous. Pollen grains were found in sample of campina-2.

Polyade not identified (Figs. 8/18,19)

Pollen grains grouped in very large polyades, inaperturate, presenting a thin exine covered with sparsely distributed short spines with rounded apices. Polyades were found in samples of campina-1 and campo.

Rubiaceae: *Amaioua guianensis* Aubl. (Figs. 10/92-94)

Pollen grains small, spheroidal, 3-colporate, reticulate.

Trees. Pollen grains were found in samples of campina-1 and arbustos-2.

Rubiaceae: *Borreria latifolia* (Aubl.) K. Schum. (Fig. 12/129)

Pollen grains of medium size, oblate, 7-colporate, reticulate.

Herbaceous. Pollen grains were found only in sample of campina-2.

Rubiaceae: *Borreria verticillata* G.F. Mey. pollen type (Fig. 10/95)

Pollen grains small, spheroidal, 3-colporate, granulate.

Herbaceous. Pollen grains were found only in sample of campina-1.

Rubiaceae: *Hemidiodia ocimifolia* K. Schum. (Fig. 10/91)

Pollen grains small to medium size, oblate, 7-8-zonocolporate, brevicolpate, reticulate-granulate.

Trees. Pollen grains were found in samples of campo.

Rubiaceae: *Psychotria*-like (Fig. 11/111)

Pollen grains of medium size, spheroidal, inaperturate, reticulate-granulate.

Pollen grains were found only in samples of campina-2.

Rubiaceae: *Sabicea amazonensis* Vernha. (Figs. 11/96-98)

Pollen grains of medium size, suboblate, 3(-4)(-5)-colporate, brevicolpate, reticulate.

Shrubs. Pollen grains were found in samples of campina-1, campina-2, arbustos-2 and mata-2.

Sapindaceae: *Paullinia* (Fig. 11/99)

Pollen grains small to medium size, oblate, 3-porate, psilate.

Climbing shrubs. Pollen grains were found in samples of arbustos-2.

Sterculiaceae: *Helicteres pentandra* L. (Figs. 11/101-103)

Pollen grains of medium size, oblate, 3-colporate, longicolpate, reticulate.

Shrubs. Pollen grains were found in samples of arbustos-2 and mata-2.

Sterculiaceae: *Sterculia pruriens* (Aubl.) Schum. (Figs. 11/106-108)

Pollen grains of medium size, prolate spheroidal, 3-colporate, reticulate.

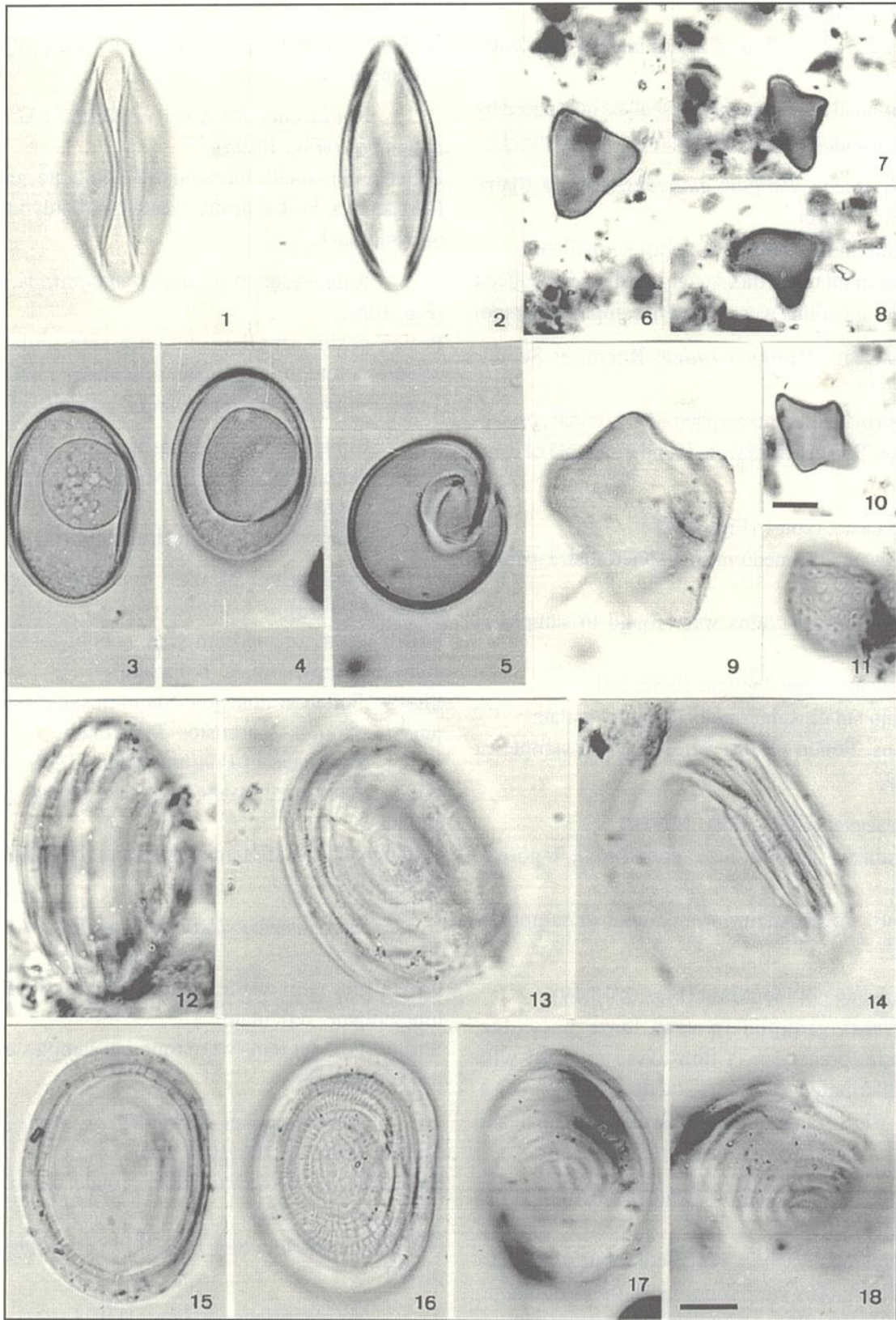
Trees. Pollen grains were found only in sample of campina-1.

No identification (Figs. 11/123, 124)

Pollen grains small, subprolate, 3-colporate, with a very fine ornamentation.

Pollen grains were found only in samples of campina-2.

Plate 1: Algae



Figs. 1-2: campina-1, probably alga; Figs. 3-4: campina-1, cf. *Spirogyra*; Fig. 5: campina-1, probably alga; Figs. 6-8: campo, probably fungal spores; Fig. 9: campo, Zygnemataceae: *Mougeotia*-type; Fig. 10: campo, Zygnemataceae: *Mougeotia*-type (bar = 20µm); Fig. 11: campina-1: Zygnemataceae: *Zygnema*-type; Figs. 12-14: campina-1, *Insertae sedis*: *Pseudoschizaea*; Figs. 15, 16: arbustos-2, *Insertae sedis*: *Pseudoschizaea*; Figs. 17,18: campina-2, *Insertae sedis*: *Pseudoschizaea*; Bar = 10µm, except Fig. 10.

Plate 2: Spores of Fungi and palynomorphs.

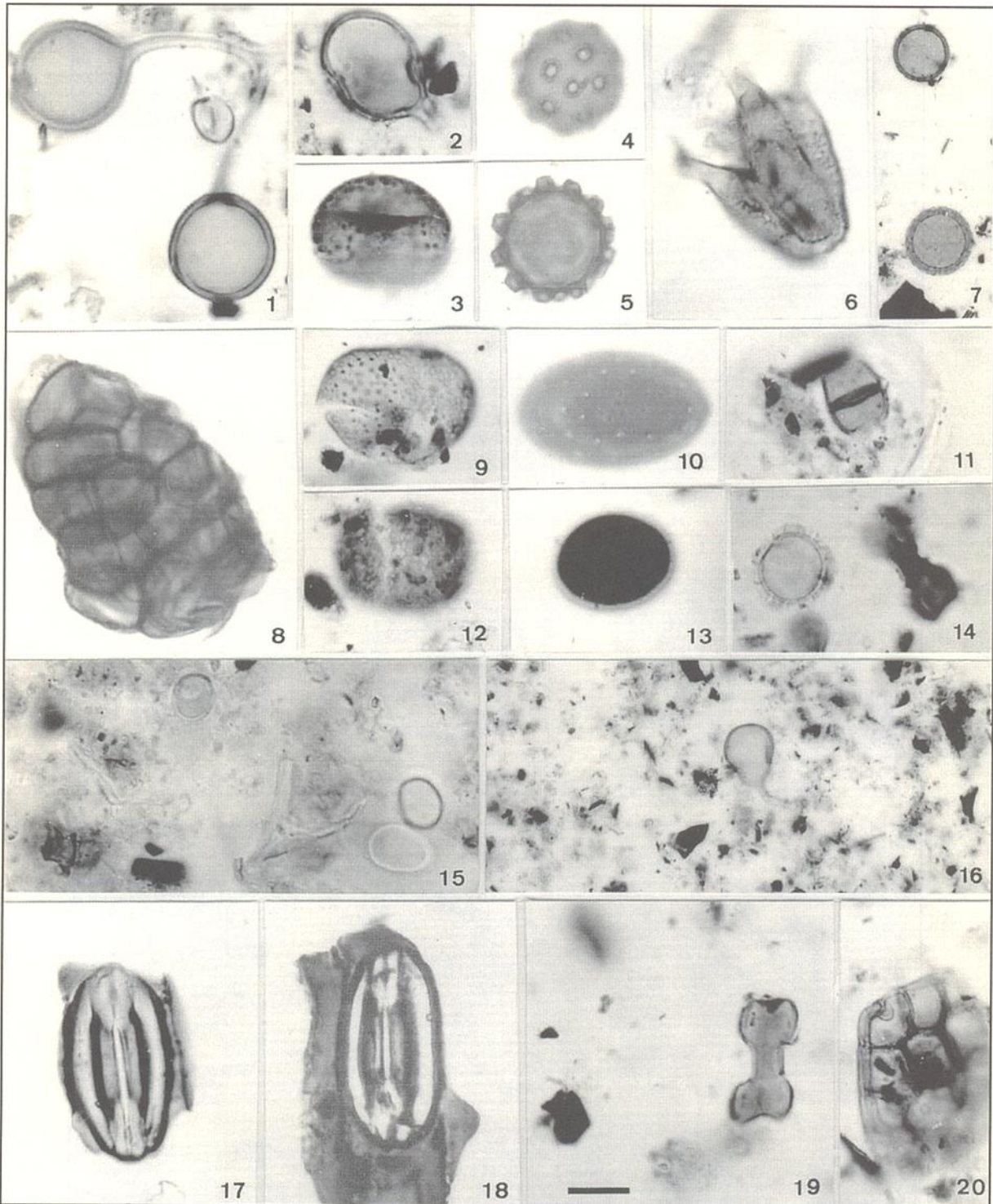


Fig. 1: mata-2, Glomaceae: *Rhizophagus*; Fig. 2: campo, Glomaceae: *Rhizophagus*; Fig. 3: arbustos-2, spore of fungus; Figs. 4-5: campo, probably a fungal spore; Fig. 6: arbustos-2, Dematiaceae: *Tetraploa*; Fig. 7: campina-1, spores, Fig. 8: campo, fungal cells; Fig. 9: campo, spore of fungus; Fig. 10: campina-1, Sordariaceae: *Gelasinospora*; Fig. 11: arbustos-2, two fungal cells; Fig. 12: campo, spore of fungus; Fig. 13: arbustos-2, Dematiaceae: *Nigrospora*; Fig. 14: campo, Lycoperdaceae: *Lycoperdon* and epidermis cell of Poaceae; Fig. 15: mata-2; sediment with light and dark spores and carbonated organic material; Fig. 16: arbustos-2: sediment with carbonated plant fragments and spore of *Rhizophagus*; Fig. 17: campina-1, stoma; Fig. 18: campina-2, stoma; Fig. 19: campo, fitolite of Poaceae; Fig. 20: campo, plant epidermis; Bar = 10µm

Plate 3: Spores of Bryophyta.

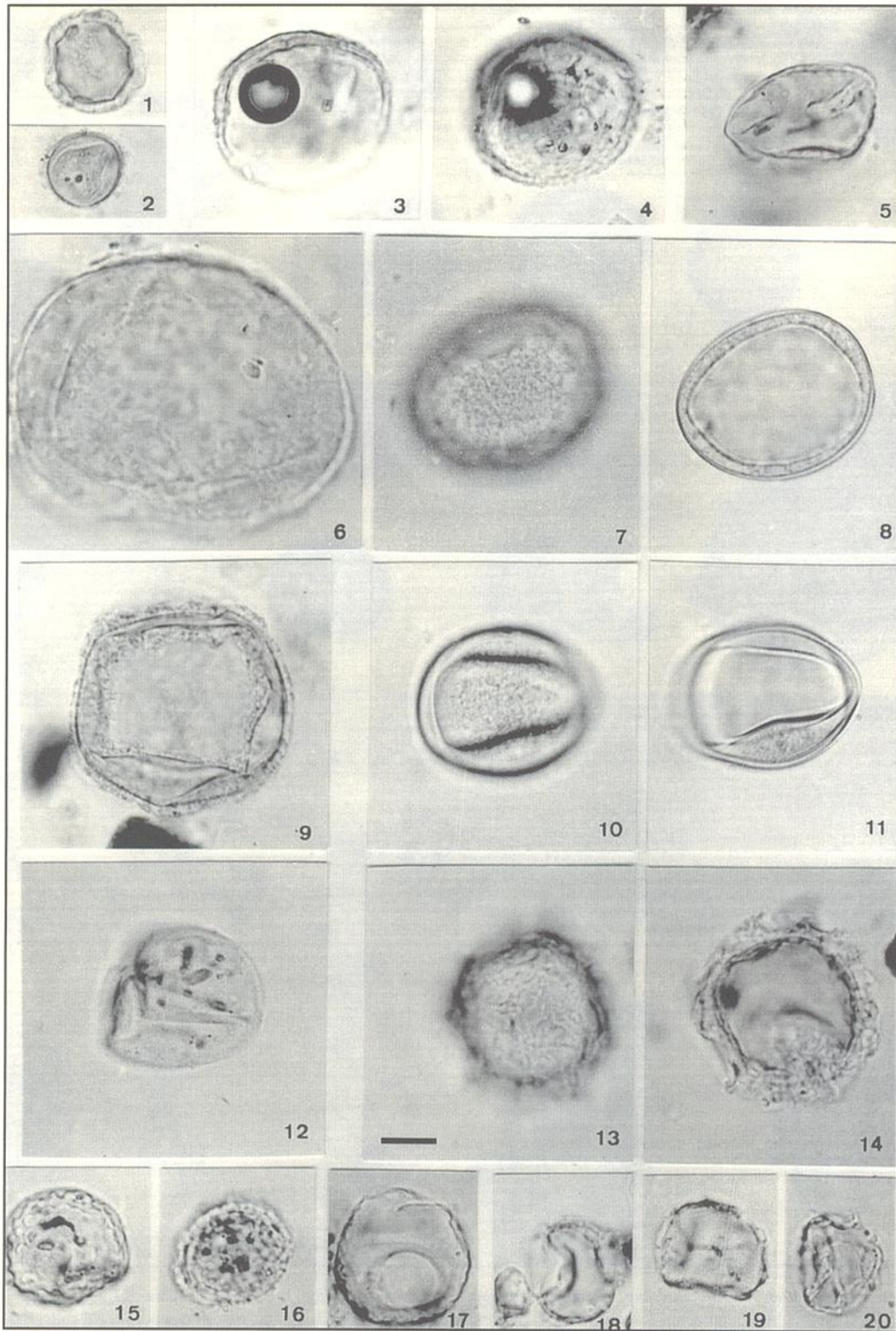
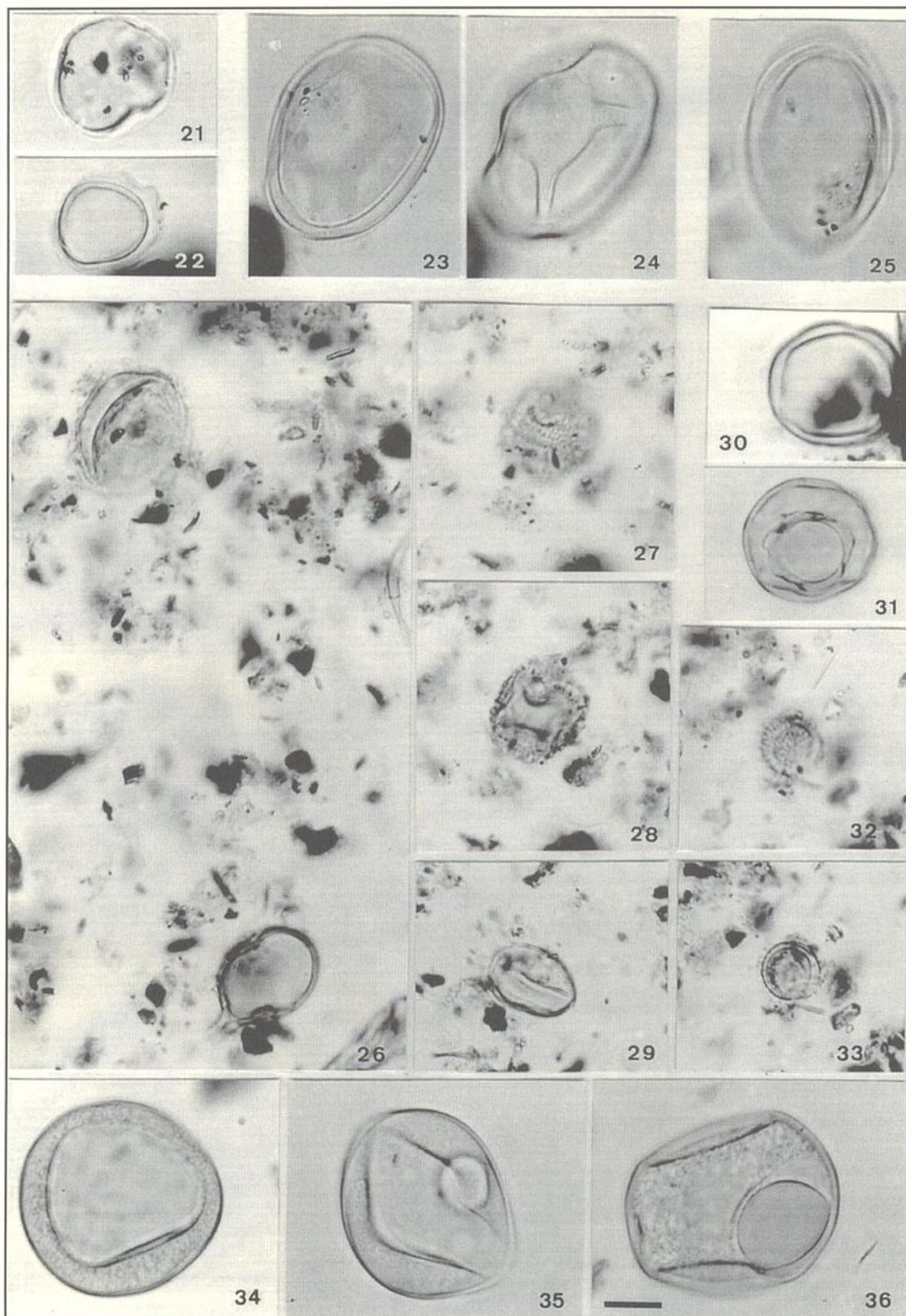


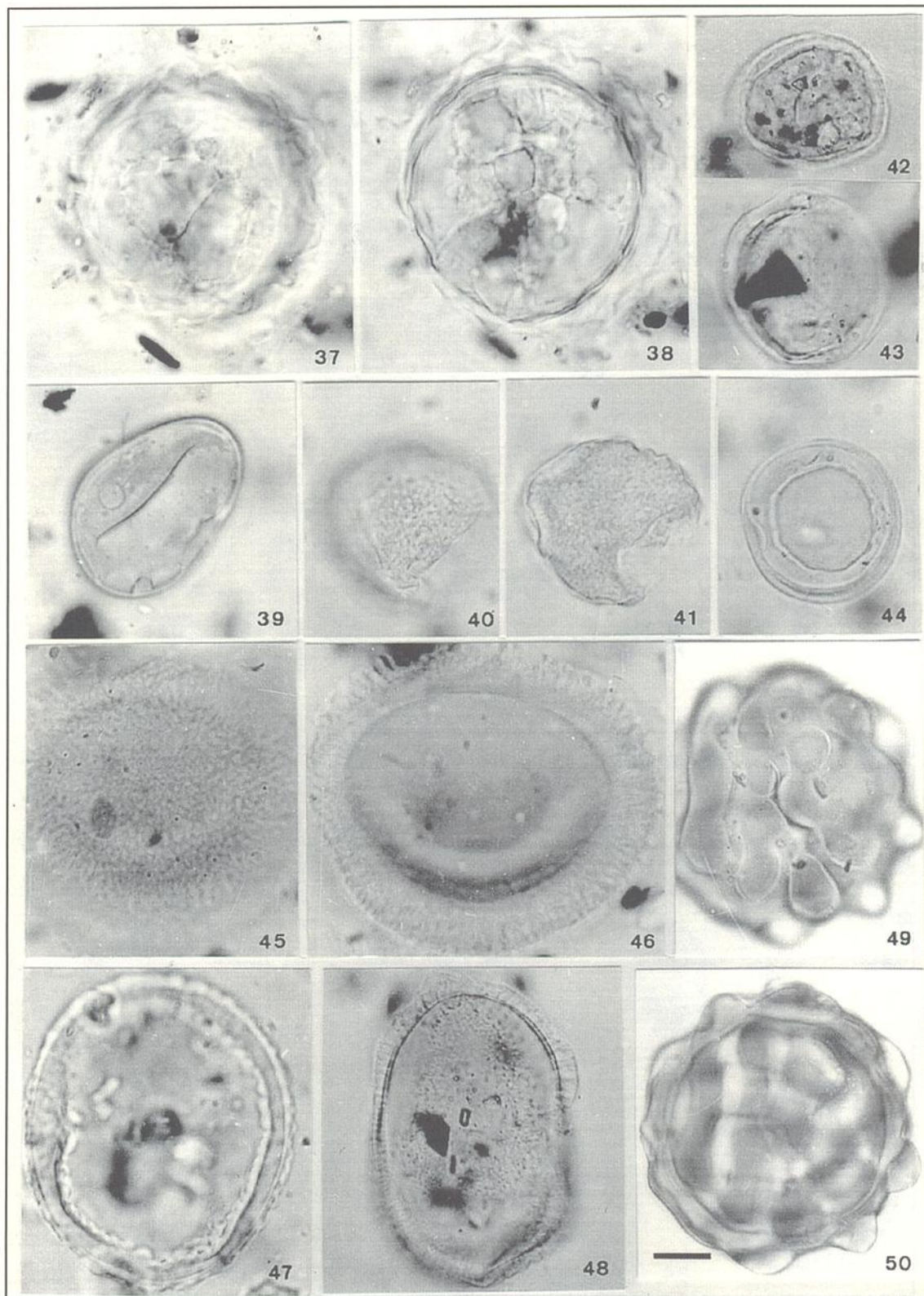
Fig. 1: mata-1; Fig. 2: arbustos-2; Fig.s. 3-4: arbustos-2; Fig. 5: arbustos-2; Fig. 6: arbustos-2; Figs. 7-8: arbusto-1, Dicranaceae; Fig. 9: campina-1; Figs. 10-11: arbustos-1, Dicranaceae; Fig. 12: campina-1, Anthocerotaceae: *Phaeoceros*; Figs. 13-14: campina-2; Fig. 15: campina-1; Fig. 16: campina-1; Fig. 17: campina-1, Dicranaceae: *Holomitrium*; Fig. 18: campina-1, Dicranaceae: *Campylopus*; Fig. 19: campina-1; Fig. 20: campina-1; Bar = 10 μ m

Plate 4: Spores of Bryophyta and of Pteridophyta *Elaphoglossum*.



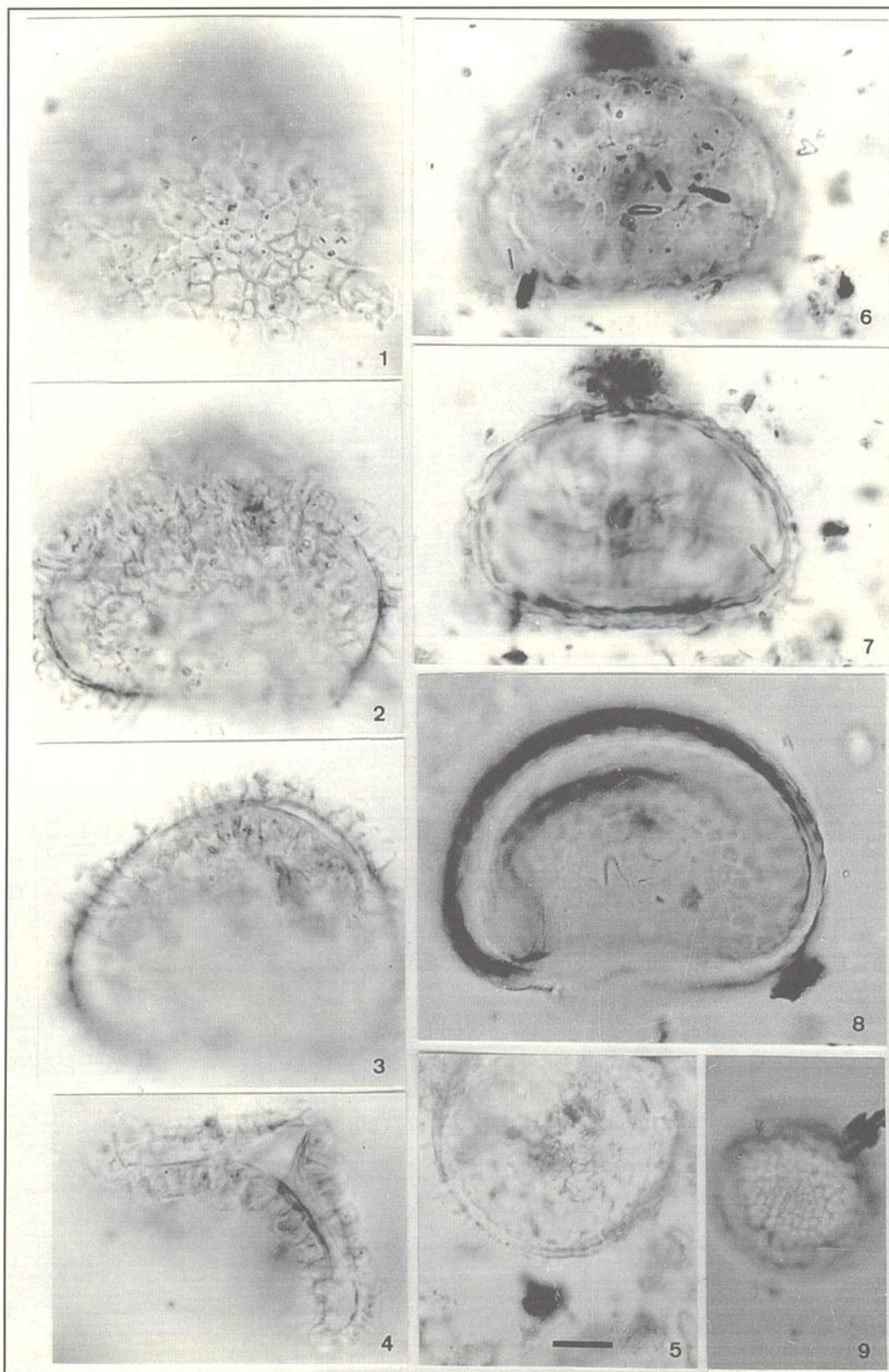
Figs. 21, 22: campina-1; Figs. 23-24: campina-1, Dryopteridaceae: *Elaphoglossum*; Fig. 25: campina-1, medium; sized smooth spore; Fig. 26: campo, sediment with a spore of Bryophyta, a spore of fungus *Rhizophagus* and carbonated plant fragments; Figs. 27-29: campo; Fig. 30: campina-1; Fig. 31: campina-2; Figs. 32-33: campina-1, Bruchiaceae (?); Fig. 34: campina-1, Dicranaceae; Fig. 35: campina-2, Dicranaceae; Fig. 36: campina-1, Dicranaceae; Bar = 10µm

Plate 5: Spores of Bryophyta and of alga *Debarya*.



Figs 37-41: campina-2; Figs. 42, 43: mata-1; Fig. 44: campina-2; Figs. 45-46: mata-1; Fig. 47: mata-1, Zygnemataceae: cf. *Debarya* (zygospore); Fig. 48: campina-1; Figs. 49, 50: arbustos-1; Bar = 10 μ m

Plate 6: Spores of Pteridophyta.



Figs. 1-4: arbustos-2, Selaginellaceae: *Selaginella* (type 1); Fig. 5: arbustos-2, Selaginellaceae: *Selaginella* (type 2); Figs. 6, 7: campo, Dryopteridaceae: *Dryopteris*; Fig. 8: campina-2, Polypodiaceae: *Polypodium*; Fig. 9: arbustos-1, trilete; Bar = 10 μ m

Plate 7: Pollen grains of Angiosperma.

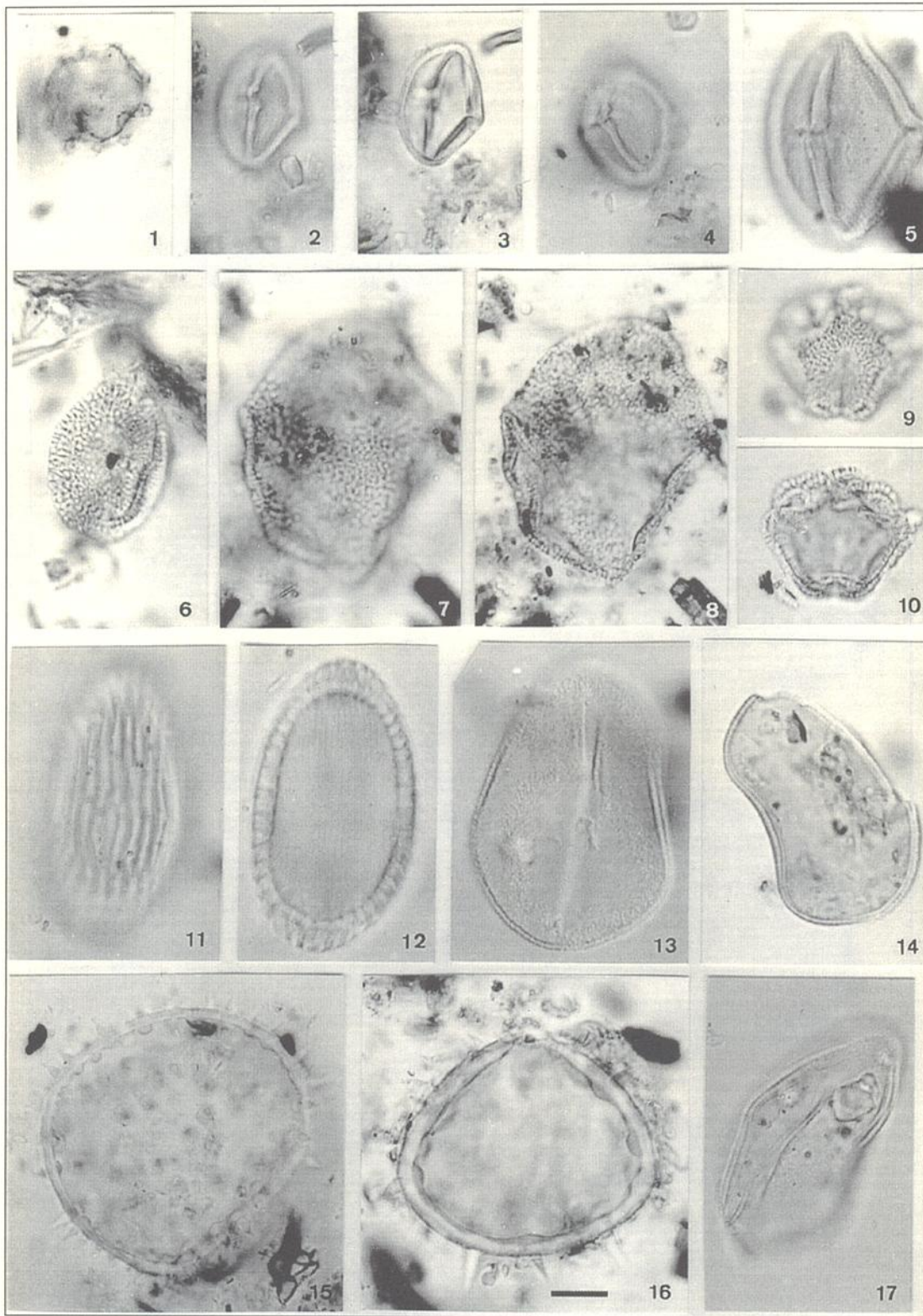
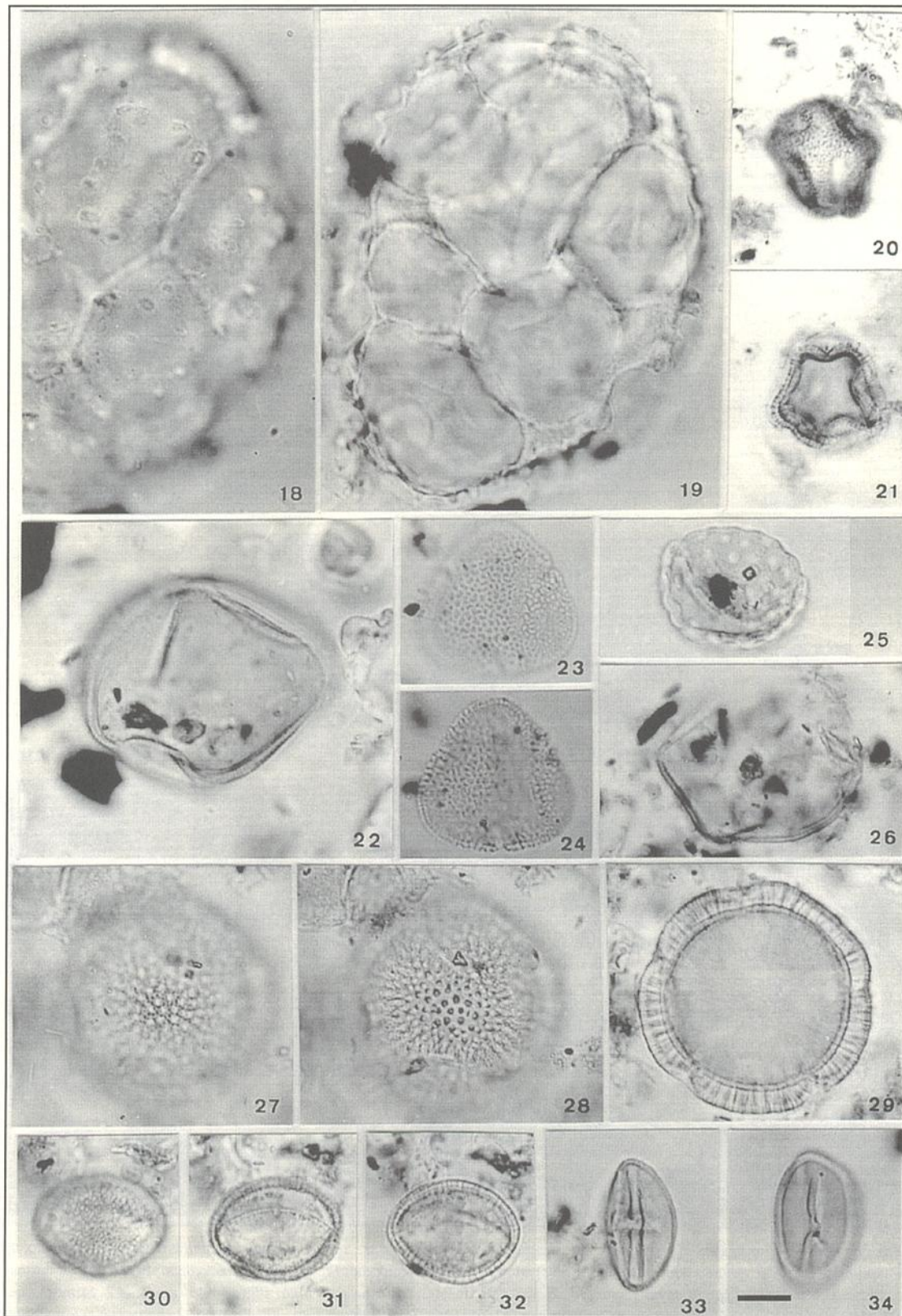


Fig. 1: campina-1, Amaranthaceae: *Alternanthera* (not well preserved pollen grain); Figs. 2-4: mata-2, Anacardiaceae: *Tapirira guineensis*; Fig. 5: campina-1, Anacardiaceae; Fig. 6: mata-2, Annonaceae: *Annona paludosa* (bar= 25 μ m); Figs. 7-8: campo, Annonaceae: *Annona paludosa* (bar= 25 μ m); Figs. 9-10: mata-2, Araliaceae: *Didymopanax morototonii*; Figs. 11-12: campina-2, Araceae: *Spathiphyllum*; Fig. 13: campina-1, Arecaceae: pollen type *Euterpe oleracea*; Fig. 14: arbustos-2, Arecaceae: pollen type *Euterpe oleracea*; Fig. 15: mata-1, Arecaceae: *Mauritia vinifera*; Fig. 16: mata-2, Arecaceae: *Mauritia vinifera*; Fig. 17: arbustos-2, Arecaceae: pollen type *Euterpe oleracea*; Bar = 10 μ m

Plate 8: Pollen grains of Angiosperma.



Figs. 18-19: campo; Figs. 20-21: mata-2, Clusiaceae: *Vismia*; Fig. 22: mata-1: Bignoniaceae: *Jacaranda copaia*; Figs. 23-24: mata-2, Bombacaceae: *Pachira aquatica* (bar= 25µm); Fig. 25: campina-1, *Amaranthus*/Chenopodiaceae; Fig. 26: campo, Cyperaceae (not well preserved pollen grain); Figs. 27-29: mata-2, Convolvulaceae; Figs. 30-32: mata-2, Dioscoreaceae: *Dioscorea*; Figs. 33-34: mata-1, Flacourtiaceae: *Casearia arborea*; Bar = 10µm

Plate 9: Pollen grains of Angiosperma.

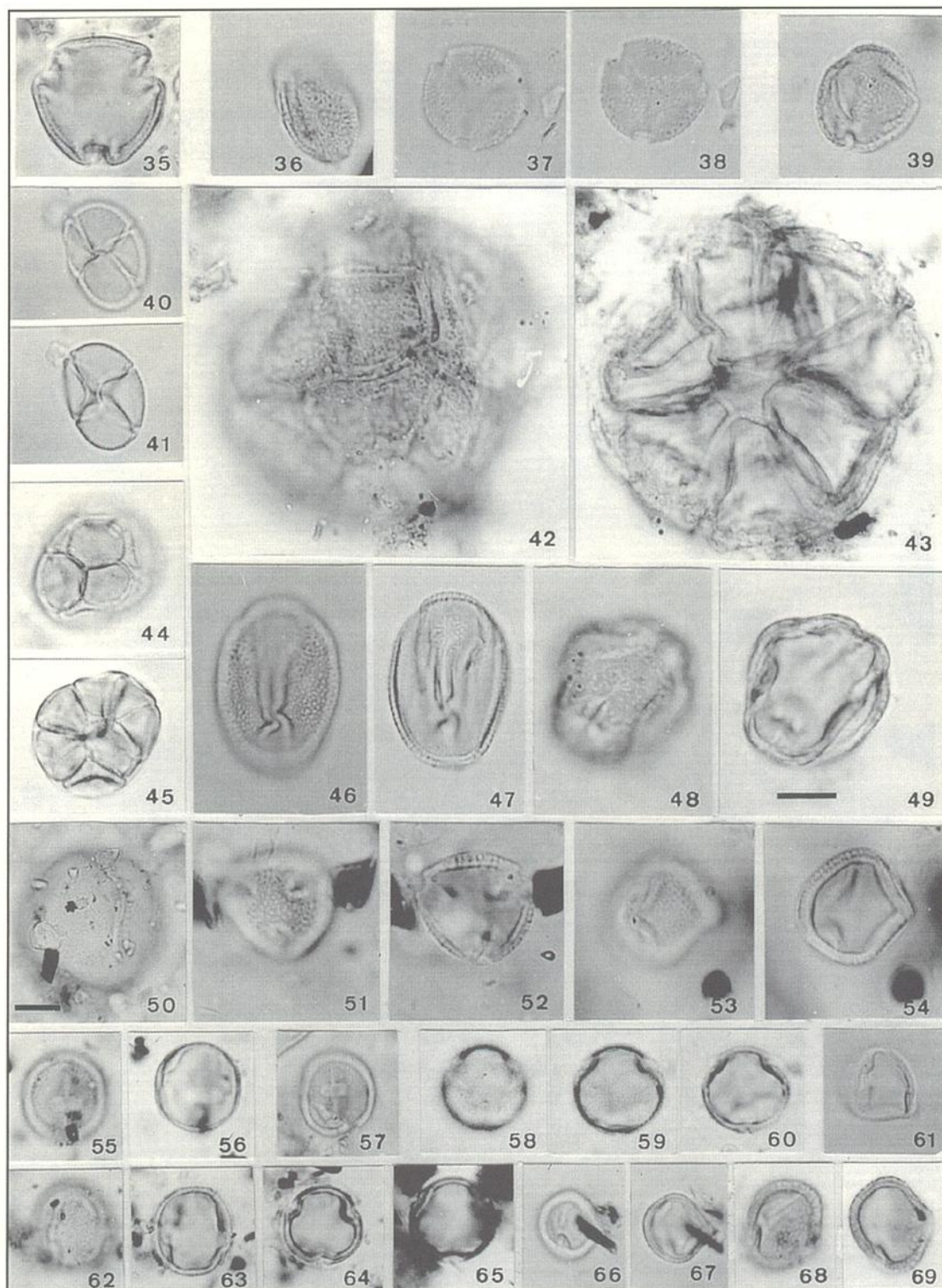


Fig. 35: mata-2, Clusiaceae: *Rheedia*; Fig. 36: campina-2, Caesalpiniaceae: *Tachygalia myrmecophyla*; Figs. 37-38: mata-1, Caesalpiniaceae: *Tachygalia myrmecophyla*; Fig. 39: campina-2, Caesalpiniaceae: *Tachygalia myrmecophyla*; Figs. 40-41: arbustos-2, Mimosaceae: pollen type *Mimosa verrucosa*; Figs. 42-43: mata-2, Mimosaceae: *Inga*; Figs. 44-45: arbustos-2, Mimosaceae: *Stryphnodendron*; Figs. 46-47: arbustos-2, Fabaceae: *Pterocarpus amazonicus*; Figs. 48-49: mata-2, Fabaceae: *Desmodium barbatum*; Fig. 50: mata-1, Fabaceae: *Mucuna altissima* (bar = 25 μ m); Figs. 51-54: mata-1, Fabaceae: pollen type *Machaerium quinata*; Figs. 55-56: campo, Fabaceae: pollen type *Derris amazonica*; Fig. 57: mata-2, Fabaceae: pollen type *Derris amazonica*; Figs. 58-60: campo, Fabaceae: pollen type *Derris amazonica*; Fig. 61: campina-2, Fabaceae; Figs. 62-65: campo, Fabaceae: pollen type *Derris amazonica*; Figs. 66-67: arbustos-2, Fabaceae; Figs. 68-69: campo, Fabaceae; Bar = 10 μ m, except Fig. 50

Plate 10: Pollen grains of Angiosperma.

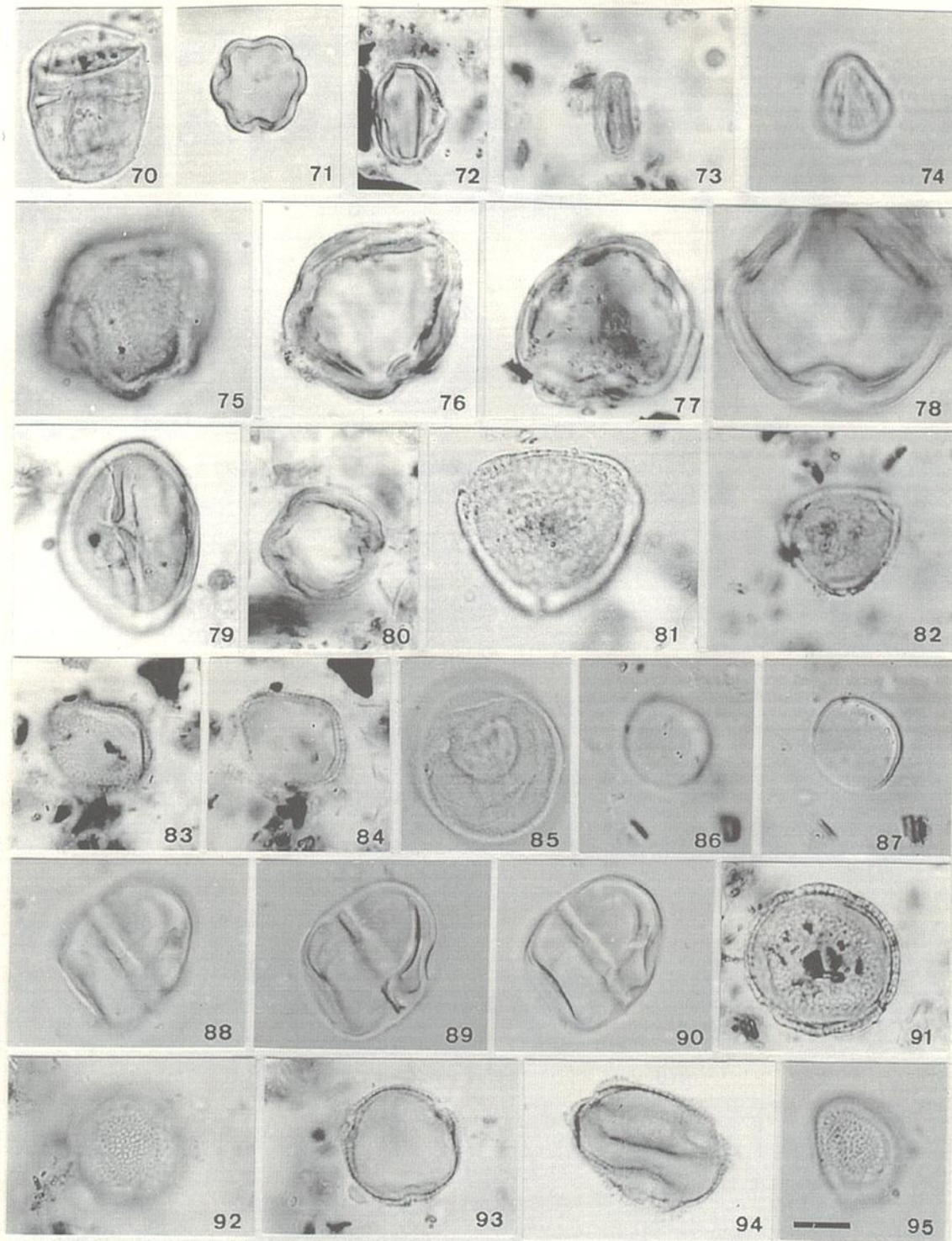
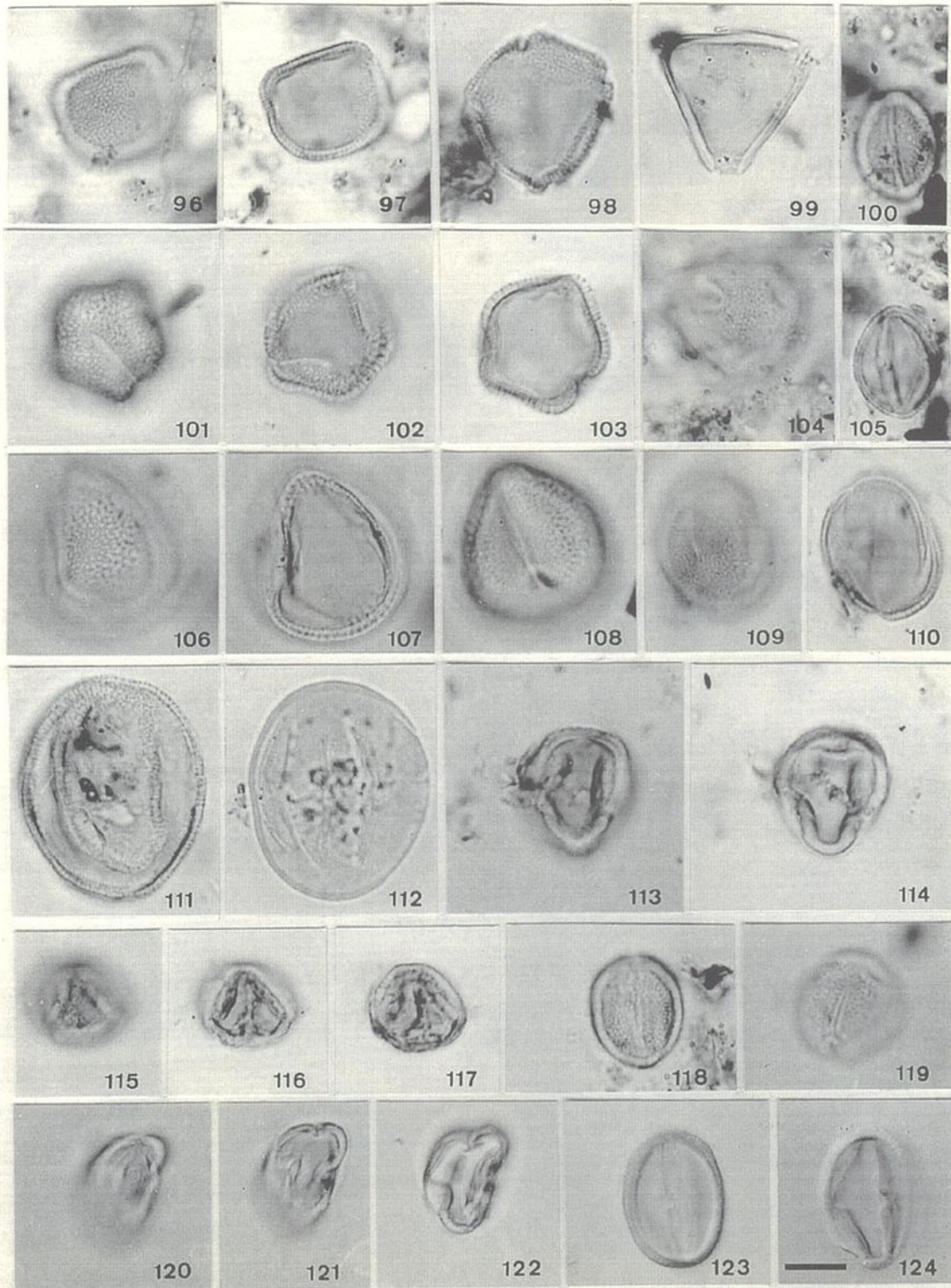


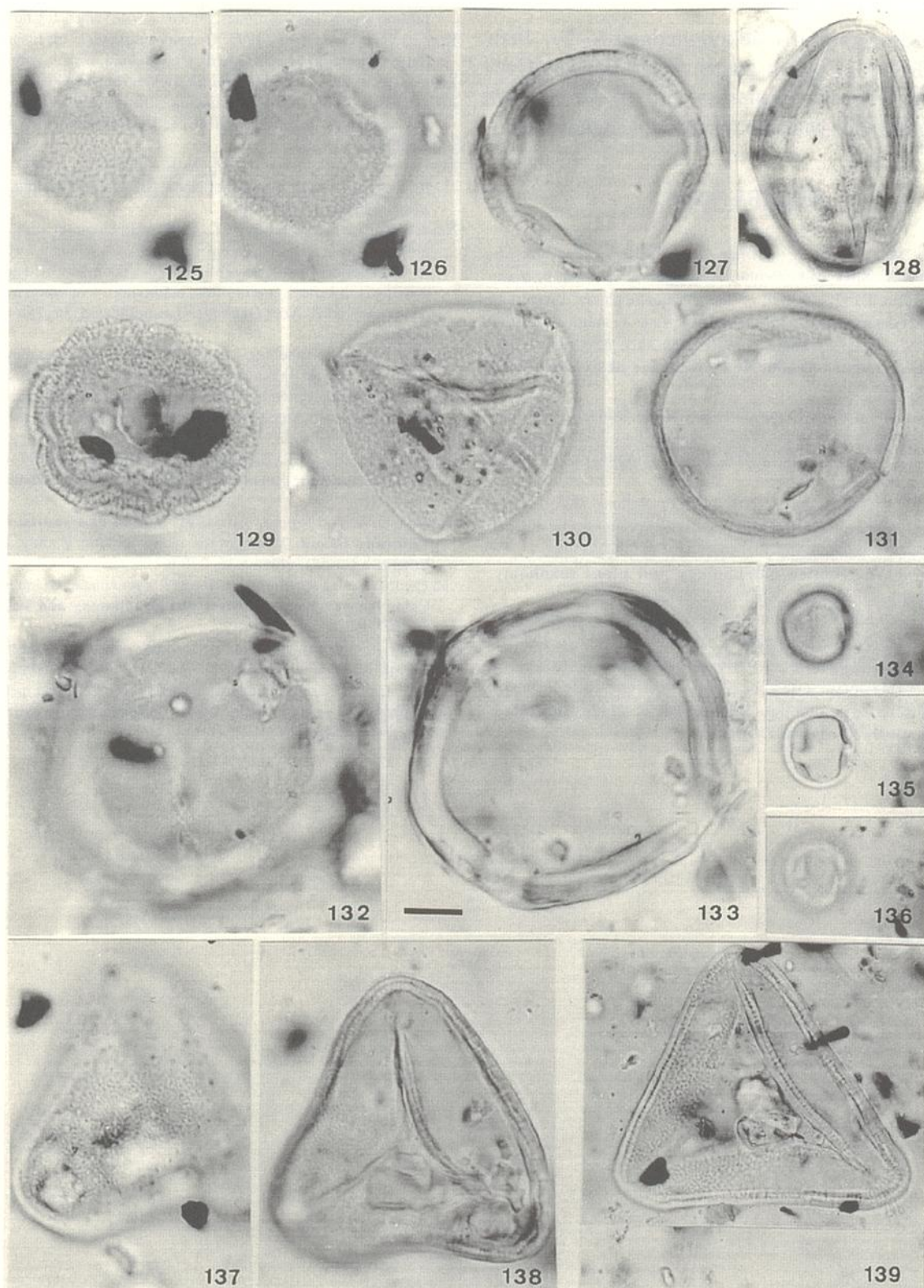
Fig. 70: mata-2, Apocynaceae (?); Fig. 71: mata-2, Melastomataceae: *Miconia alata*; Fig. 72: campo, Melastomataceae: *Miconia alata*; Fig. 73: campo, Melastomataceae: *Clidemia hirta*; Fig. 74: arbustos-2, Melastomataceae: *Clidemia hirta*; Figs. 75-78: campina-1, Meliaceae: *Carapa guianensis*; Figs. 79-80: mata-2, Meliaceae: *Cedrela fissilis*; Fig. 81: arbustos-1, Myrtaceae: *Psidium guineense* (smooth leaves); Fig. 82: campo, Myrtaceae: *Psidium guineense* (hairy leaves); Figs. 83-84: campo, Myristicaceae: *Virola surinamensis* and carbonized material; Fig. 85: campina-1, Poaceae, pollen type 1; Figs. 86-87: arbustos-2, Poaceae, pollen type 2; Figs. 88-90: arbustos-2, Apocynaceae (?); Fig. 91: campo, Rubiaceae: *Hemidiodia ocimifolia*; Figs. 92-93: arbustos-2, Rubiaceae: *Amaioua guianensis*; Fig. 94: campina-1, Rubiaceae: *Amaioua guianensis*; Fig. 95: campina-1, Rubiaceae: pollen type *Borreria verticillata*; Bar = 10µm

Plate 11: Pollen grains of Angiosperma.



Figs. 96-98: arbustos-2, Rubiaceae: *Sabicea amazonensis*; Fig. 99: arbustos-2, Sapindaceae: *Paullinia*; Figs. 100, 105: mata-2, Caesalpiniaceae: *Chamaecrista lucens*; Figs. 101-103: arbustos-2, Sterculiaceae: *Helicteres pentandra*; Fig. 104: mata-2, Clusiaceae: *Rheedia*; Figs. 106-108: campina-1, Sterculiaceae: *Sterculia pruriens*; Figs. 109-110: campo, pollen type Myrsinaceae; Fig. 111: campina-2, Rubiaceae: pollen type *Psychotria*; Fig. 112: campina-1, Lamiaceae: pollen type *Hyptis*; Figs. 113-114: mata-2, Lecythidaceae (pollen type 1); Figs. 115-117: mata-1, Lecythidaceae (pollen type 2); Fig. 118: mata-2, Caesalpiniaceae: *Chamaecrista lucens*; Fig. 119: campina-2, Caesalpiniaceae: *Chamaecrista lucens*; Figs. 120-122: arbustos-2, Anacardiaceae: *Tapirira guianensis* (polar view); Figs. 123-124: campina-2, 3-colporate; Bar = 10µm

Plate 12: Pollen grains of Angiosperma.



Figs. 125-127: campina-2, Fabaceae; Fig. 128: mata-1, Fabaceae: *Mucuna altissima*; Fig. 129: campina-2, Rubiaceae: *Borreria latifolia*; Figs 130, 131: campina-2, Poaceae (pollen type 3); Figs. 132, 133: campina-2: Malpighiaceae; Figs. 134-136: campina-2: Malpighiaceae: *Byrsonima aff. crassifolia*; Figs. 137, 138: mata-1: Arecaceae: *Astrocaryum murumuru*; Fig. 139: mata-1: Arecaceae; Bar = 10 μ m

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