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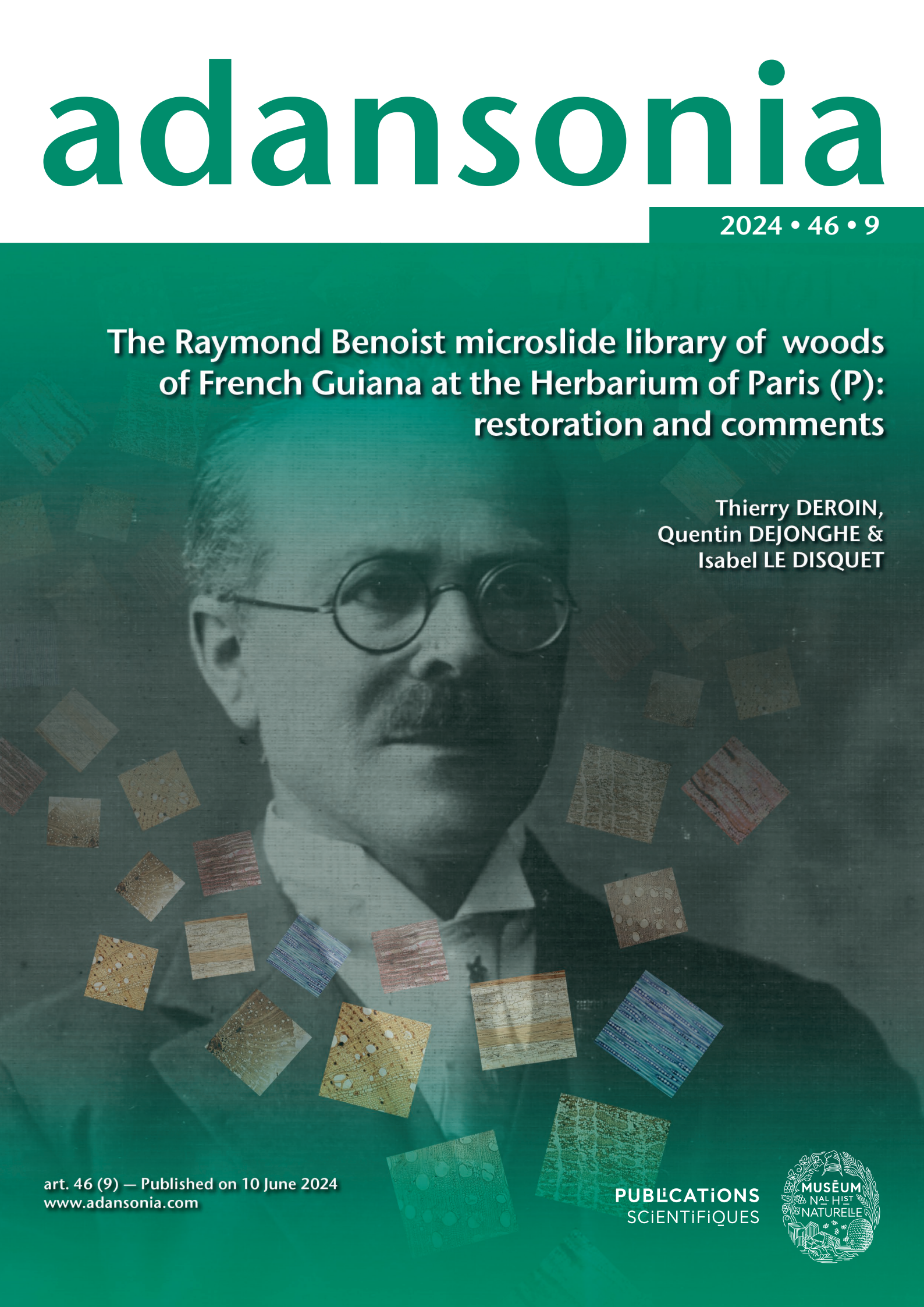

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ABSTRACT
Few attention has been paid to collections of plant anatomy gathered since more than a century and half, even if they are referential for classical published works and an iconographical source, which might be enhanced by modern microscopical imagery and the databases interconnection. The main hindrance is their unachieved or deteriorated mounting, as well as poor keeping, resulting in a very weak availability to botanists and other concerned people. Here we propose a simple restoration schedule for Phanerophytes, applied to a collection of histological sections from French Guiana. Results and prospects are briefly commented.

KEY WORDS
French Guiana, collection enhancement, microscope slides, restoration schedule, xylology.

RÉSUMÉ
L'histothèque des bois de Guyane de Raymond Benoist à l'Herbier de Paris (P) : restauration et commentaires.
Les collections d'anatomie végétale constituées depuis plus d'un siècle et demi ont peu retenu l'attention, même lorsqu'elles sont les références d'ouvrages classiques et une source iconographique qui pourrait être revalorisée par l'imagerie microscopique actuelle et l'interconnexion des bases de données. Le principal obstacle est dans leur montage souvent incomplet ou détérioré et leur conditionnement peu satisfaisant, rendant leur accessibilité très faible aux botanistes et autres personnes intéressées. Nous proposons ainsi un protocole simple de restauration – le premier chez des Phanérophytes – d'une collection de coupes histologiques de Bois de Guyane française. Nous commentons brièvement les résultats et les perspectives.

MOTS CLÉS
Guyane française, lames de microscopie, protocole de restauration, valorisation des collections, xylologie.

Fig. 1. — Raymond Benoist (1881-1970): **A**, portrait of *c.* 1930, Muséum national d'Histoire naturelle ©; **B**, a tray with the arrangement of slides of wood until 2021.

INTRODUCTION

During the years 1913 and 1914, the botanist and hymenopterist Raymond Benoist (1881-1970, Fig. 1 ; Leandri 1970) collected in the French Guiana *c.* 450 woody species, whose trunk reached at least 20 cm in diameter and studied wood anatomy for 123 species, completed by 34 species from a previous collection by Mélinon. Twenty years later, all these xylological results were published in a book, with 58 black-and-white photographic plates at a fixed magnification of 30 (Benoist 1933). Moreover, the author provided a lot of informations about the wood structure and properties as well as local uses. All the samples – specimens and histological sections – were deposited in the herbarium (barcodes are given in Figs 4-6) and xylarium of P, allowing thus any systematic check or revision. The gathering was achieved with the technical support of local prison system (especially the convicts in different fieldworks) – heartily acknowledged with some humour for its kind reception – and the encouragements of Prof. Henri Lecomte, who was undertaking at the same time a wide review of Indochinese woods, mainly collected by Auguste Chevalier and associates.

R. Benoist yielded very few information about the making of his slides (Benoist 1933: 15, only 6 lines). All wood

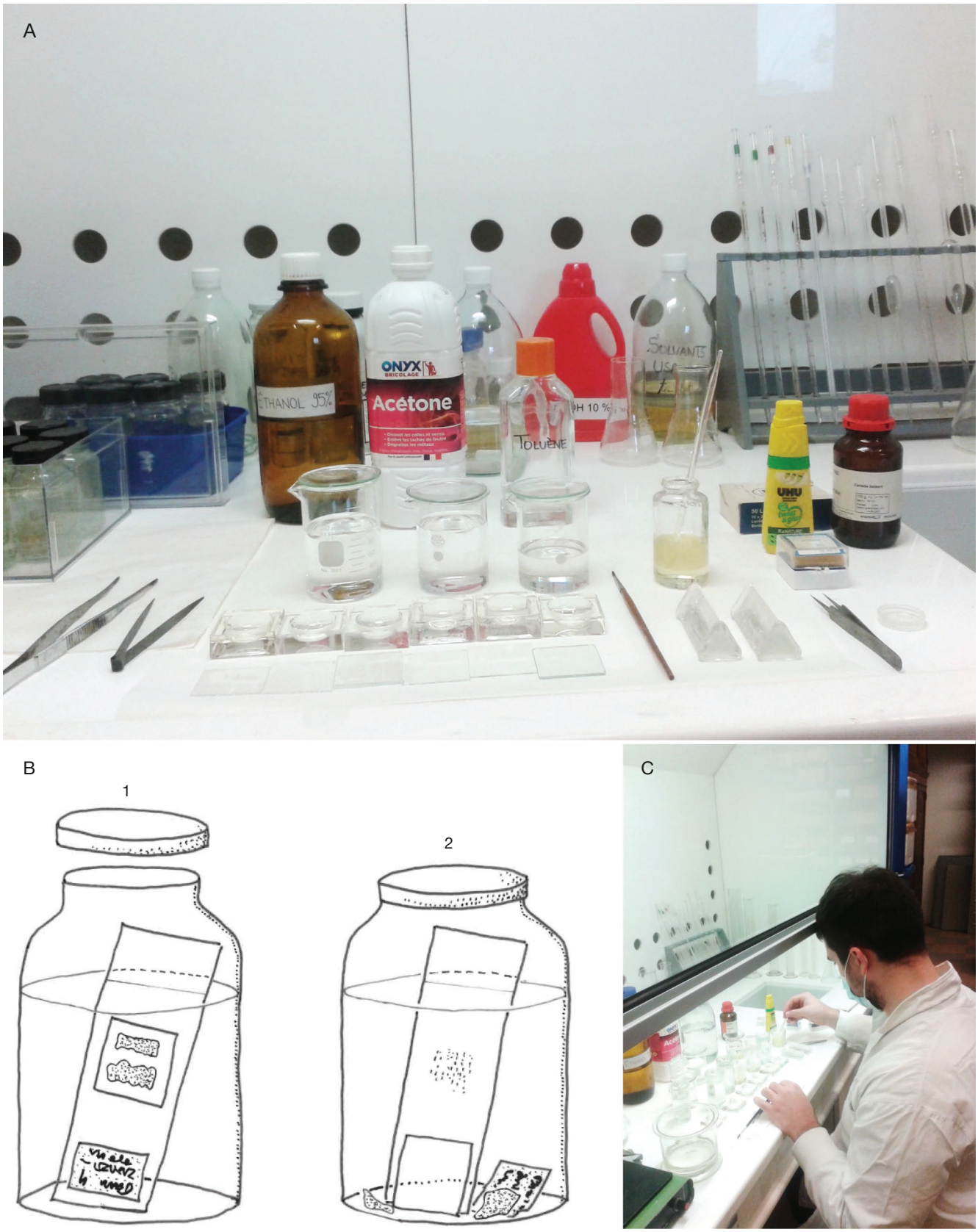

Fig. 2. — Restoration process at the lab: **A**, restoration battery of histological slides; **B**, dismantling process of mounting: **1**, slide in cold water; **2**, removal of section, label and coverslip after 24-48 h at 60°C; **C**, dehydration and remounting of specimens under the extractor hood.

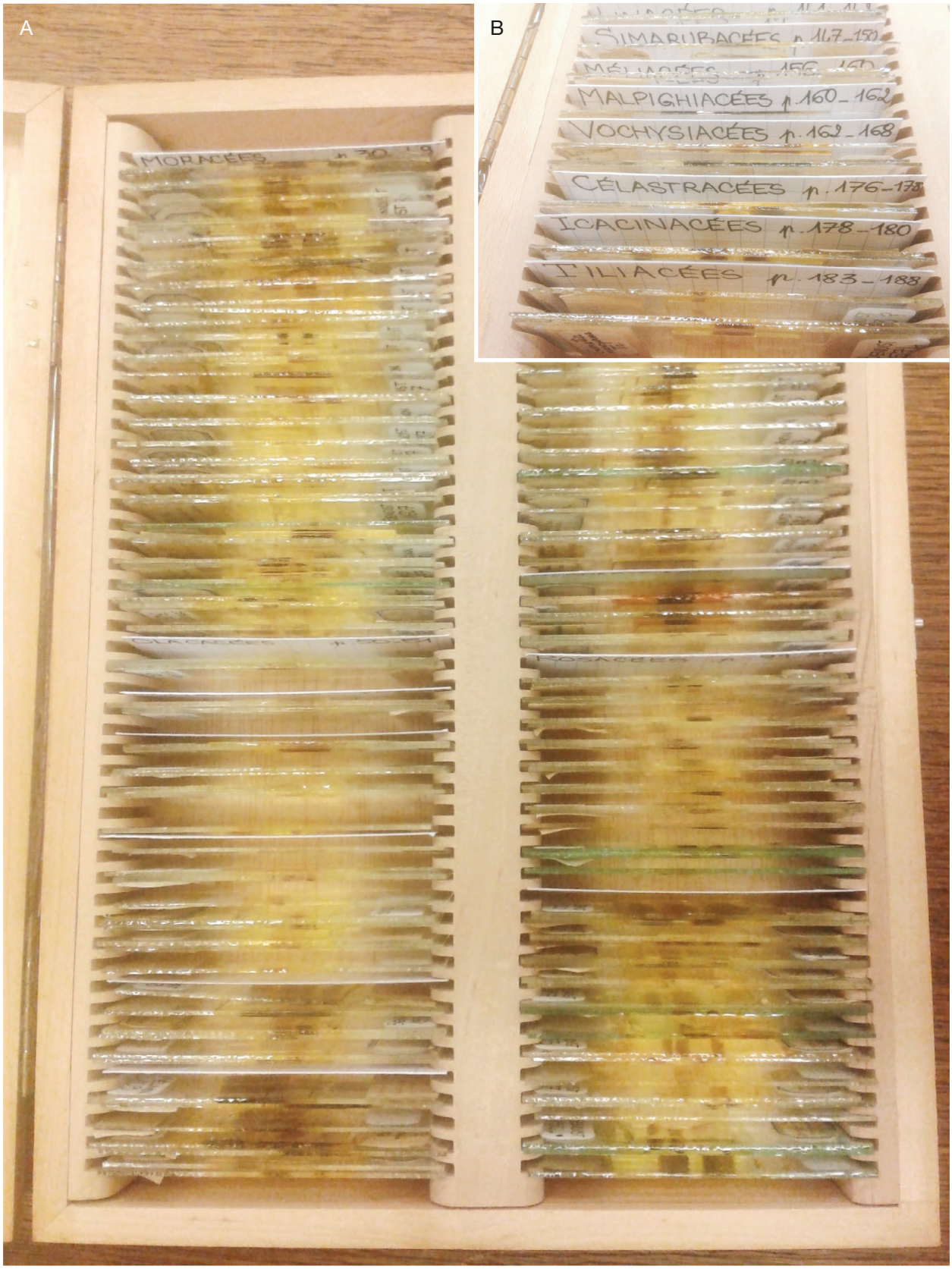

Fig. 3. — Views of the Benoist slide collection as kept at P (present arrangement).

samples were cut in transverse and tangential sections by a razor, possibly with a hand microtome in some cases. Although never described in detail, some barks were cut too. No section was stained (except for *Capparis maroniensis* Benoist (synonym of *Neocalyptrocalyx maroniensis* (Benoist) Cornejo & Iltis, see below), but retained its original colour after drying. As usual, sections were put between slide and coverslip 20 × 20 mm, but as temporary mountings allowing observations and photographs, dried out yet after more than 80 years. Different mediums were likely used: mixture of glycerol and water, perhaps gum Arabic with chloral, and in peculiar cases glycerol and gelatine reduced to small yellowish sticky patches. Slides were fortunately further kept horizontally on trays, thus preventing any disorder. All labels were moreover filled in, well-written with India ink on a firm paper sticked by gum Arabic. Surprisingly the slides of *Neocalyptrocalyx (Capparis) maroniensis* were yet stained and mounted in Canada Balsam (Fig. 6A, B), suggesting a permanent reference collection was planned. Of course, the restoration of such a collection is a crucial technical step before any further slides digitalization. The authors then plan to develop an appropriate restoration protocol.

RESTORATION SCHEDULE

Water dismantling (Fig. 2B)

1) Each microslide is put label at the bottom in a small (100 ml) bottle, then soaked with tap water, tightly closed and kept in an oven at 60°C during 48 h.

2) In most cases, label, coverslip and sections come off the slide and fall to the bottom. In other cases, sections remained sticked on the slide and coverslip is sometimes to be gently removed by tweezers.

Dehydration and remounting (Fig. 2C)

Each slide is processed at once. Labels and free cleaned slides are dried on a heating table at 50°C. As a rule, all coverslips are damaged and should be replaced, sometimes by 32 × 22 mm coverslips, really appropriate for large and numerous sections.

Sections are recovered and dehydrated by Ethanol 95%, Acetone and Toluene (two baths of each in saltcellars, the whole process under hood spends *c.* 6 min). They are transferred by flat tweezers or a brush, then arranged in a large drop of rather fluid Canada Balsam, left on the original slide by a glass rod, at last the new coverslip, whose the size might be more suitable, is put down. After a quick microscopical check (especially bubbles and overlapping of sections), the original label is sticked again with a vinylic glue. All the restored slides are put in an oven at 45°C, during at least three weeks, becoming firm enough for keeping them in wooden rack boxes. When sticked sections cannot be safely removed from the slide either by tweezers or brush, it is then better to dehydrate the whole slide in borrels. Sticked and free sections from a same slide should be dealt in parallel and gathered together on the final mounting. The same careful approach might be used when several slides are sticked together. Finally in scarce cases the dismantling is not feasible, due to excess medium (glycerol-gelatine) which became insoluble after more than eighty years, it is preferable to dry the whole slide and to seal with nail varnish.

SOME INTERESTING MOUNTINGS

All the 284 restored slides (from 84 species) were ordered following the book of Benoist (1933), each label reminding the family and corresponding pages (Fig. 3B). It is noteworthy that at least *c.*110 slides (concerning 49 species, most of them are Fabaceae) were "lost" or rather removed and never returned, while *c.* 21 slides (among them 8 Annonaceae) were not cited. The taxonomical updating of the labels is made easier both by our SONNERAT database built up on the P herbarium and a recent annotated checklist of tree species of French Guiana (Molino *et al.* 2022).

As expected, the mounting in Canada Balsam improves greatly the microscopical examination of sections (Figs 4-6) allowing to complete the original descriptions of Benoist. Early and late woods are often well-distinguished (Fig. 4A, E), sometimes with thin boundaries (Fig. 6A). In *Lecythis poiteaui* (Fig. 5A) the banded apotracheal axial parenchyma is obvious, while tyloses are seen in vessels. Paratracheal parenchyma might be thoroughly described (Figs 4A; 6B). Damages are rather limited to some clefts in tissues as seen in *Vouacapoua americana* (Fig. 4C), but are not drawbacks for histology. Rays are very easy to analyse, as uniseriate (Fig. 4B, 6C) or multiseriate (Figs 4D, F; 5B-D). The main hindrance is the lack of any radial section in the whole collection, thus affording no detailed observation of wall pits, which are now considered as significant xylological features. This kind of presentation – only based on transversal and tangential sections – follows that of the contemporary wood studies of Emile Perrot (1921), although the processes used by Benoist were much less sophisticated.

Despite their fragmentation, the bark mountings (Figs 5E, F; 6D-F) might be considered as preliminary materials for further studies.

DISCUSSION

Worldwide, natural history collections house millions of microslides with entire specimens, body parts of a specimen, or histological sections for both reference and research purposes (Brown 1997; Neuhaus *et al.* 2017; Schmid *et al.* 2021). Their long-lasting conservation often needs process for restoration that constitutes a major deal to keep in good state very valuable research specimens.

The occurrence of dried temporary mounts is often recognized in the old botanical slide libraries. In fact they exhibit a research work at different stages. When conveniently labelled – or when references may be retrieved with

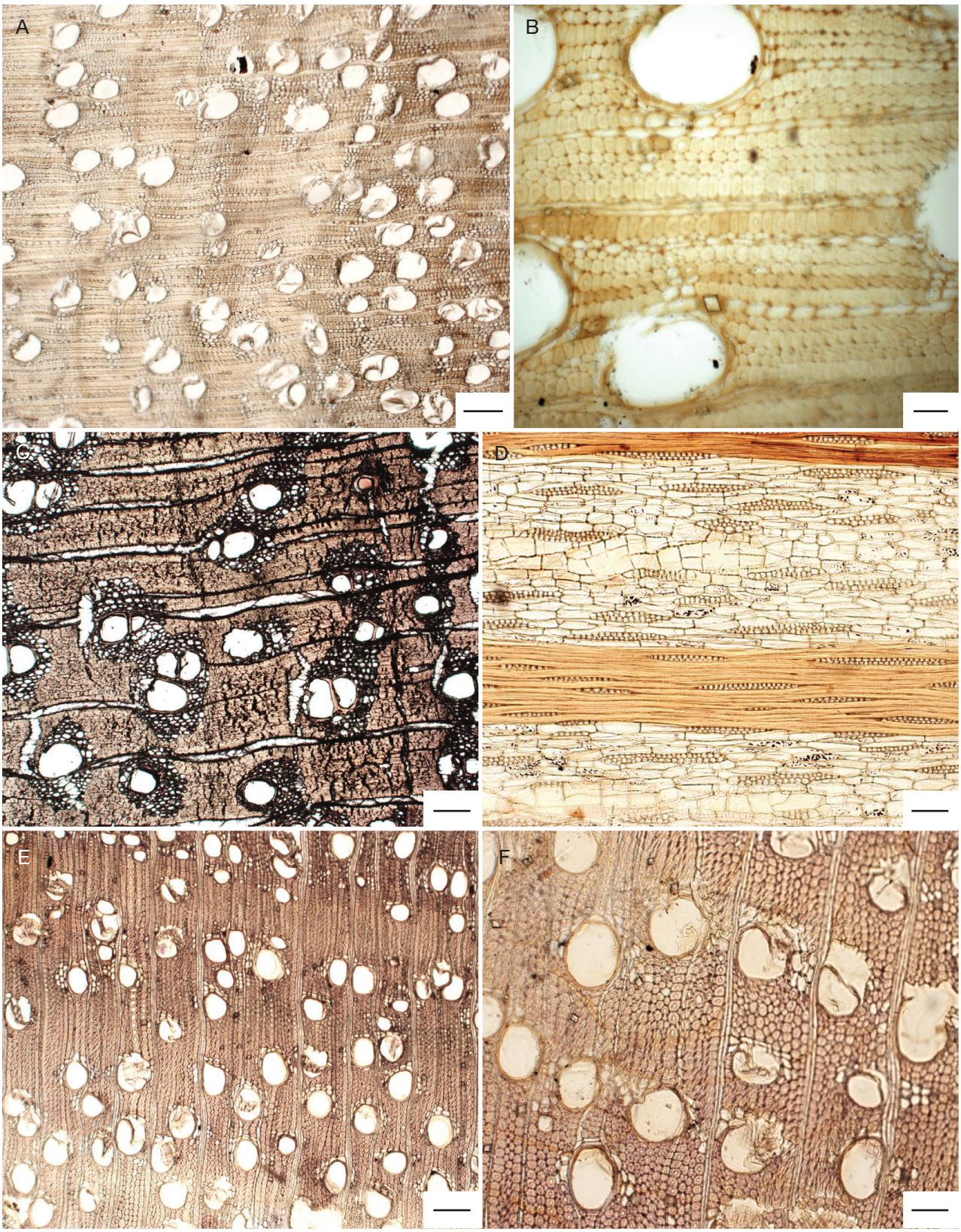

FIG. 4. — Xylem details: **A**, **B**, *Roucheria calophylla* Planch. (synonym of *Hebepetalum humiriifolium* (Planch.) Benth. & Hook.f. ex B.D. Jacks., det. by D. Sabatier 1996, *Benoist 1582* [P04755674]) transverse sections; **C**, **D**, *Vouacapoua americana* Aubl. (*Mélinon 596 23* [P00793775]), transverse and tangential sections; **E**, **F**, *Aspidosperma album* (Vahl) Benoist ex Pichon (*Benoist 331* [P00402200]). Scale bars: A, C, E, 200 µm; B, 50 µm; D, F, 100 µm.

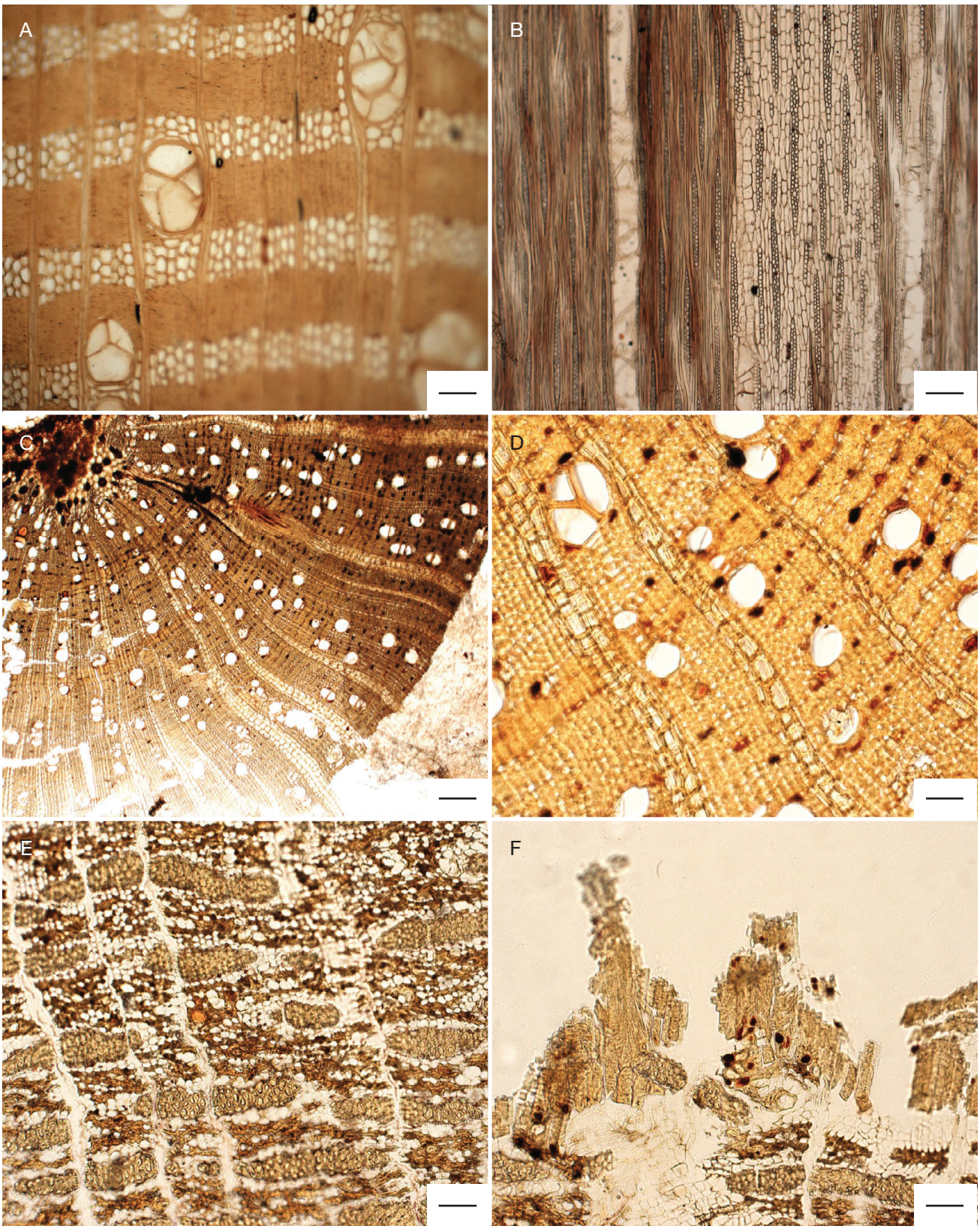

Fig. 5. — Histological details: xylem: **A**, **B**, *Lecythis poiteaui* Berg (*Benoist 192* [P04543005]), transverse and tangential sections; **C**, **D**, *Unonopsis rufescens* (Baill.) R.E. Fries (*Benoist 1267* [P02132803]), transverse sections; bark: **E**, **F**, *Enterolobium schomburgkii* (Benth.) Benth. (*Benoist 133* [P00199488]), phelloderm and phellem. Scale bars: A, E, F, 100 µm; B, C, 200 µm; D, 50 µm.

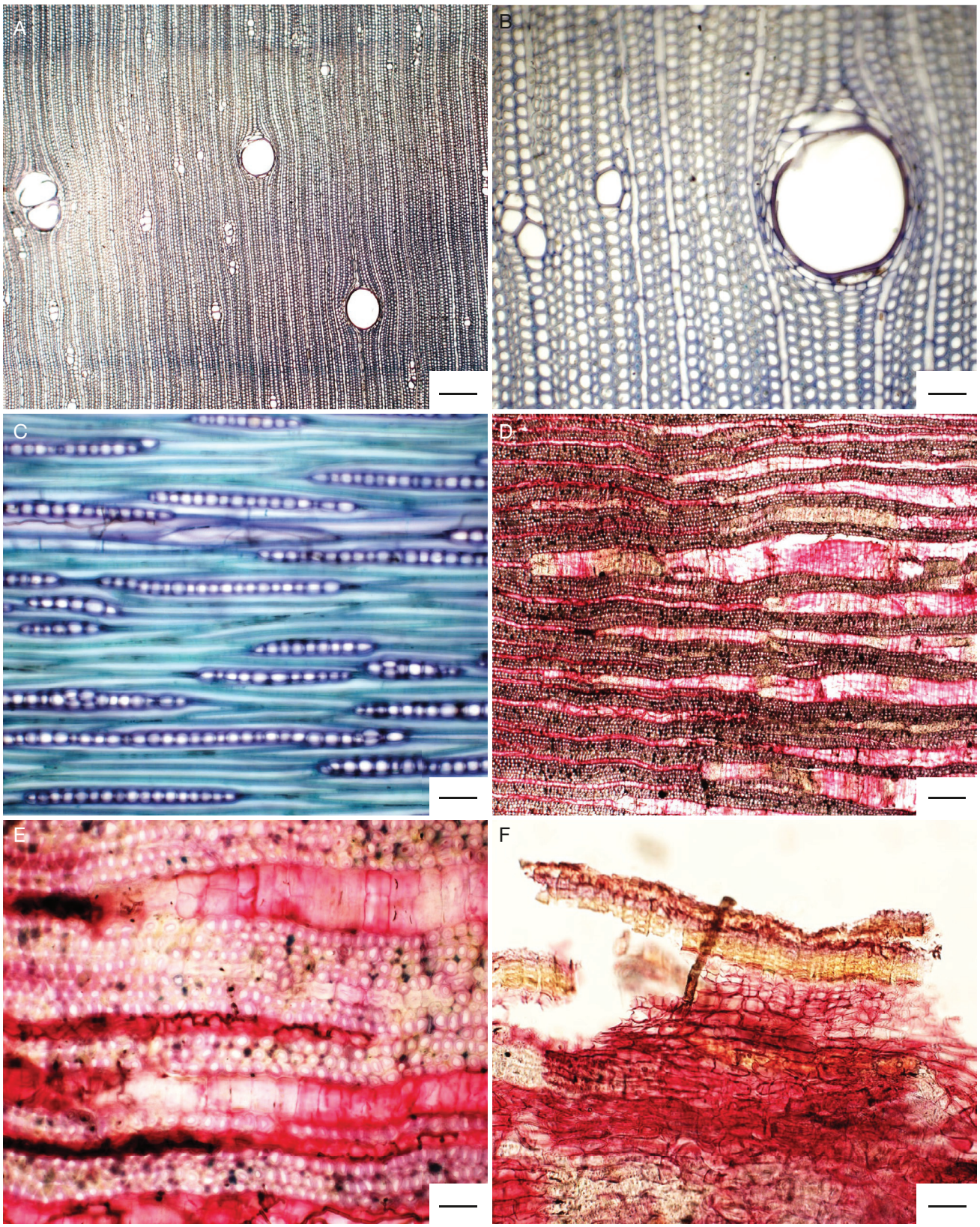

Fig. 6. — Histological details in *Capparis maroniensis* Benoist (synonym of *Neocalyptrocalyx maroniensis* (Benoist) Cornejo & Iltis, after Molino *et al.* 2022: 412, *Benoist 698* [P05427765]), stained by an Alum Carmine/Iodine Green combination, xylem: **A**, **B**, transverse sections; **C**, tangential section; bark: **D**, **E**, phelloderm; **F**, phellem. Scale bars: A, D, 200 µm; B, C, E, F, 50 µm.

confidence – it is useful to have a simple, quick and safe schedule for their restoration, even for repairing some spoiled specimens in an otherwise well-mounted range. As tested on zoological data by Schmid *et al.* (2021), the Canada balsam remains one of the longest lasting media for mounting compared to other ones which degrade to unusable microslides within a few years. We follow here the same principles of dismantling as those set out by Neuhaus *et al.* (2017: 128), but avoiding the use of all the tools essential for dealing the zoological – usually more complex and fragile – mountings. In the same scope of easiness, we did not use any enzyme treatment for cleaning the sections from remnants of old mounting medium, as successfully done by Garner & Horie (1984) for entire mosses. Hot water appeared to be enough and more delicate for thin sections.

Such kind of process is mandatory for published studies, allowing a perpetuation of reference collections (Schmid 1976), which are commonly the unique iconographical source for some seminal plant anatomical papers (e.g., those of P. Van Tieghem, see Deroin *et al.* 2018), moreover often including several mountings from nomenclatural types (e.g., in Decary collection, see Deroin *et al.* 2012).

During this work another wood collection (*c.* 150 slides) from Ecuador by R. Benoist was retrieved and might be restored with the schedule proposed here, although we have only herbarium numbers written on the slides, without any label and no published support. The link with other available databases could hardly be re-established in some cases. This stacking of different series of mountings at various status is a common feature in old collections and should be tackled carefully.

CONCLUSION

An easy histological slides restoration schedule is for a first time applied to the Phanerophytes. Such an approach was already followed on several zoological groups (Neuhaus *et al.* 2017), and even in the case of soil invertebrates leads to images database (Decker *et al.* 2018). Here, the proposed protocol is the basic step to develop a virtual microscopic slides collection closely linked to the sheets of the P herbarium.

In the case of the Benoist's slide library the ethnobotanical and industrial interest is obvious, as was yet reminded by Gazel (1990), and should be further strengthened by improvements in timber development, especially in an environmental scope. That justifies fully the maintenance of such a collection.

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