



Sporepollinic morphology of fluvial terrace sediments in the Western Amazon

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ABSTRACT

Morphological descriptions were made for pollen grains and spores extracted from samples from three sedimentary sections – Chandless 1, Purus 10 and Purus 30 – from fluvial terraces on the Chandless and Purus rivers, Acre State, Brazil. Level CH1-12 at Chandless 1 was C^{14} -dated to 4861 - 5050 cal yr BP, P10-3 of Purus 10 was dated through the OSL method at 8200 +/- 65 yr BP, while P30-6 at Purus 30 was C^{14} dated to 7845 - 7998 cal yr BP. For pollen analysis, 2 cm³ of each sample was removed, treated with potassium hydroxide (KOH) and acetolysed, followed by palynomorph separation with bromoform/alcohol density 2.0 solution. A total of 49 palynomorphs were morphologically described (39 pollen types and 10 Pteridophyte spores). The most frequent pollen types belonged to Anacardiaceae, Arecaceae, Euphorbiaceae, Fabaceae, Rutaceae and Amaranthaceae, while the most frequent spores belonged to Polypodiaceae and Pteridaceae. The pollen richness found in the studied samples reflects the current vegetation occupying the banks of the rivers.

Keywords: Acre, Amazon, Chandless, palynomorphs, Purus

Introduction

Studies of past vegetation changes and climatic inferences facilitate understanding of the origins and maintenance of floristic biodiversity. Past variations can be examined through analysis and surveys of pollen grains, pteridophyte spores, algae and fungi preserved in sediments, along with C14 dating, making it is possible to determine the impacts of past climatic changes on the flora and fauna of the Quaternary (Salgado-Labouriau 2001).

Pollen grains are the male structure of spermatophyte plants (Gymnosperms and Angiosperms), while spores are the reproductive structures of lower plants, including Pteridophytes. Both pollen grains and spores have an

external wall (the exine) that is strongly resistant to weathering. Accordingly, such structures can be preserved for thousands of years (Absy & Silva 2009).

Morphological descriptions are important for Quaternary palynological research, since pollen grains and spores are morphologically similar to those of the current vegetation. This allows comparisons with taxa of extant botanical genera and families, permitting a more direct analysis of palaeoclimate and paleoclimatic studies (Freitas & Carvalho 2012). Consequently, palynological catalogs and palynological reference libraries are important as they help with palynomorph identification. Amazonia has one of the most diverse floras in the world, with more than 80,000 vascular plants described, and a density of around 300 species per hectare (Gentry 1994). Most Angiosperm species

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occur in the tropics, thus explaining the great diversity of Amazonian forest species, as well as the great variety of pollen grains and spores (Cronquist 1988).

Research carried out by geologists and paleontologists shows that the fossil record from the Solimões Formation has been essential for understanding the Cenozoic South American paleofauna, as well as for the evolution of the Western Amazonian landscape. In the state of Acre, the fossil record from the Late Miocene Solimões Formation has been described and synthesized by several researchers, including Cozzuol (2006), Kay & Cozzuol (2006), Latrubesse *et al.* (1997; 2007; 2010), Negri *et al.* (2010), among others. In addition to the well known Late Miocene fossiliferous record, Early Quaternary paleovertebrates have also been found and described in the Southwestern Brazilian Amazonia (Simpson & Couto 1981).

The landscape of Southwestern Brazilian Amazon is characterized by a low elevation dissected fluvial landscape caused by insertion of the main rivers into the uppermost part of the Solimões Formation that generated fluvial belts composed of Quaternary terraces and fluvial deposits (Latrubesse *et al.* 2007; 2010).

Rancy (1991) and Latrubesse & Rancy (1998) collected from the banks of the Juruá River, located in the state of Acre, Western Amazon and identified three alluvial plain Quaternary units: sediments from the Early Pleistocene, Late Pleistocene and Holocene. Late Pleistocene and Holocene sediments formed low terraces. A rich fauna from the Lujanense was recovered in Late Pleistocene conglomerate sediments. Both the mammalian fauna and conglomerate sediments indicate a more arid climate than at present, one that may have occurred in the Last Glacial Maximum (LGM) 25,000 to 18,000 years BP of the Last Glaciation. Another younger stage of sedimentation was recognized from the presence of fine sediments, lateral accretion deposits and the remains of logs, leaves and branches in the sediments, indicating the Amazon forest was already widespread in the area during the Holocene.

Both, the Juruá and the Purus are meandering tropical lowland rivers in the state of Acre, Western Amazonia. On the upper reaches of these rivers, studies by Latrubesse & Kalicki (2002) found that tectonic activity contributed to the extension and migration of the meanders during the Late Pleistocene and Holocene and that the basin also underwent important paleohydrological changes during the Late Pleistocene, while in the Holocene, savanna environments were supplanted by Amazonian forest. Over time this river system has retained a meandering pattern, with aggradation of coarser materials during the Last Glacial (sediments of Late Pleistocene terraces) and the deposition of finer sediments during the Lateglacial and Holocene (lower terrace and floodplain) (Latrubesse & Kalicki 2002).

Palynological studies of Neogene Acre outcrops in the Southwestern Amazonian have focused on the Late Miocene sediments of the Solimões Formation collected at

the Murici, Patos and the Elizete ravines in the upper Rio Acre. The presence of *Grimsdalea* (a palm) and the abundance of spores and other angiosperms indicate swampy and forest paleoenvironments (Latrubesse *et al.* 2007).

However, the palynological record of the Quaternary sediments of Acre is still unknown. Advances have been made in the palynological study of lacustrine and fluvial Quaternary deposits and, although the morphological description of palynomorphs preserved in sediment serves as an important tool for paleoenvironmental analyses, there are still few studies about Quaternary research carried out in the Brazilian Amazonia such as Absy (1979); Hammen & Absy (1994); Colinvaux *et al.* (1999); D'Apolito *et al.* (2013; 2017; 2018); Feitosa *et al.* (2015). Thus, the objective of this study was to provide morphological descriptions of pollen grains and spores of the samples of three sedimentary profiles of fluvial terraces of the Chandless and Purus rivers in the state of Acre, aiming to contribute to Quaternary paleoecological and paleoenvironmental research in the Western Amazon region.

Materials and methods

Study area

The study area is in Acre State, in Southwestern Brazilian Amazonia (Fig. 1), between 07°07'S – 11°08'S and 66°30'W – 74°W. The study site covers 164,221.36 km² (16.422.136 ha), equivalent to 4 % of Brazilian Amazon and 1.9 % of national territory. Acre borders the states of Amazonas and Rondônia, and shares borders with Peru and Bolivia (IBGE 1995).

The Solimões Formation is the main unit cropping out on the surface, and it occupies an area of approximately 500,000 km², across Brazilian territory in the Solimões, Acre and Amazonas sedimentary basins (Maia *et al.* 1977). In the Acre region, this Formation is made up of fluvial depositional environments (floodplain lakes, paleosoils). The age of the total thickness and deepest levels of the Solimões Formation is not well known, but the fossiliferous uppermost levels cropping out in Western Brazilian Amazon were assigned to the Late Miocene (Latrubesse *et al.* 2007; 2010; Bissaro-Júnior *et al.* 2019).

The main rivers in the central region of Acre State are the Tarauacá and Purus, with two tributaries on the right bank: the Chandless and its tributary the Jaco, and the Acre river and its tributary the Antimari (Acre 2010). The Acre, Purus and Jaco rivers originate in the Andes-Antepian basin. The Purus River is ~1600 km long, drains an area of 372,000 km², discharges approximately 110,000 m³ of water s⁻¹, and transports about 29 million tons of sediment annually (Latrubesse *et al.* 2005).

The climate of the state is hot and humid equatorial; Af/Am, according to the Köppen (1936) classification. Climatically there are two seasons: a rainy season (October



to April) and a dry season (June-September). In the former, rainfall generally exceeds 110 mm/month, while in the latter average rainfall is below 60 mm/month (SEMA 2012). Mean temperature is approximately 24.5 °C and the maximum around 32 °C, which is practically uniform throughout the state (Nimer 1989).

Acre and the Southwest Amazonian ecoregion are considered a conservation hot spot (Olson *et al.* 2001), and a priority area for botanical surveys (MMA 2001). Taxonomists also consider Acre as a hot spot due to high diversity, endemism and unexpected floristic affinities (Daly & Silveira 2008).

Acre has two major phytoecological components: Dense Ombrophylous Forest (DOF) and Open Ombrophylous Forest (OOF). Additionally, Campinarana occurs in the northwest portion of the state. Both DOF and OOF have a wide variety of plant subformations, distinguished by soil types. The classifications of these regions are based more on physiognomy and structural consideration than on floristic aspects (RADAM 1977). The older terraces are covered by alluvial forest and the younger Holocene terraces occasionally flood.

Field activities

Sediment samples were taken from outcrops of ancient river terraces, one on the banks of the Chandless River, the

other two on the banks of the Purus River (Fig. 1). Outcrops were named Purus 10 (8°56'33.0"S 69°22'47.3"W) with four samples collected, Purus 30 (9°03'15.9", 69°41'29.9"W) with seven samples collected and Chandless 1 (9°13'59.2»S 69°53'36.0»W) with nine samples collected.

AMS Carbon 14 dating

Two samples were selected for Accelerator Mass Spectrometer (AMS) C14 dating at the Beta Analytic Radiocarbon Dating laboratory, Miami, Florida, USA. The ages were given as conventional age (A.P. years) and calibrated age (cal. yrs BP) ($\pm 2\sigma$), following Hogg *et al.* (2013).

Optically Stimulated Luminescence– OSL

Two other samples were dated with Optically Stimulated Luminescence - OSL, at the Luminescence Dating Research Laboratory of Baylor University, Texas, USA. This was done by calculating the equivalent dose in a fraction of pure quartz with 40-100 grains/aliquot and analyzed via blue light (470 ± 20 nm) excitation using single aliquot regeneration protocols (Murray & Wintle 2003). U, Th, and K were analyzed by inductively coupled plasma mass spectrometry at ALS Laboratories, Reno, Nevada, USA.

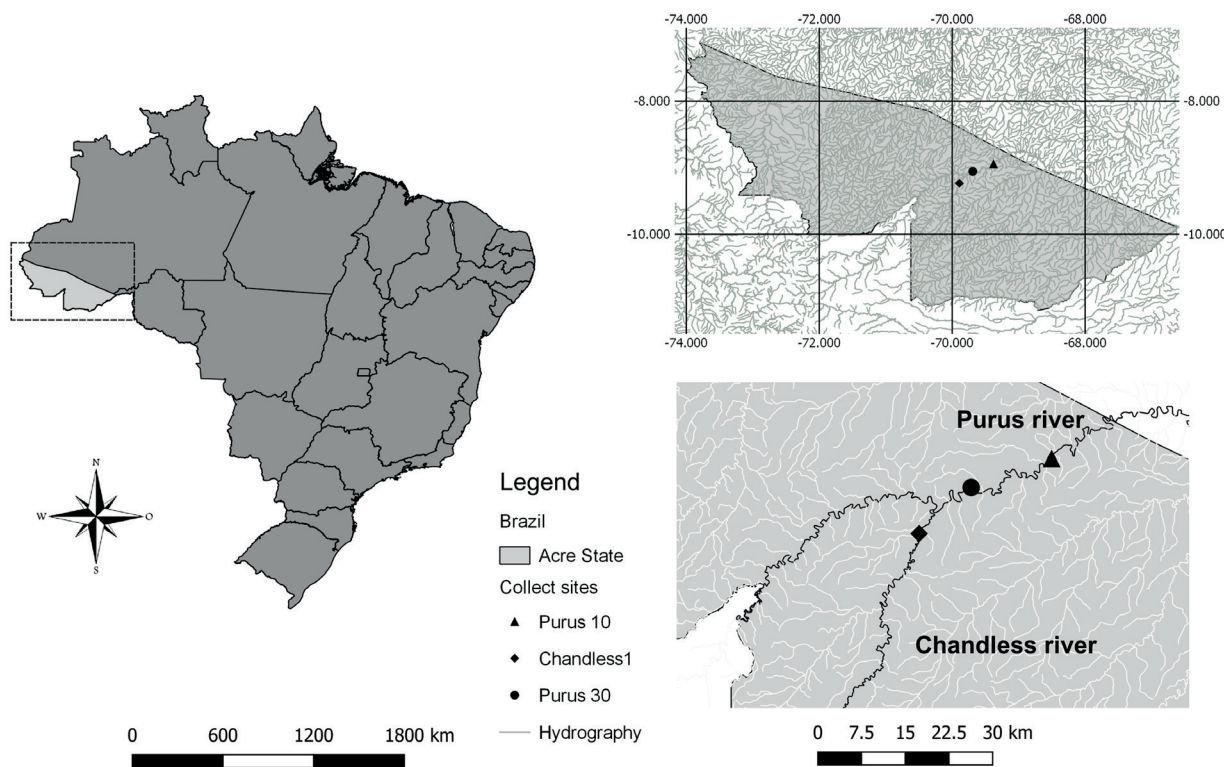


Figure 1. Location of study area and sample points.



Sedimentological description

Nine sediment samples were collected from the Chandless 1 riverbank (9°13'59.2"S - 69°53'36.0"W) (Fig. 2). This showed: basal levels with clayey layers intercalated with organic layers presenting plant remains, superimposed by reddish brown silt sand from 0 to 5 m, and greenish gray to light gray green silty clay with surface bioturbations from 5 to 13 m.; CH1-12 profile was dated with C¹⁴ (level CH1-12 presented an age of 4861 – 5050 cal yrs BP) (Tab. 1).

Table 1. Radiometric datings of rivers bank samples from Chandless and Purus rivers.

Samples	Laboratory Number	Material	Conventional Age (¹⁴ C years BP)	Calibrated Age (cal years BP)
P30-6	Beta - 133338	Plant/Wood	7,140 ± 35	7,845 – 7,998
Ch 1-12	Beta - 133339	Plant/Wood	4,440 ± 25	4,861 – 5,050

From the Purus 10 riverbank (8°56'33.0"S 69°22'47.3"W) (Fig. 2) four sediment samples were collected. The sediment samples collected from the Purus 10 outcrops comprised a reddish paleosol with calcium carbonate concretions occurring on the Solimões Formation, which is overlaid in unconformity by Quaternary alluvial deposits nonconformity. Yellowish brown silty sand with some oxides and a crushed stratification occurred from 0 to 6 m. The alluvial materials of the P-10 profile, were dated with OSL (level P10-3, gave an age of 8200 +/- 605 cal yrs BP) (Tab. 2). The top of the profile is formed for young colluvial material,

Table 2. OLS dating of river bank samples from Purus river.

Sample	Laboratory Number	Aliquots	K(%)	Th (ppm)	U (ppm)	Equivalent Dose (Gray)	Dose Rate (mGray/yr)	Central Model OSL age (yr)
P - 10	BG4071	31/35	1.34 ± 0.01	8.33 ± 0.01	2.18 ± 0.01	18.61 ± 0.86	2.27 ± 0.13	8200 ± 605

sand deposits with coloring ranging from dark brown to brown.

While seven were removed from the Purus 30 locality (river bank) (9°03'15.9"S 69°41'29,9"W) (Fig. 2). The sediment samples collected from the Purus 30 outcrops had intercalations of laminated layers and organic strata with vaportite "leaves" and tree trunks from 0 to 6 m, colluvial material from 6 to 8 m and massive clay sediments from 8 to 14 m. The P-30 profile was dated with C¹⁴ (level P30-6 gave an age of 7845 - 7998 cal yrs BP) (Tab. 1).

Palinological analysis

For the palynological analysis, 19 samples were collected and 2 cm³ of each sample extracted. These samples were then treated with 10% potassium hydroxide (KOH), acetolysized, the bromoform/alcohol density 2.0 solution used to separate the palynomorphs (Erdtman 1960; Kümmel & Raupp 1965; Faegri & Iversen 1989).

Slides were assembled in glycerine gelatin and sealed with paraffin. To identify the pollen types, most references were consulted: Erdtman (1952); Absy (1979); Hooghiemstra (1984); Roubik & Moreno (1991); Carreira *et al.* (1996); Colinvaux *et al.* (1999). The National Research Institute of the Amazon (INPA) Laboratory of Palynology pollen library was also consulted to aid with identification by comparison.

Whenever possible, 300 pollen grains were counted from each sample. Measurements and photomicrographs

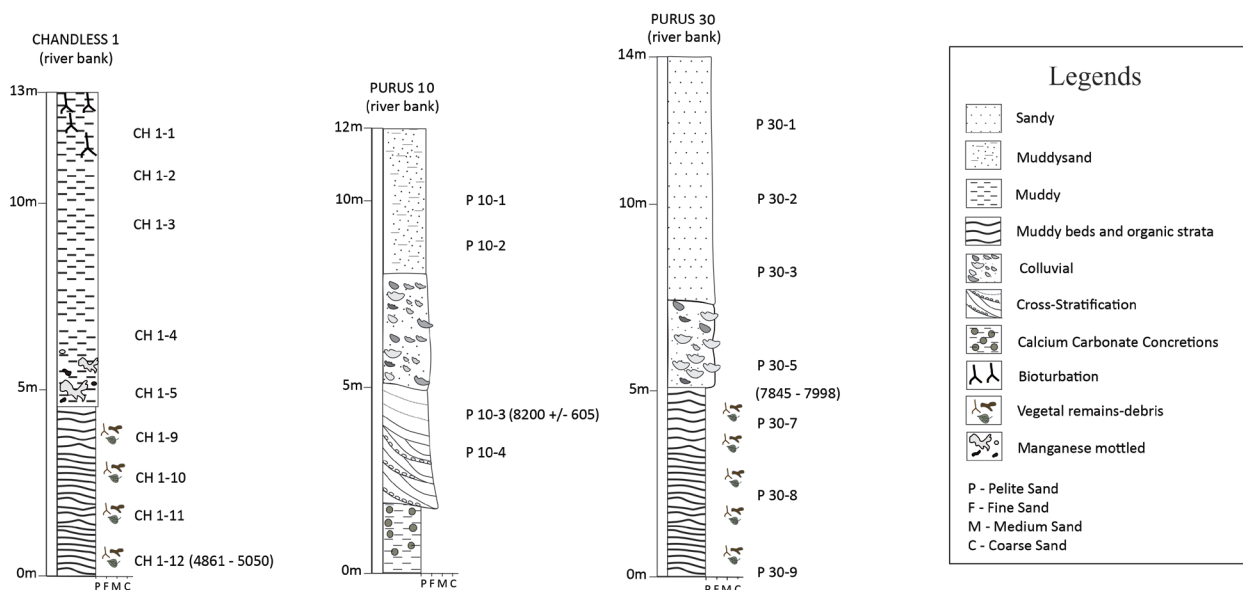


Figure 2. Sedimentar sections of the locations.

were obtained with a microscope (Zeiss-Primo Star Axio CamICc1), and the Axio Vision capture image program.

Pollen grains and spores were described according to pollen dispersion unit, grain size, polarity, symmetry, shape, number, position and character of the openings, exine ornamentation and exosporium (Punt *et al.* 2007). The work follows the classification system of Angiosperm Phylogeny Group – APG IV (APG IV 2016).

Abbreviations used: **Cl**, colpi; **D**, diameter; **E**, equatorial axis; **GEA**, greater equatorial axis; **LEA**, lesser equatorial axis; **Ea**, endoaperture length; **Ex**, exine thickness; **P**, polar axis; **Pr**, pore; **PV**, polar view; **EV**, equatorial view; **Exos**, exosporium; **PPV**, proximal polar view; **DPV**, distal polar view.

Results and discussion

Palynological analysis of the Holocene alluvial sediments from the Chandless and Purus river fluvial terraces resulted in identification of 97 sporo-pollinic types. In this study, 49 types were described: 10 pteridophytes, 39 angiosperms. Information on the location and depth of each sample and palynological descriptions are given below (Figs. 3-9).

The most frequent pollen types found in the samples belonged to the following families: Anacardiaceae, Arecaceae, Combretaceae, Euphorbiaceae, Fabaceae, Polygonaceae, Rutaceae, Amaranthaceae.

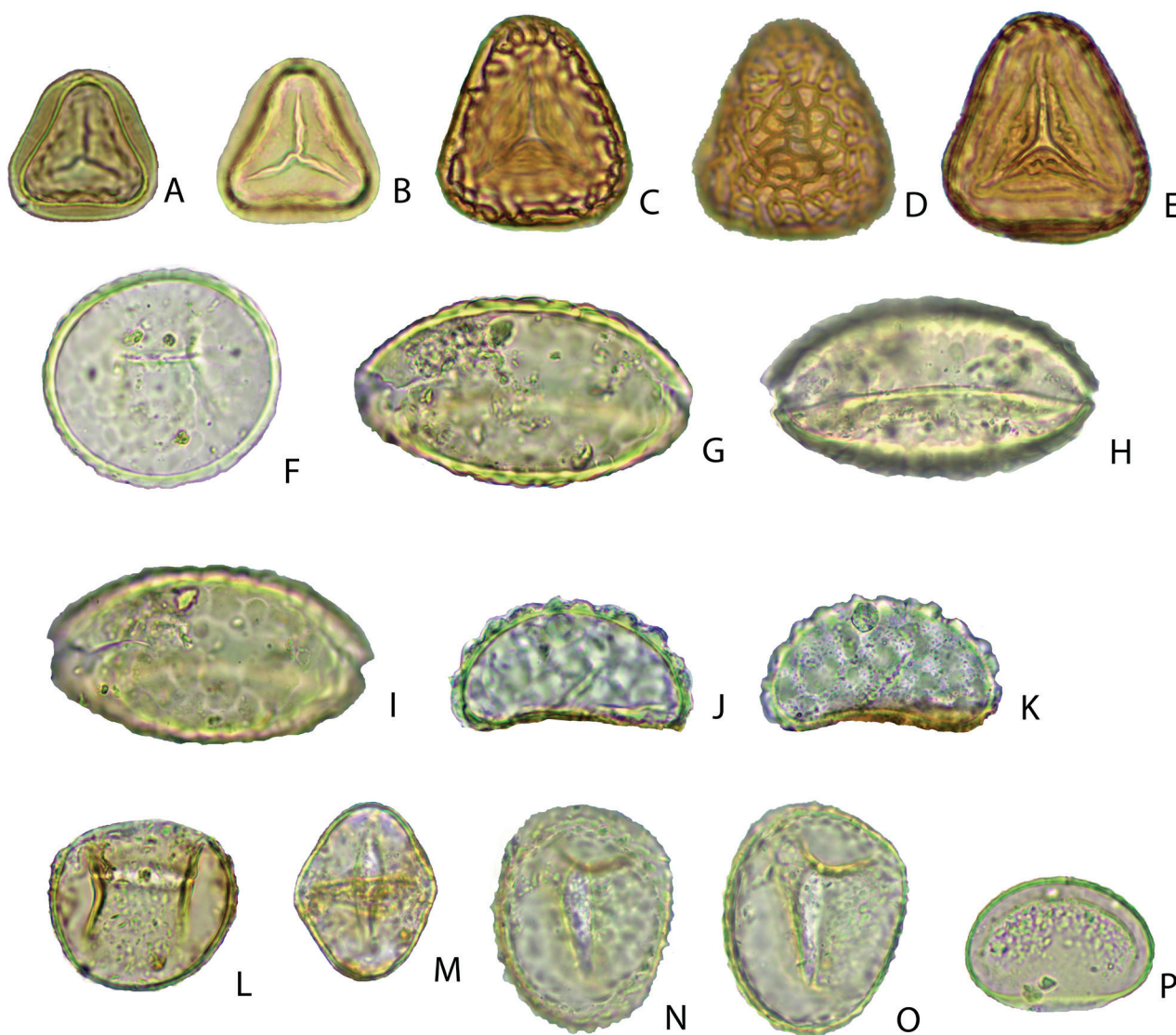


Figure 3. Dennstaedtiaceae: *Microlepia* (A-B); Polypodiaceae: *Pityrogramma* (C-E); Polypodiaceae type 1 (F. VP/ G-I. VE); Polypodiaceae type 2 (J-K); Polypodiaceae type 3 (L. VP/ M. VE); Polypodiaceae type 4 (N-O); Polypodiaceae type 5 (P). Scale = 20 μ .

Pteridophyta

Dennstaedtiaceae Lotsy, 1909

Microlepidia Presl, 1836 (Fig. 3A-B)

Monad; medium; heteropolar; radiosymmetric; trilete; exospore with PPV = laevigate DPV = rugulate; triangular; concave sides; tip rounded.

Dimensions: P = 36.05 μ ; E = 34.37 μ ; Exos = 5.68 μ ; laesura = 17.95 μ ; rugulate = 1.15 μ width and 4.06 μ length.

Location: Chandless 1; 6 m; Blade CH1 – 4 A

Polypodiaceae Presl & Presl, 1822

Pityrogramma type Link, 1833 (Fig. 3C-E)

Monad; medium; heteropolar; radiosymmetric; trilete; exospore with PPV = striate and DPV = fossulate; triangular; concave side; apex rounded.

Dimensions: P = 42.79 μ ; E = 42.71 μ ; Exos = 2.93 μ ; lumen = 4.75 μ ; laesura = 25.3 μ .

Location: Chandless 1; 0.5 m; Blade CH1 – 12 B

Polypodiaceae type 1 (Fig. 3F-I)

Monad; large; isopolar; bilateral; monolete; exospore with PPV and DPV verrucate; elipsoidal.

Dimensions: P = 57.35 μ ; EM = 62.78 μ ; Exos = 0.9 μ ; laesura = 18.66 μ ; verruca 3.43 μ length and 9.56 μ width.

Location: Purus 10; 10 m; Blade P 10 – 1 D

Polypodiaceae type 2 (Fig. 3J-K)

Monad; large; isopolar; bilateral; monolete; exospore with PPV and DPV = verrucate; elipsoidal.

Dimensions: P = 32.72 μ ; EM = 62.68 μ ; Exos = 1.14 μ ; laesura = 25.5 μ ; verruca 4.24 μ length and 9.88 μ width.

Location: Chandless 1; 0.5 m; Blade CH1 – 12 D

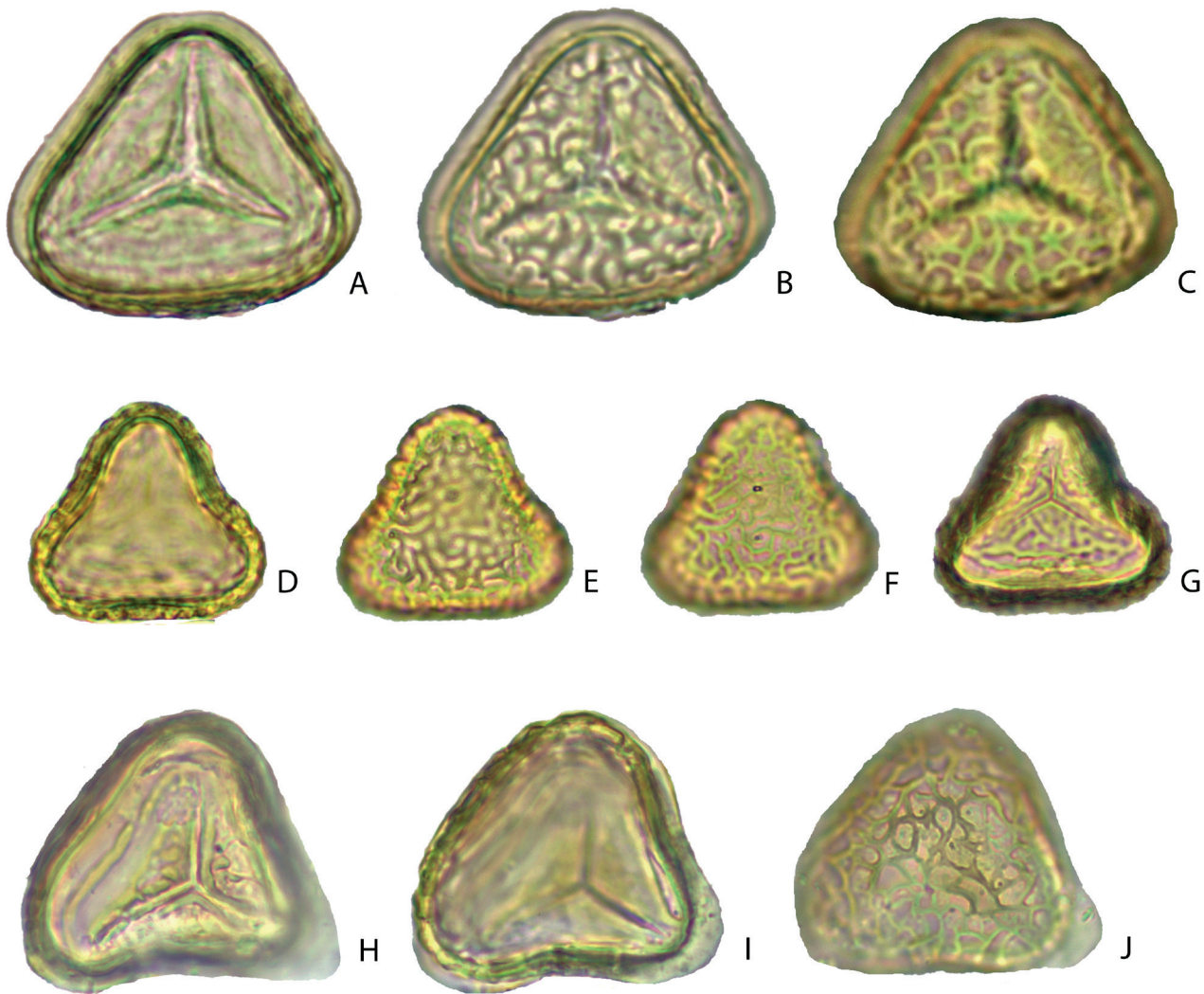


Figure 4. Pteridaceae type (A-C); Trilete type 1 (D-G); Trilete type 2 (H-J). Scale = 20 μ .

Polypodiaceae type 3 (Fig. 3L-M)

Monad; medium; isopolar; bilateral; monolete; exospore with PPV and DPV = finely - verrucate; elipsoidal.

Dimensions: Exos = 0.85 μ ; P = 40.73 μ ; GEA = 44.05 μ ; laesura = 18.95 μ ; finely verrucate 1.53 μ length and 1.76 μ width.

Location: Purus 30; 6 m; Blade P 30 – 5 B.

Polypodiaceae type 4 (Fig. 3N-O)

Monad; large; isopolar; bilateral; monolete; exospore with PPV and DPV = verrucate; elipsoidal.

Dimensions: P = 60.74 μ ; E = 45.88 μ ; Exos = 2.91 μ ; laesura = 29.04 μ ; verruca 1.78 μ length and 3.06 μ width.

Location: Chandless 1; 0.5 m; Blade CH1 – 12 B.

Polypodiaceae type 5 (Fig. 3P)

Monad; medium; isopolar; bilateral; monolete; exospore with PPV and DPV = finely - verrucate; elipsoidal.

Dimensions: P = 31.73 μ ; GEA = 45.09 μ ; Exos = 0.75 μ ; laesura = 20.97 μ ; verruca 1.02 μ length and 2.48 μ width.

Location: Chandless 1; 0.5 m; Blade CH1 – 12 D.

Pteridaceae Kirchner, 1831

Pteridaceae type Kirchner, 1831 (Fig. 4A-C)

Monad; medium; heteropolar; radiosymmetric; trilete; exospore with PPV = striate

DPV = reticulate; triangular; concave side; apex rounded.
Dimensions: P = 48.06 μ ; E = 48.86 μ ; Exos = 4.6 μ ; laesura = 32.77 μ ; lumen = 4.19 μ .

Location: Chandless 1; 6 m; Blade CH1 – 4 A

Trilete type 1 (Fig. 4D-G)

Monad; medium; heteropolar; radiosymmetric; trilete; exospore with PPV = striato – reticulate and DPV= fossulate; triangular; concave side; apex rounded.

Dimensions: P = 34.56 μ ; E = 34,57 μ ; Exos = 3.12 μ ; laesura = 15.17 μ ; lumen = 2.68 μ ; fossula with 2.55 μ length and 3.1 μ width.

Location: Chandless 1; 6 m; Blade CH1 – 4 A.

Trilete type 2 (Fig. 4H-J)

Monad; medium; heteropolar; radiosymmetric; trilete; exospore with PPV = striate and DPV = fossulada; triangular; concave side; apex rounded.

Dimensions: P = 47.57 μ ; E = 46.86 μ ; Exos = 2.97 μ ; laesura = 23.52 μ ; fossula with 2.99 μ length and 4.69 μ width.

Location: Chandless 1; 0.5 m; Blade CH1 – 12 B.

Angiosperms

Amaranthaceae Jussieu, 1789

Alternanthera Fors.1775 (Fig. 5A-B)

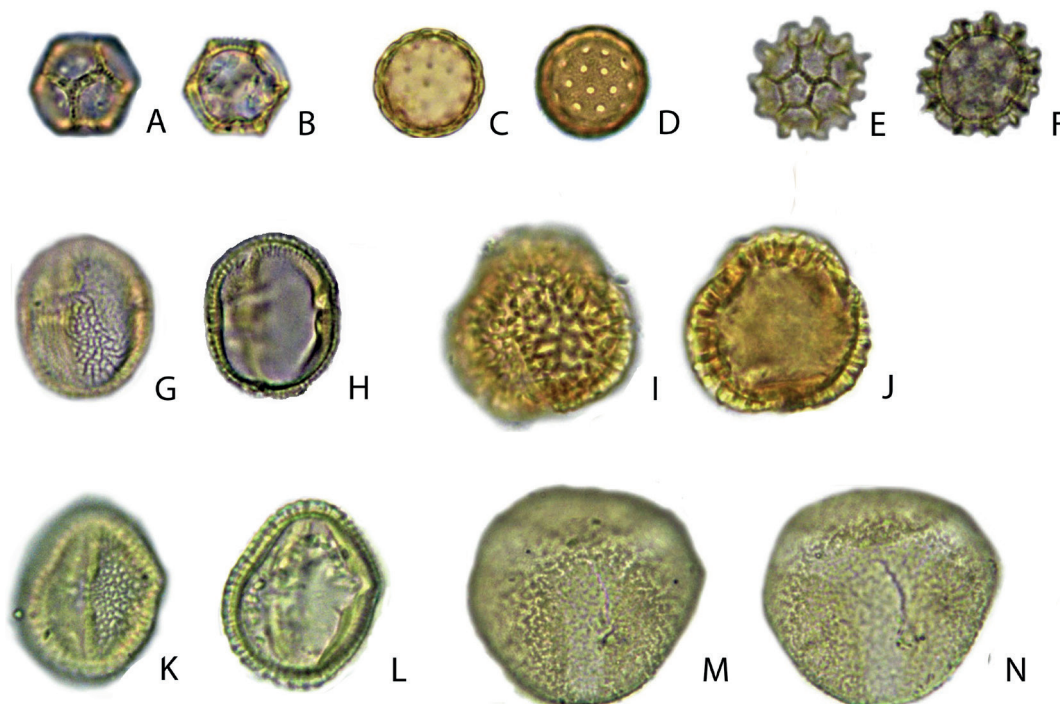


Figure 5. Amaranthaceae: *Alternanthera* (A-B); *Amaranthus* (C-D); *Gomphrena* (E-F); Anacardiaceae: *Astronium* (G-H); Aquifoliaceae: *Ilex* (I-J. VP/ K-L. VE); Arcaceae: *Bactris* (M- N). Scale = 20 μ

Monad; small; apolar; radiosymmetric; periporate; exine granulate-baculate, murus simple baculate with tiny spicules; spheroidal.

Dimensions: P = 15.8 μ x E = 17.5 μ ; P/E = 1 μ ; Ex = 1.9 μ ; Lumen = 6.4 μ .

Location: Chandless 1; 4 m; Blade CH1 – 9B.

Amaranthus Linnaeus, 1753 (Fig. 5C-D)

Monad; medium; apolar; radiosymmetric; periporate; exine baculate; spheroidal. Dimensions: D = or GEA = 29.8 μ ; LEA = 29.2 μ ; Pr = 2.6 μ ; Ex = 2.8 μ .

Location: Chandless 1; 6 m; Blade CH1 – 4B.

Gomphrena Linnaeus, 1753 (Fig. 5E-F)

Monad; small; apolar; radiosymmetric; periporate; exine reticulate – baculate with columellae evident; spheroidal.

Dimensions: GEA = 22.4 μ x LEA = 21.6 μ ; Ex = 3.2 μ .

Location: Chandless 1; 0.5 m; Blade CH1 – 12B.

Anacardiaceae Brown, 1818

Astronium Jacq., 1760 (Fig. 5G-H)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine striate – reticulate; subprolate.

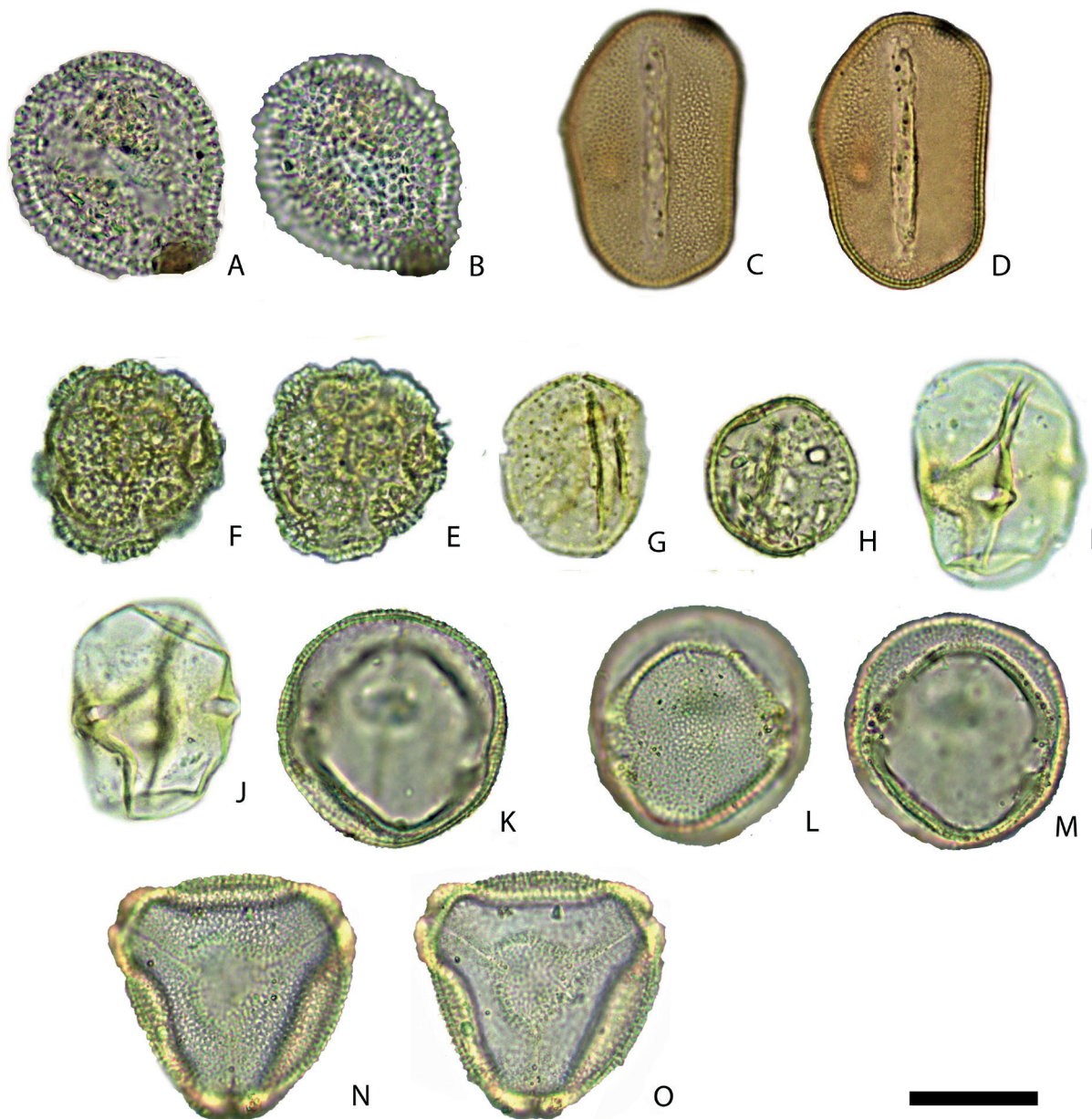


Figure 6. Arecaceae: *Iriarteia* (A-B), *Maximiliana* (C-D); Bignoniaceae: *Mansoa* (E-F); Boraginaceae: Boraginaceae (G), *Cordia* (H); Burseraceae: *Protium* (I-J); Cucurbitaceae: Cucurbitaceae type (K-M. VE/ N-O - VP). Scale = 20 μ .

Dimensions: P = 28.9 μ x E = 23.5 μ ; P/E = 1.2 μ ; Ex = 2.75 μ ; Ea = 3.6 μ .

Location: Chandless 1; 4 m; Blade CH1 – 9B.

Aquifoliaceae Bercht. & J. Presl, 1825

Ilex Linnaeus, 1753 (Fig. 5I-L)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine pilate; subprolate. Dimensions: P = 31.3 μ x E = 25.8 μ ; P/E = 1.2 μ ; Ex = 2.9 μ ; Ea = 5.80 μ .

Location: Chandless 1- 4 m and 0.5m respectively; Blades CH1 – 9D (EV) and CH1 – 12B (PV).

Areceaceae Bercht & Presl, 1820

Bactris Jacq., 1777 (Fig. 5M-N)

Monad; medium; heteropolar; radiosymmetric; Trichotomosulcate; exine reticulate – baculate; oblate spheroidal.

Dimensions: P = 41.6 μ x E = 42,7 μ ; P/E = 0.9 μ ; Ex = 1.4 μ .

Location: Chandless 1; 0.5 m; Blade CH1 – 12B.

Iriarteia Ruiz & Pavón, 1794 (Fig. 6A-B)

Monad; Large; isopolar; radiosymmetric; monosulcate; exine baculate; oblate spheroidal.



Figure 7. Euphorbiaceae: *Acalypha* (A), *Aparisthmium* (B-C), *Micrandra* (D-E), *Nealchornea* type (F-G); Fabaceae: Caesalpinioideae – *Aldina* (H- I. VE/ J-K. VP), Mimosoideae: *Acacia* (L-M), *Pentaclethra* type (N-O), *Piptadenia* type (P); Lecythidaceae: *Eschweilera* (Q-R); Malpighiaceae (S-T). Scale = 20 μ .



Dimensions: P = 54.04; μ x E = 43.91 μ ; P/E = 1.08 μ ;
Ex = 2.4 μ .

Location: Purus 10.10 m, Blade P10 – 1F.

Maximiliana Mart, 1824 (Fig. 6C-D)

Monad; large; heteropolar-bilateral; monosulcate; exine reticulate; homobrochate; Prolate.

Dimensions: P = 58.8 μ x E = 35.6 μ ; P/E = 1.6 μ ; Sulcus = 41.3 μ ; Ex = 1.8 μ .

Location: Chandless 1; 6 m; Blade CH1 – 4A.

Bignoniaceae Jussieu, 1789

Mansoa Cand., 1838 (Fig. 6E-F)

Monad; medium; apolar; asymmetric; pantocolpate; exine reticulate with heterobrochate areas with murus simplibaculate; prolate spheroidal. Dimensions: GEA= 39.2 μ x LEA = 31.7 μ ; P/E = 1,2 μ ; Ex=1.1 μ ; Lumen = 12.2 μ .

Location: Chandless 1 – 0.5 m; Blade CH1 – 12D.

Family Boraginaceae Jussieu, 1789

Boraginaceae (Fig. 6G)

Monad; medium; isopolar; radiosymmetric; tricolporate; reticulate–echinate; subprolate. Dimensions: P = 38.6 μ x E = 28.9 μ ; P/E = 1.3 μ ; Ex = 1.2 μ .

Location: Chandless 1 - 4 m; Blade CH1 – 9E.

Cordia Linnaeus, 1753 (Fig. 6H)

Monad; medium; isopolar; radiosymmetric; monoporate; exine echinate; spheroidal. Dimensions: GEA = 32.9 μ x LEA = 31.9 μ ; P/E = 1 μ ; Ex = 1.8 μ .

Location: Chandless 1 - 4 m; Blade ; CH1 – 9D.

Burseraceae Kunth, 1824

Protium Burm, 1768 (Fig. 6I-J)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine finely reticulate; subprolate.

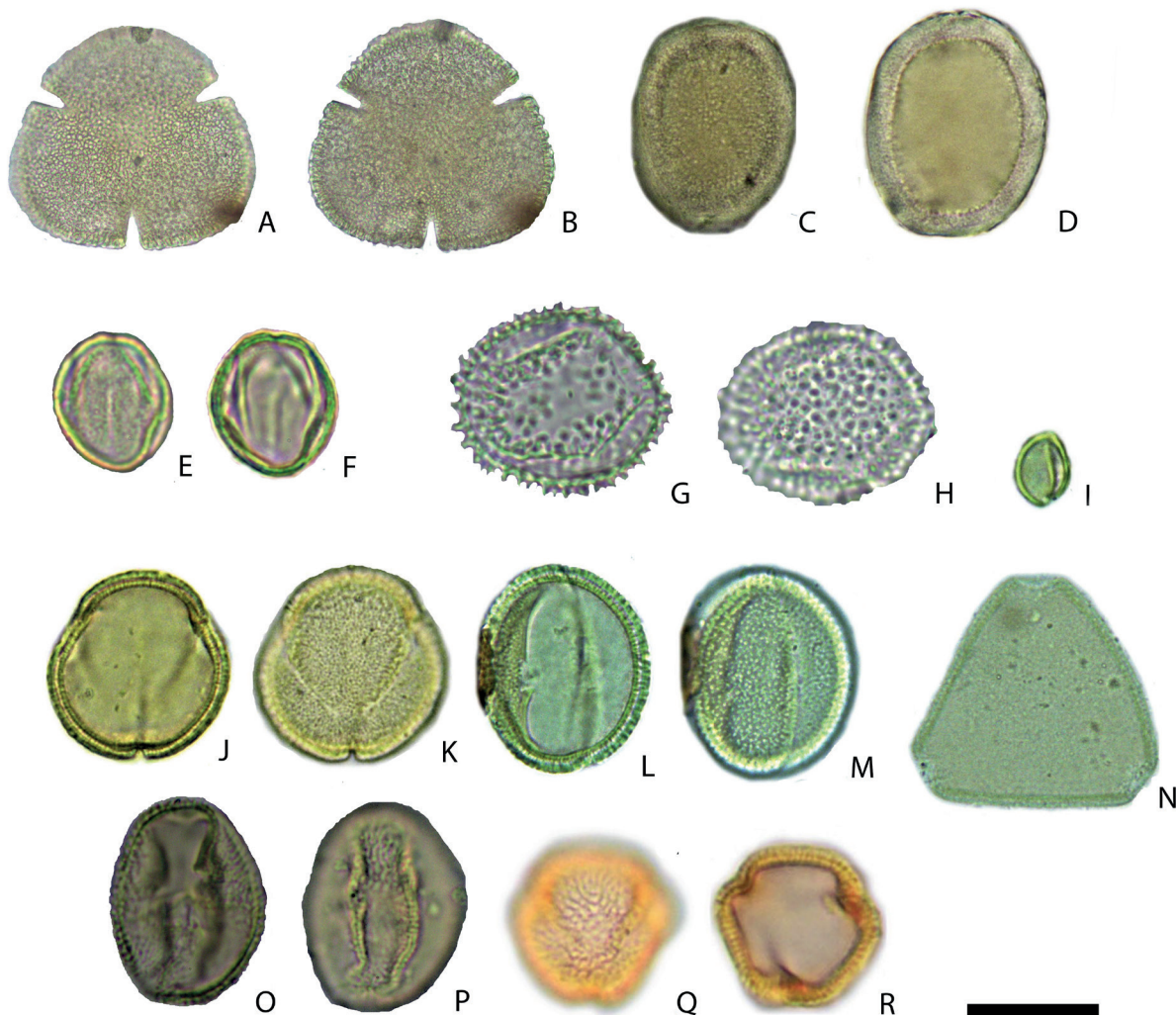


Figure 8. Malvaceae: *Pseudobombax* (A-B); Marantaceae (C-D); Melastomataceae: *Bellucia* (E-F); Picrodendraceae: *Piranhea* (G-H); Piperaceae: Piper (I); Polygonaceae: *Triplaris* (J-K . VP/ L-M. VE); Proteaceae: *Roupala* (N); Rutaceae: *Zanthoxylum* (O-P. VE/ Q-R. VP). Scale = 20 μ .

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Dimensions: $P = 47.1 \mu \times E = 36.1 \mu$; $P/E = 1.3 \mu$; $Ex = 1 \mu$; $Ea = 8.8 \mu$; $Cl = 40.9 \mu$.

Location: Chandless 1- 4 m; Blade CH1 – 9D.

Cucurbitaceae Jussieu, 1789

Cucurbitaceae type Jussieu, 1789 (Fig. 6K-O)

Monad; large; isopolar; radiosymmetric; tricolporate; exine microreticulate – heterobrochate; spheroidal.

Dimensions: $P = 59.03 \mu \times E = 56.86 \mu$; $P/E = 1.03 \mu$; $Ex = 2.61 \mu$; $Ea = 12.8 \mu$; $Cl = 34.5 \mu$.

Location: Purus 10; 3 m; Blade P 10 – 4O

Euphorbiaceae Jussieu, 1789

Acalypha Linnaeus, 1753 (Fig. 7A)

Monad; small; isopolar; radiosymmetric; zonocolporate; exine escabrata; suboblate.

Dimensions: $P = 17.05 \mu \times E = 18.06 \mu$; $P/E = 0.9 \mu$; $Ex = 1.5 \mu$; $Pr = 2.2 \mu$.

Location: Chandless 1- 4 m; Blade CH1 – 9B.

Aparisthium Endl., 1840 (Fig. 7B-C)

Monad; small; isopolar; radiosymmetric; tricolporate; exine reticulate- rugulate; oblate spheroidal.

Dimensions: $P = 20.5 \mu \times E = 19.6 \mu$; $P/E = 1 \mu$; $Ex = 1.4 \mu$.

Location: Chandless 1 - 6 m; Blade CH1 – 4A.

Micrandra Bentham, 1854 (Fig. 7D-E)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine reticulate – clavate; prolate.

Dimensions: $P = 47.4 \mu \times E = 33.6 \mu$; $P/E = 1.4 \mu$; $Ex = 3.5 \mu$; $Cl = 37.5 \mu$.

Location: Chandless 1 - 0 m; Blade CH1 – 12C.

Nealchornea type Huber, 1913 (Fig. 7F-G)

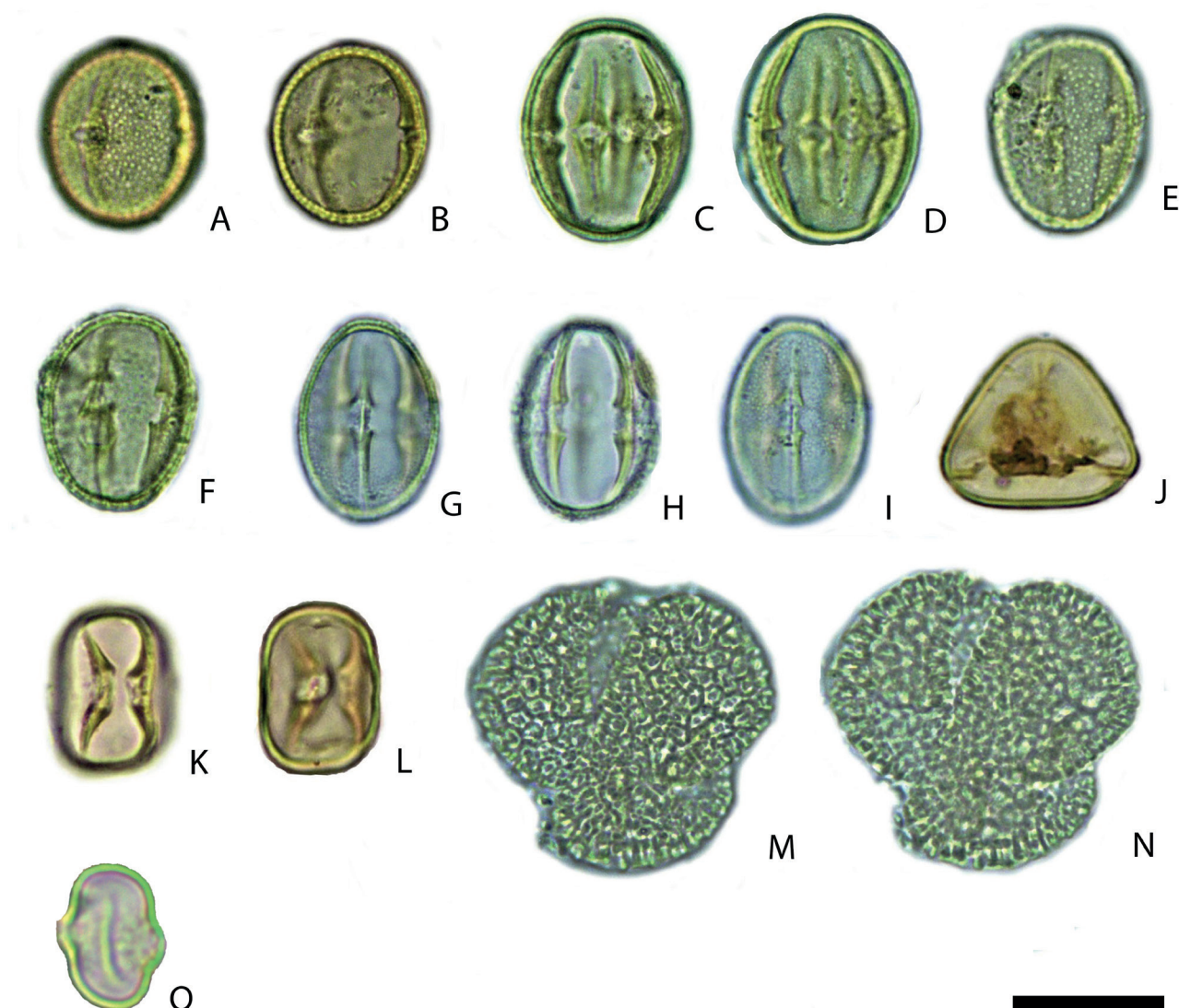


Figure 9. Salicaceae: Salicaceae (A – B), *Casearia* (C – D), *Laetia* (E – F), *Ryania* (G, H, I); Sapindaceae (J); Sapotaceae: *Pouteria* (K – L); Turneraceae (M – N); Urticaceae: *Cecropia* (O). Scale = 20 μ .

Monad; medium; isopolar; radiosymmetric; tricolporate; exine reticulate – simplicolumellate; spheroidal – prolate spheroidal.

Dimensions: P = 46.06 μ x E = 41.96 μ ; P/E = 1.09 μ ; Ex = 3.03 μ ; Lumen = 6.52 μ .

Location: Chandless 1 - 6 m; Blade CH1 – 4 A.

Fabaceae Lindley, 1836

SubFamily Caesalpinioideae

Aldina Endlicher, 1840 (Fig. 7H-K)

Monad; small; isopolar; radiosymmetric; tricolporate; exine reticulate; spheroidal. Dimensions: P = 20.9 μ x E = 19.6 μ ; P/E = 1.0 μ ; Ex = 1.6 μ .

Location: Chandless 1 - 0 m, Blade CH1 – 12B.

SubFamily Mimosoideae

Acacia Milleer, 1754 (Fig. 7L-M)

Polyad; medium; isopolar; radiosymmetric; inaperturate; exine psilate; spheroidal to prolate - spheroidal. Dimensions: GEA = 35.7 μ x LEA = 31.5 μ ; Ex = 1 μ .

Location: Chandless 1 - 0 m, Blade CH1 – 12D.

Pentaclethra type Bentham, 1840 (Fig. 7N-O)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine microreticulate; spheroidal.

Dimensions: P = 45.02 μ x E = 41.7 μ ; P/E = 1.07 μ ; Ex = 3.3 μ ; Cl = 24.18 μ .

Location: Chandless 1 – 3.5 m; Blade CH1 – 10 D.

Piptadenia type Bentham, 1840 (Fig. 7P)

Polyad; small; isopolar; radiosymmetric; inaperturate; psilate; spheroidal.

Dimensions: GEA = 19.35 μ ; LEA = 18.56 μ ; Ex = 0.83 μ .

Location: Purus 10 - 3 m; Blade P 10 – 4D.

Lecythidaceae Richard 1825

Eschweilera Martius, 1828 (Fig. 7Q-R)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine reticulate – homobrochate; prolate.

Dimensions: P = 36.7 μ x E = 25.9 μ ; P/E = 1.4 μ ; Ex = 2.4 μ ; Cl = 29.2 μ .

Location: Chandless 1 - 4 m; Blade CH1 – 9B.

Malpighiaceae Jussieu., 1789

Malpighiaceae (Fig. 7S-T)

Monad; medium; apolar; asymmetric; pantoporate; exine psilate; spheroidal.

Dimensions: D = 33.9 μ ; Ex = 3.7 μ ; Pr = 5.3 μ .

Location: Chandless 1 - 0,5m; Blade CH1 – 12C.

Malvaceae Jussieu, 1789

Pseudobombax Dugand, 1943 (Fig. 8A-B)

Monad; large; isopolar; radiosymmetric; tricolporate; exine reticulate- homobrochate; oblate spheroidal.

Dimensions: P = 97.2 μ x E = 99.53 μ ; P/E = 0.97 μ ; Ex = 4.9 μ .

Location: Purus 10 - 10 m; Blade P 10 – 1 A.

Marantaceae Brown, 1814 (Fig. 8C-D)

Marantaceae (Fig. 4G-H)

Monad; large; apolar; asymmetric; inaperturate; exine finely reticulate; subprolate.

Dimensions: P = 51.6 μ x E = 40.9 μ ; P/E = 1.2 μ ; Ex = 5.7 μ .

Location: Chandless 1; 0.5 m; Blade CH1 – 12B.

Melastomataceae Jussieu, 1789

Bellucia Necker, 1838 (Fig. 8E-F)

Monad; small; isopolar; radiosymmetric; heterocolpate; exine finely granulate – tectate; prolate spheroidal.

Dimensions = 20.08 μ x E = 17.71 μ ; P/E = 1.13 μ ; Ex = 1.1 μ ; Cl = 12.65 μ .

Location = Purus 30 - 0 m; Blade P 30 – 9A.

Picrodendraceae Samll, 1917

Piranhea Baillon, 1866 (Fig. 8G-H)

Monad; medium; isopolar; radiosymmetric; pantoporate; reticulate with spines of various sizes or echinate; spheroidal.

Dimensions: D = 33.47 μ ; Ex = 1.53 μ ; Thickness = 2.07 μ height.

Location: Purus 10 - 10 m; Blade P 10 – 1F.

Piperaceae Giseke, 1792

Piper Linnaeus, 1753 (Fig. 8I)

Monad; small; heteropolar; bilateral; monocolpate; exine psilate; subprolate. Dimensions: P = 13.6 μ x E = 10 μ ; P/E = 1.3 μ .

Location: Chandless 1 - 4 m; Blade CH1 – 9C.

Polygonaceae Jussieu, 1789

Triplaris Loeffl., 1758 (Fig. 8J-M)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine reticulate – baculate, heterobrochate; subprolate.

Dimensions: P = 45.9 μ x E = 38,7 μ ; P/E = 1.1 μ ; Ex = 4.8 μ ; Ea = 5.3 μ .

Location: Chandless 1; 0.5 m; Blade CH1 – 12C.

Proteaceae Jussieu., 1789

Roupala Aublet, 1775 (Fig. 8N)



Monad; large; isopolar, radiosymmetric; triporate; exine reticulate – homobrochate; suboblatae.

Dimensions: $P = 46.5 \mu \times E = 51.8 \mu$; $P/E = 0.8 \mu$; $Ex = 2,8 \mu$; $Pr = 7.3 \mu$.

Location: Chandless 1 – 3.5 m; Blade CH1 – 10C.

Rutaceae Jussieu, 1789

Zanthoxylum Linnaeus, 1753 (Fig. 8O-R)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine striate – reticulate, homobrochate; subprolate.

Dimensions: $P = 28 \mu \times E = 20.7 \mu$; $P/E = 1.3 \mu$; $Ex = 1.7 \mu$; $Ea = 1.1 \mu$.

Location: Chandless 1 – 0.5 m; Blade CH1 – 12B.

Salicaceae Mirbel, 1815

Salicaceae (Fig. 9A-B)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine reticulate – homobrochate; prolatespheroidal.

Dimensions: $P = 32.3 \mu \times E = 27.2 \mu$; $P/E = 1,1 \mu$; $Ex = 2.7 \mu$; $Ea = 6.5 \mu$ and $Cl = 22.4 \mu$.

Location: Chandless 1 - 4 m; Blade CH1 – 9B.

Casearia Jacq., 1760 (Fig. 9C-D)

Monad; medium; isopolar; radiosymmetric; zonocolporate; exine finely reticulate; subprolate.

Dimensions: $P = 38.5 \mu \times E = 28.8 \mu$; $P/E = 1.3 \mu$; $Ex = 2.3 \mu$; $Cl = 29.4 \mu$; $Ea = 8 \mu$.

Location: Chandless 1 – 0.5 m; Blade CH1 – 12C.

Laetia Loef., 1759 (Fig. 9E-F)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine reticulate – heterobrochate; subprolate.

Dimensions: $P = 35.3 \mu \times E = 27.7 \mu$; $P/E = 1.2 \mu$; $Ea = 5.4 \mu$.

Location: Chandless 1- 3.5 m; Blade CH1 – 10D.

Ryania Vahl, 1796 (Fig. 9G-I)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine reticulate – homobrochate; prolate.

Dimensions: $P = 36.2 \mu \times E = 25.4 \mu$; $P/E = 1.4 \mu$; $Ex = 1.9 \mu$; $Ea = 6 \mu$; $Cl = 30.2 \mu$.

Location: Chandless 1 - 4 m, Blade CH1 – 9B.

Sapindaceae Jussieu, 1789

Sapindaceae (Fig. 9J)

Monad; medium; isopolar; radiosymmetric; tricolporate; exine psilate; triangular –oblate spheroidal.

Dimensions: $P = 31.1 \mu \times E = 34.1 \mu$; $P/E = 0.9 \mu$; $Ex = 1.8 \mu$.

Location: Chandless 1- 0.5 m; Blade CH1 – 12B.

Sapotaceae Jussieu., 1789

Pouteria Aublet, 1775 (Fig. 9K-L)

Monad; small; isopolar; radiosymmetric; tricolporate; exine psilate; prolate. Dimensions: $P = 23.5 \mu \times E = 16.5 \mu$; $P/E = 1.4 \mu$; $Ex = 1.7 \mu$; $Ea = 3.8 \mu$; $Cl = 16.8 \mu$.

Location: Chandless 1 – 0.5 m; Blade CH1 – 12B.

Turneraceae Kunth, 1828

Turneraceae (Fig. 9M-N)

Monad; large; isopolar; radiosymmetric; tricolporate; exine reticulate – heterobrochate; oblate spheroidal.

Dimensions: $P = 50.4 \mu \times E = 53 \mu$; $P/E = 0.9 \mu$; $Ex = 5 \mu$; $Cl = 23.7 \mu$.

Location: Chandless 1 – 3.5 m; Blade CH1 – 10D.

Urticaceae Jussieu, 1789

Cecropia Loefling, 1758 (Fig. 9O)

Monad; small; isopolar; radiosymmetric; diporate; exine finely granulate; prolate.

Dimensions: $P = 14.05 \mu \times E = 10.27 \mu$; $P/E = 1.36 \mu$; $Ex = 0.88 \mu$; $Pr = 2.65 \mu$.

Location: Purus 30 - 4 m; Blade P 30 – 7 A.

Final considerations

The current vegetation covering the riverbanks was confirmed by pollen diversity recorded. The identified taxa were mainly represented by: Polypodiaceae (Pteridophyte spores), Amaranthaceae, Anacardiaceae, Arecaceae Euphorbiaceae, Fabaceae, Polygonaceae, Rutaceae (pollen types).

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