Identifying the presence of vegetative parenchyma

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Despite the ubiquity of underground storage organs (USOs), or 'roots and tubers', in global economies today, and the links drawn between the early use and cooking of these plants and hominin evolution, there is little archaeological evidence for their past use. This is because, as amorphous structures, constituted in most part by homogenous starchy packing cells, known as 'vegetative parenchyma', fragments of USOs have historically been overlooked in archaeological deposits or, if recognised, considered too difficult to identify.

The following is a *very* basic guide to recognising vegetative parenchyma in charred plant macrofossil assemblages. It is not meant as a comprehensive guide to identification, but as a starting point to recognising the presence of vegetative parenchyma and its analytical potential. Most of the techniques discussed build directly from the work of Jon Hather (1993, 2000). They are illustrated with archaeological specimens from Madjedbebe rockshelter and with modern plant reference specimens from northern Australia. All these specimens were collected on Mirarr Country with the express permission of the Mirarr people and the Gundjeihmi Aboriginal Corporation. The modern reference specimens were collected under the guidance and employing the Traditional Ecological Knowledge of Mirarr elder, May Nango, and Nawarddeken elder, Djaykuk Djandjomerr. Where possible plants are referred to by their scientific name, Kundjeihmi[1] name, and English name.

Parenchyma

Parenchyma is the botanical term for relatively undifferentiated tissue, composed of many similar thin-walled cells. Parenchyma cells are often broadly isodiametric, or spherical, in shape and appear to 'pour' around other tissue within a plant body (see Figs 1 and 2). These cells are ubiquitous in fleshy organs, such as fruits, roots and stems, and are often used to store starches (see Fig. 1). Woods, leaves and flowers also contain parenchyma. However, parenchyma cells in these plant tissues are often more sparsely spaced and specialised than in USOs and fruit flesh.

Archaeological USO fragments: morphological and anatomical identification

Most USO macrofossils found archaeologically are recovered highly fragmented (see Figs 3 and 4). Their identification is therefore often dependant on anatomical analysis, including the presence, patterning, and composition of a number of anatomical features. However, the presence of surface morphology, such as skin texture, and the presence of rootlets or attachment scars (see Figs 5 and 6), found on some fragments and can be very helpful in the identification process.

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1. Kundjeihmi is the dialect of the Bininj Kunwok traditionally spoken by the Mirarr peoples.

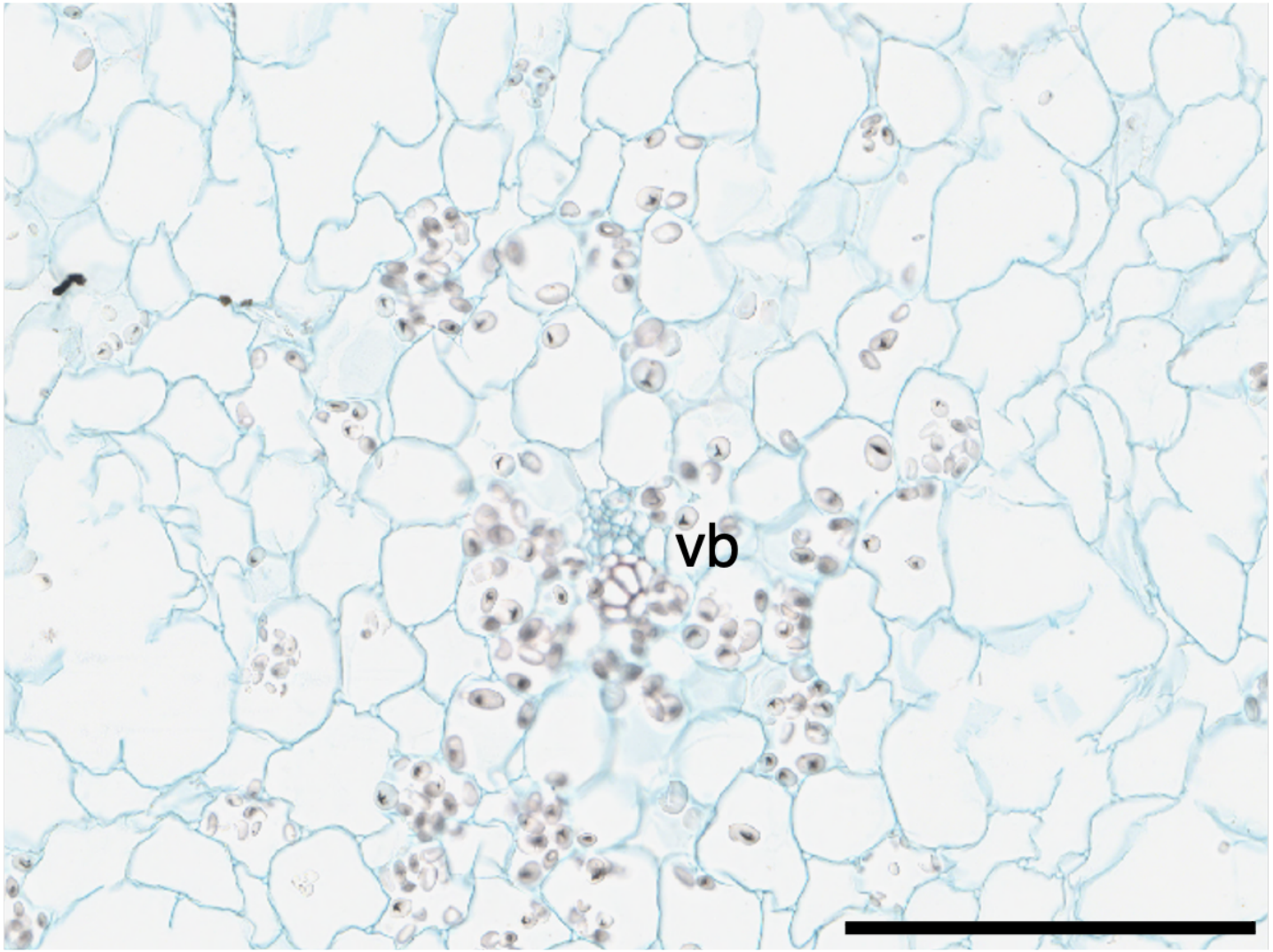

Figure 1: Thin section of the transverse section of a *Dioscorea transversa* (karrbarda or long yam) rhizome, displaying large thin-walled parenchyma cells and a vascular bundle (vb), including xylem (red cells) and phloem (small blue cells), and starch grains (clear, broadly oblong structures within parenchyma cells); scale bar is 500µm.

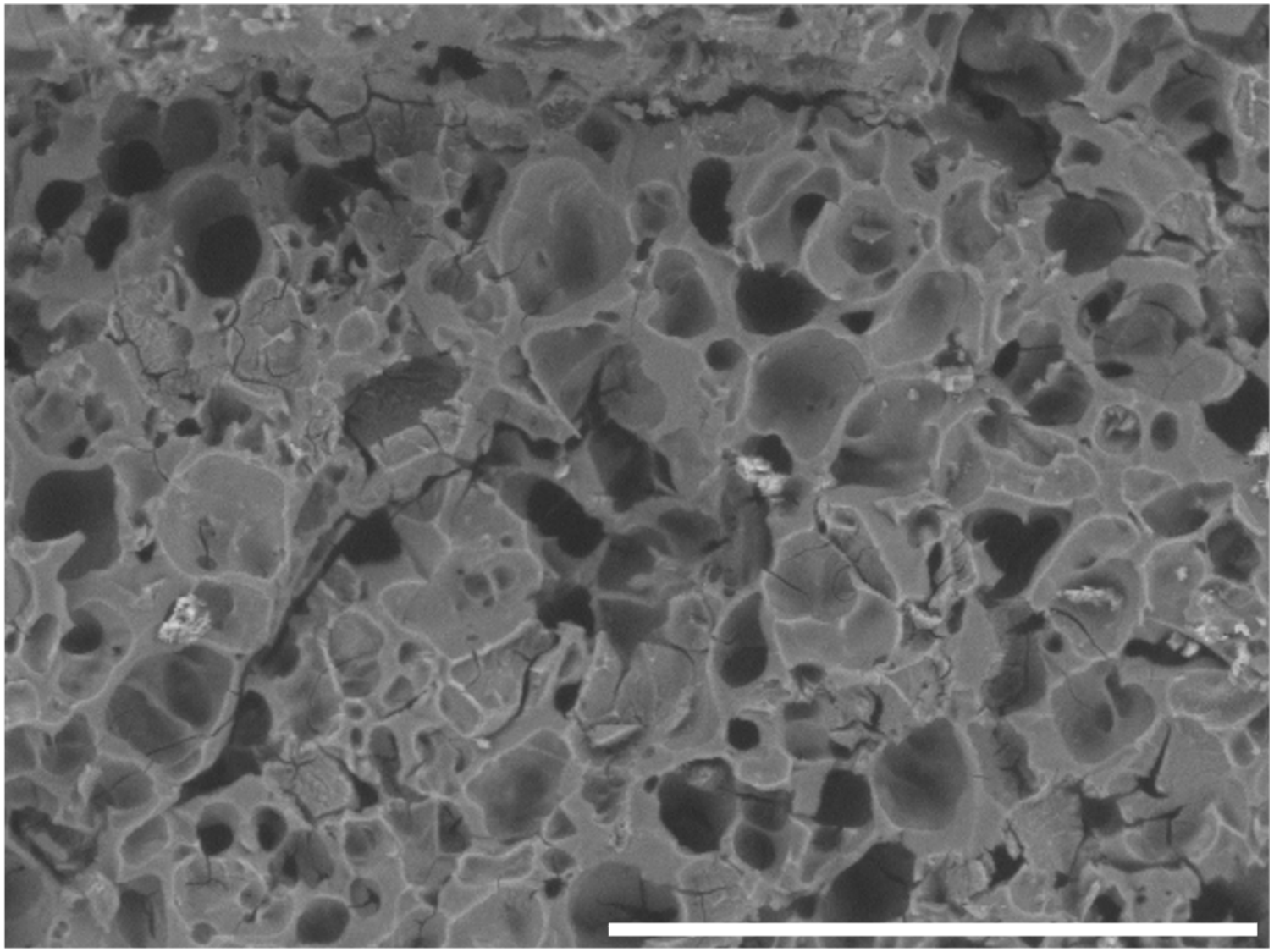

Figure 2: Scanning electron micrograph of archaeological charred vegetative parenchyma from Madjedbebe; scale bar is 500µm.

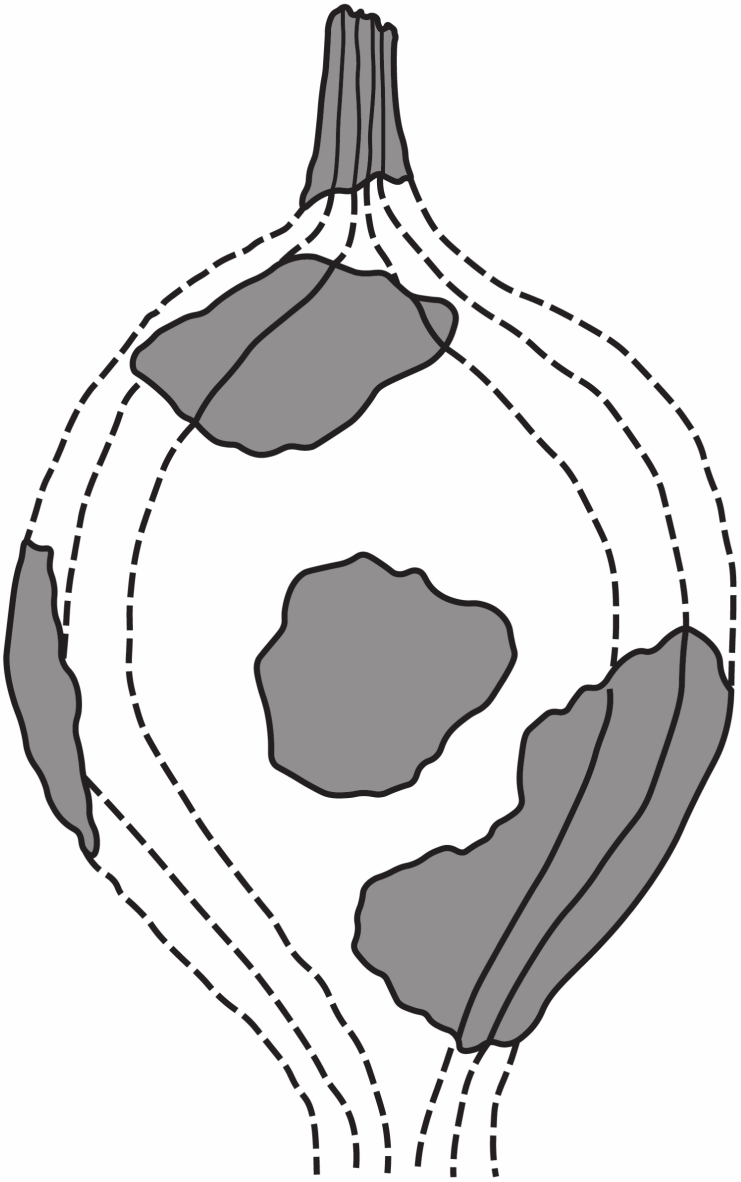

Figure 3: Diagram showing the possible origin of archaeological fragments from an underground storage organ, adapted from Hather (2000).

One of the most helpful anatomical features for the identification of USOs are their vascular tissue (i.e., the xylem and phloem tissues that circulate water and nutrients through the plant). Some of the arrangements of vascular tissue are specific at a Family or genus level. Figures 7 and 8 show the characteristic vascular bundles of an archaeological *Nymphaea* sp. (waterlily) stem fragment and a modern reference *Nymphaea violacea* stem, respectively. The air duct positioned between the two closed collateral vascular bundles is diagnostic of this family (Nymphaeaceae). Its location in northern Australia, where no other genera of Nymphaeaceae are found, allowed for the identification of the archaeological specimen from Madjedbebe as *Nymphaea* sp. stem tissue. (Note, however, the sharper angles on the cells of the archaeological vascular bundle. This is likely an effect of partial drying prior to charring; the cells constricting in shape with water loss.) However, the vascular bundles alone may not allow for identification of an archaeological parenchyma fragment to Family, genus or species.

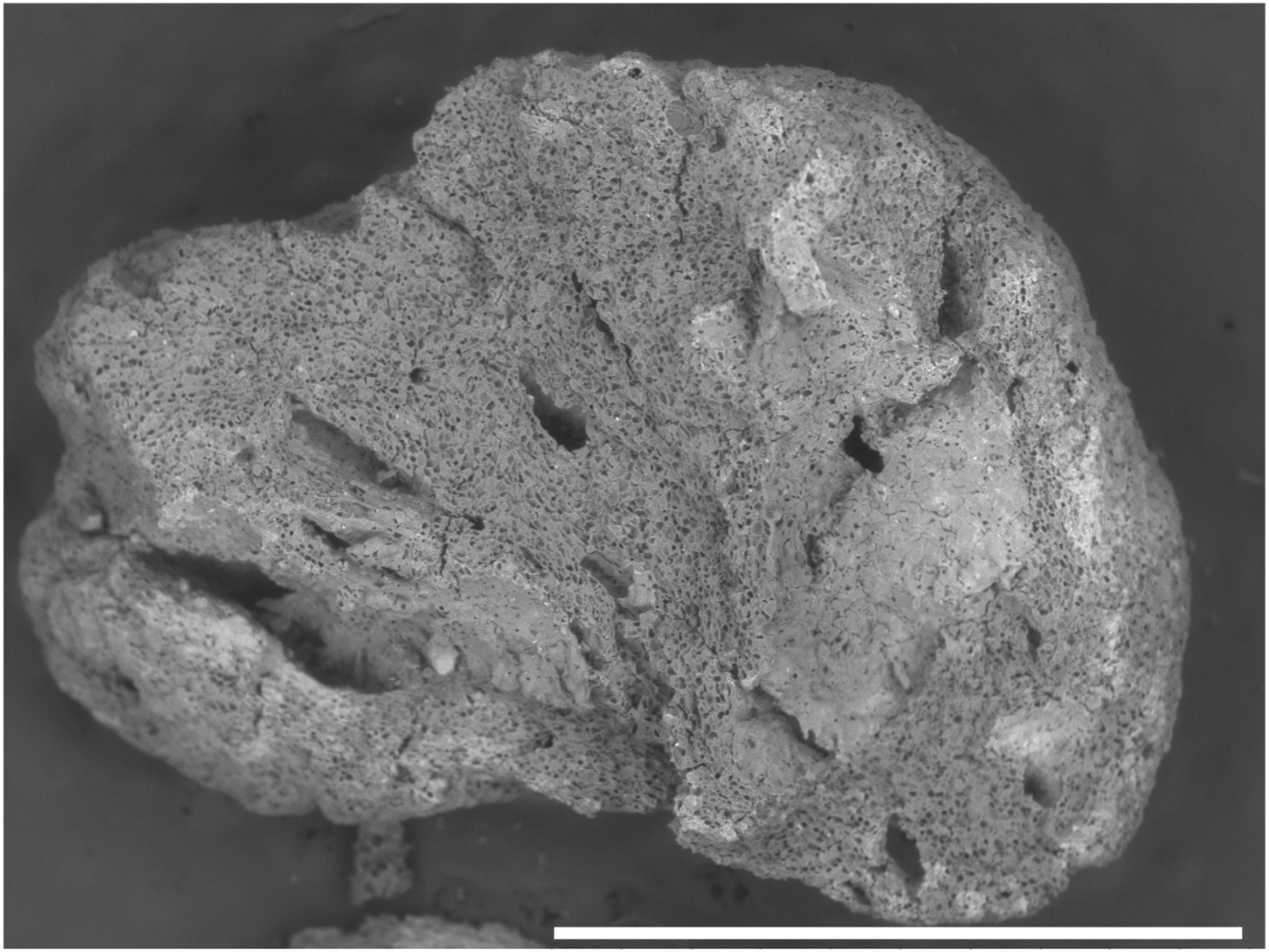

Figure 4: Scanning electron micrograph of a typical, albeit large, fragment of archaeological vegetative parenchyma from Madjedbebe; scale bar is 2mm.

Figure 5: *Eleocharis dulcis* (ankurladj or water chestnut) corm, showing several surface morphologies, including concentric scale leaf scars and the root attachment.

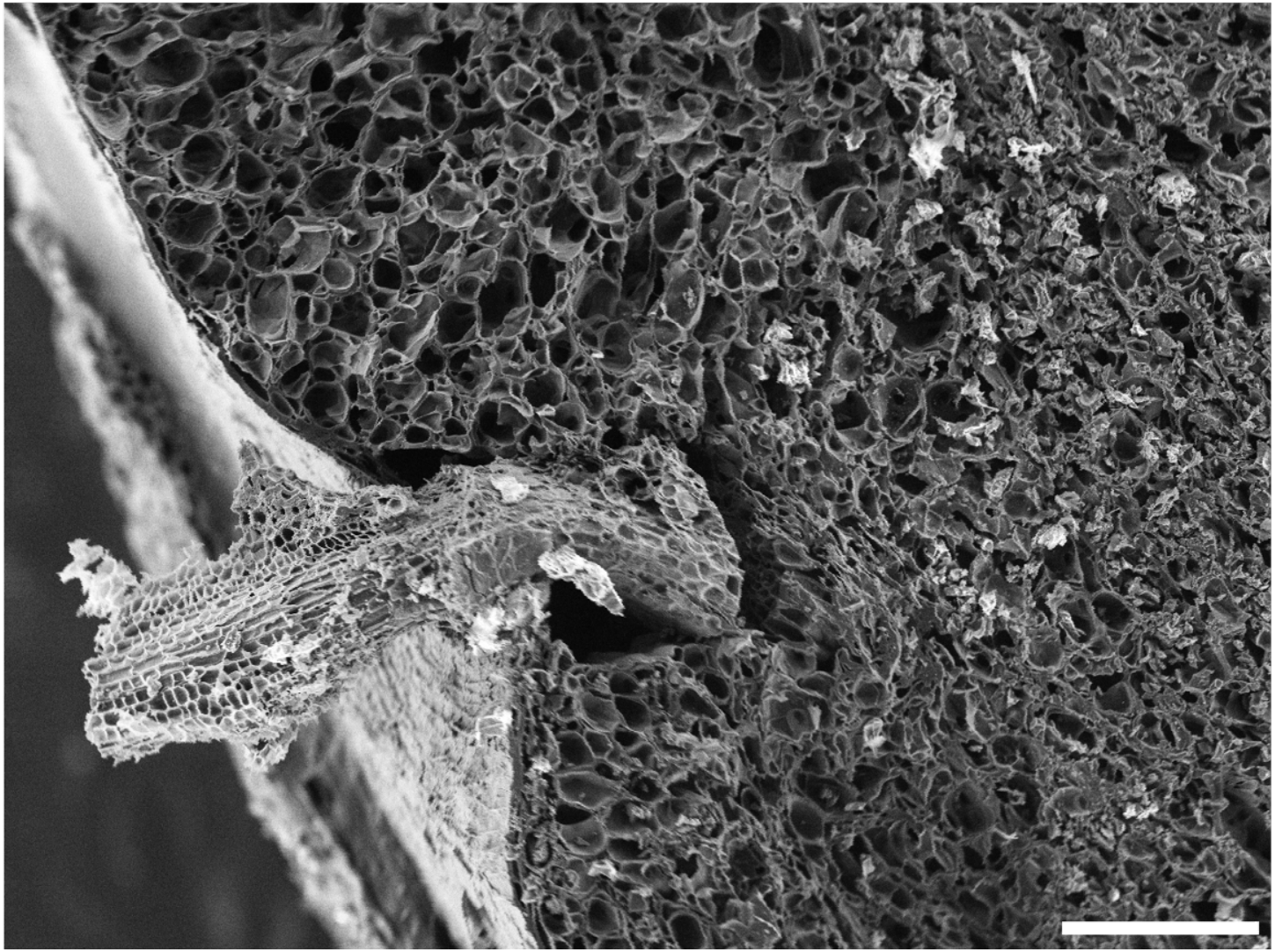

Figure 6: Scanning electron micrograph of a fragment of a *Dioscorea bulbifera* (ankindjek or cheeky yam) rhizome, displaying a rootlet and skin surface.

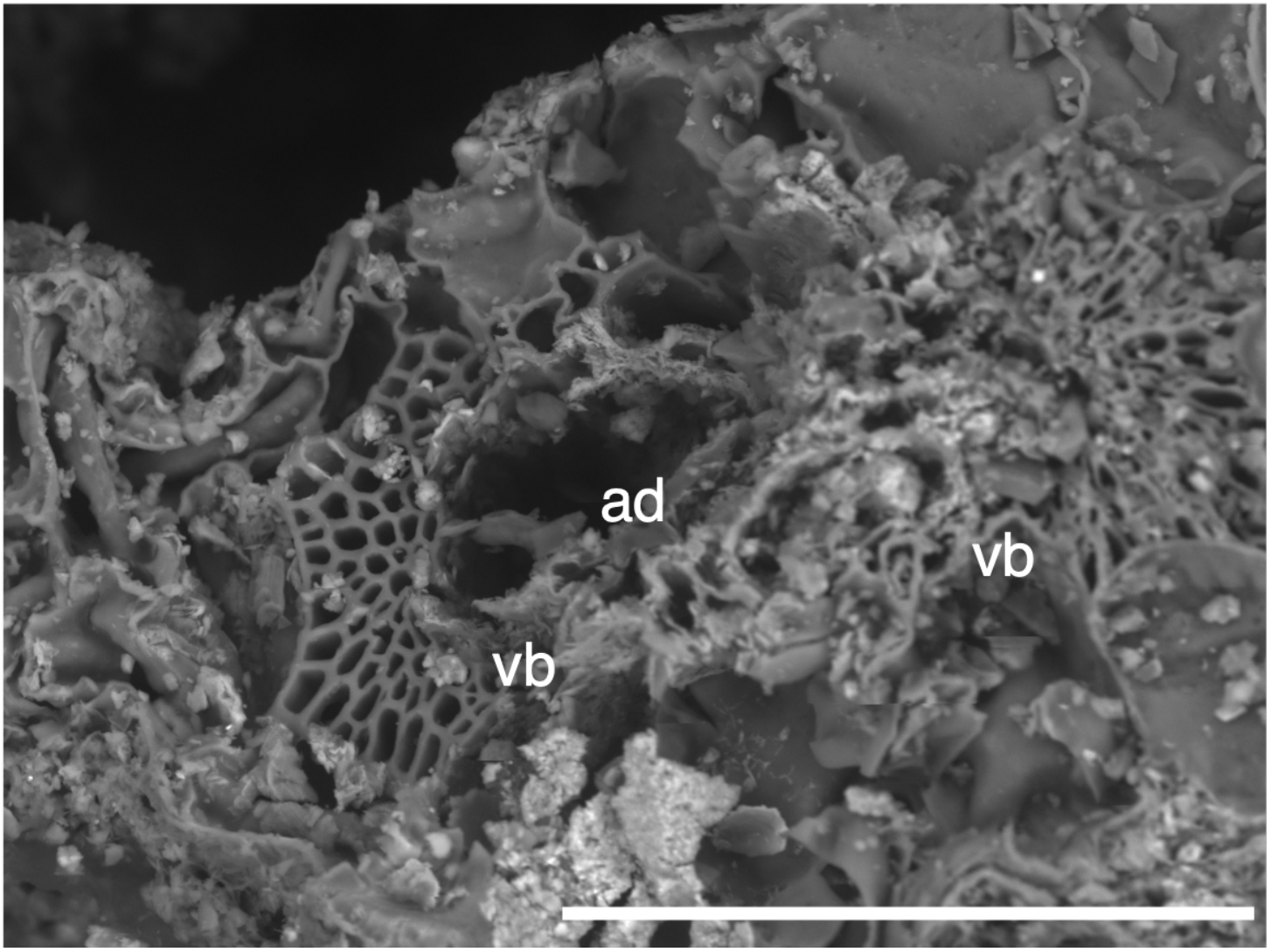

Figure 7: Scanning electron micrograph of a transverse section of an archaeological *Nymphaea* sp. (waterlily) stem from Madjedbebe, displaying two closed collateral vascular bundles (vb) in opposite orientation with an air duct (ad) between them; scale bar is 200µm.

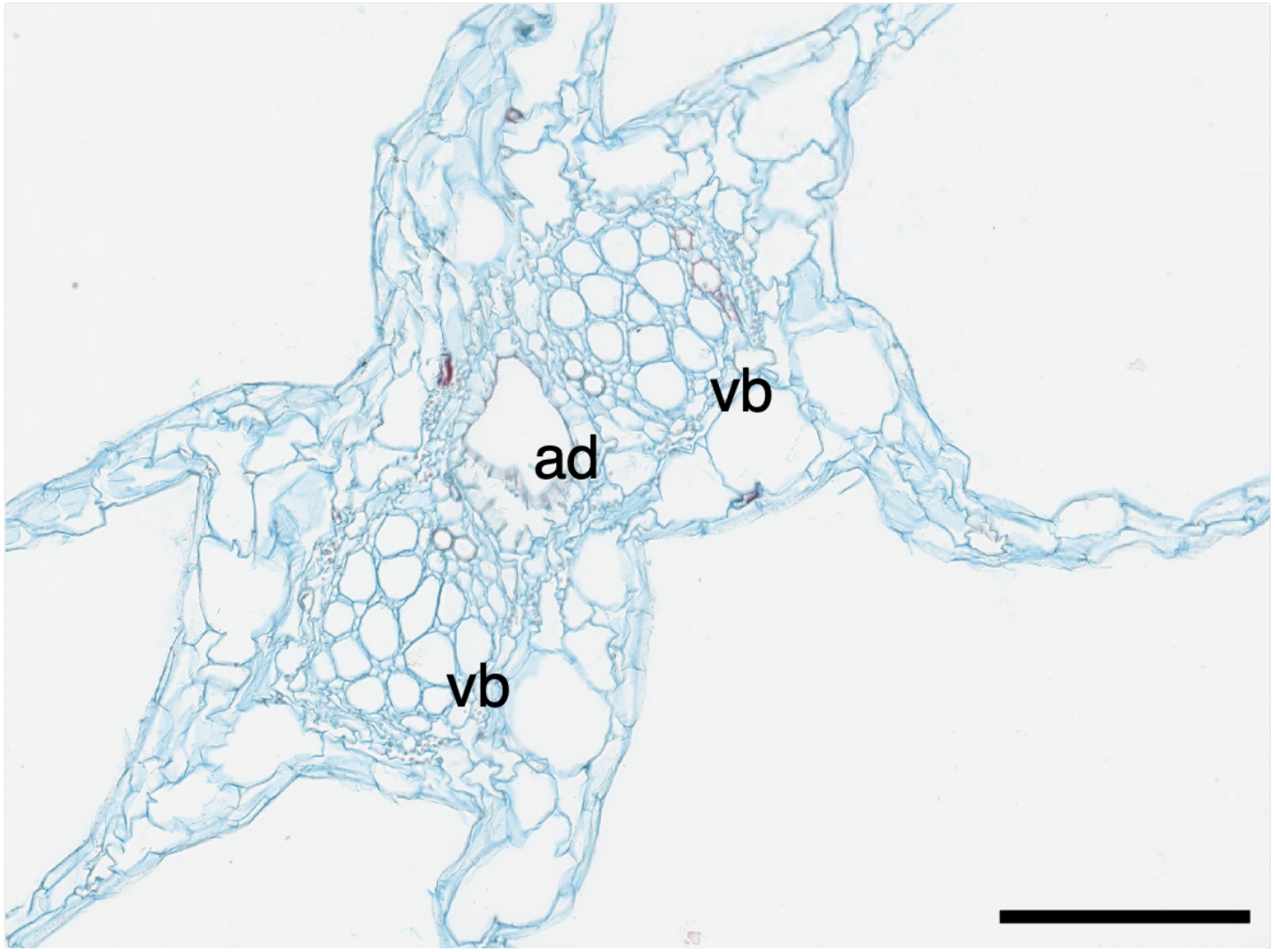

Figure 8: Thin section of the transverse section of a *Nymphaea violacea* (wayuk or waterlily) stem, displaying two closed collateral vascular bundles (vb) in opposite orientation with an air duct (ad) between them; scale bar is 300µm.

The placement of vasculature within a fragment of vegetative parenchyma is, however, very often helpful in its identification. USOs are made up of both root (e.g., carrots, *Daucus carota sativus*) and stem (e.g., potatoes, *Solanum tuberosum*) tissues and are common in both monocotyledonous and dicotyledonous plants. Stem tissue and primary root tissue can be identified as monocots or dicots/eudicots based on the arrangement of their vasculature (see Fig. 9). However, secondary root tissues, such as root tubers (e.g., sweet potatoes, *Ipomoea batatas*), are less easy to characterise as monocots or dicots/eudicots (see Figs 10 and 11). These tissues are developed through secondary growth, and their xylem (inner) and phloem (external) tissue are highly parenchymatous.

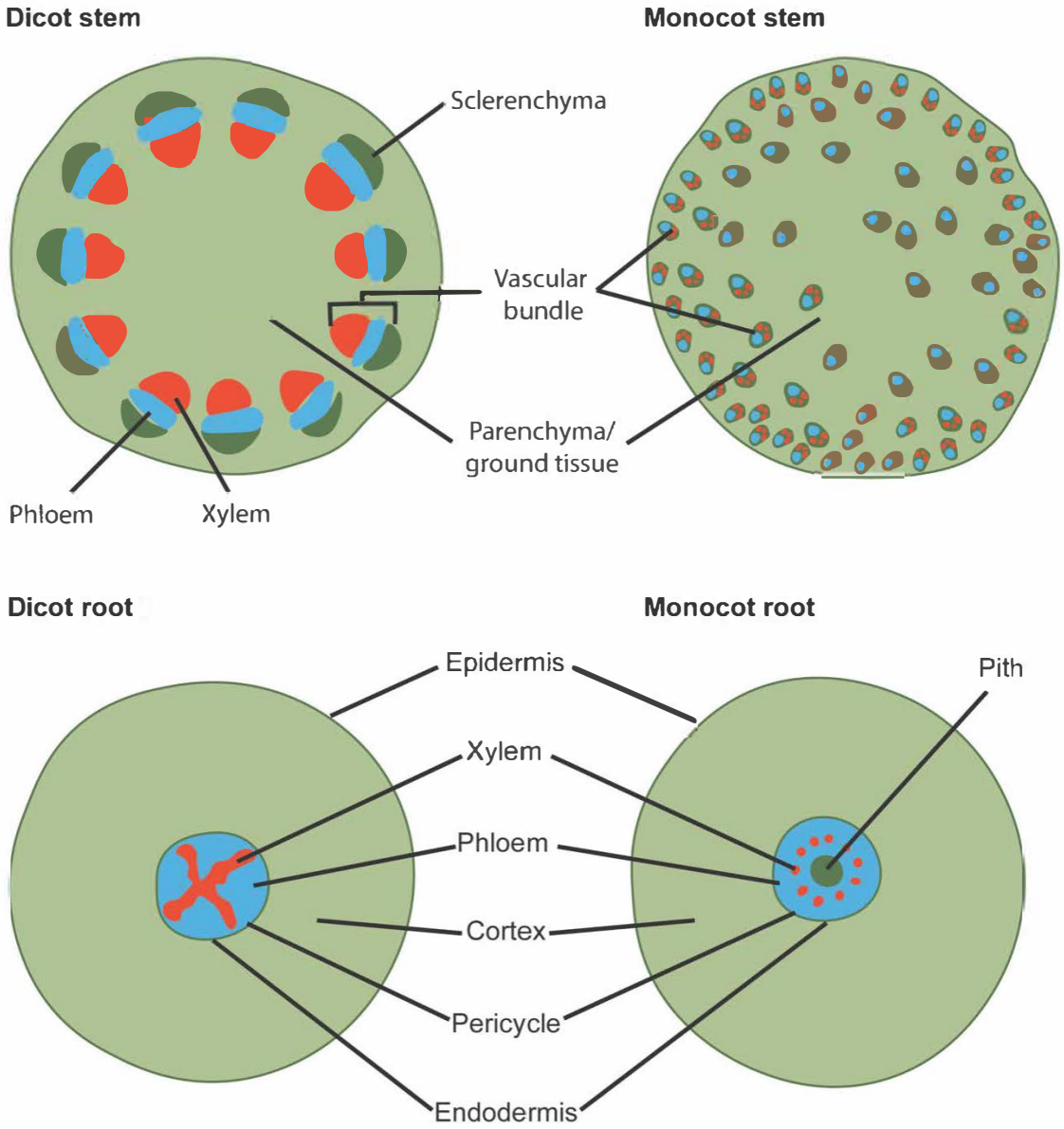

Figure 9: Anatomical structure of stem and primary root tissues in dicots/eudicots and monocots.

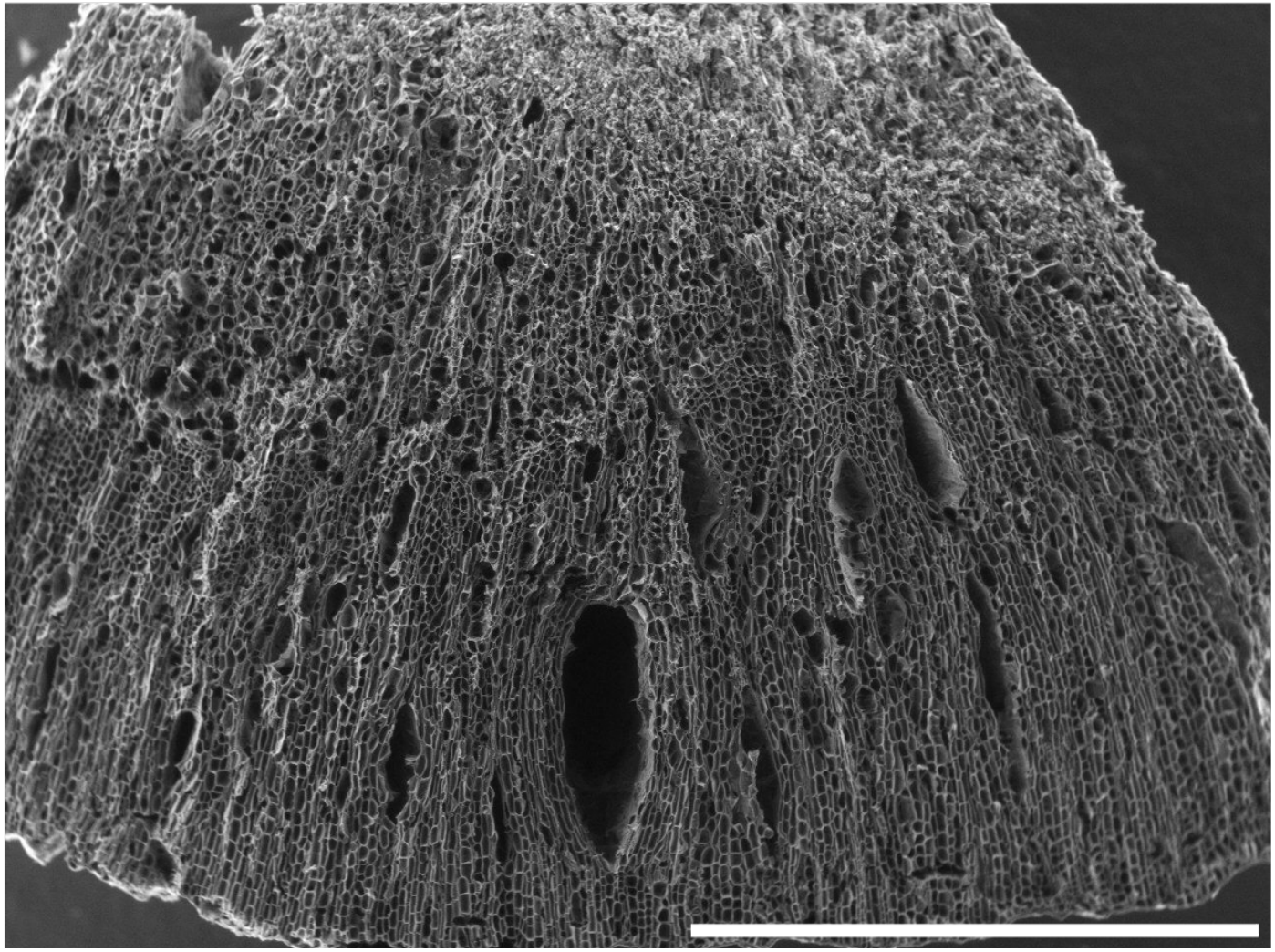

Figure 10: Scanning electron micrograph of a transverse section of an *Eriosema chinense* (bulubbi) root tuber, with its inner xylem tissues separated from its outer phloem tissues or secondary cortex by a thin cambium; scale bar is 2mm.

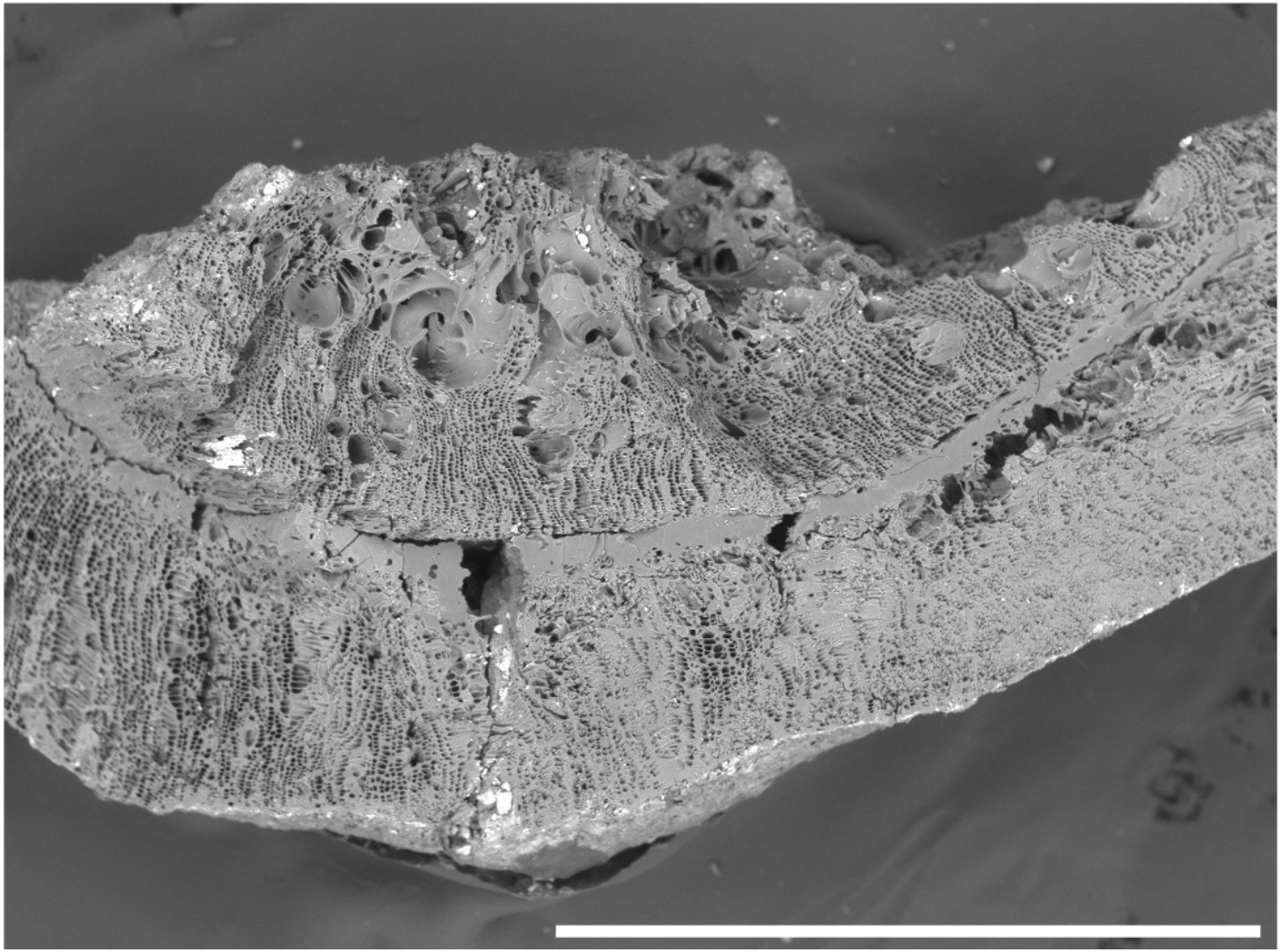

Figure 11: Scanning electron micrograph of a transverse section of an archaeological fragment of secondary root tissue, displaying a vitrified cambium, separating the inner xylem tissues and outer phloem tissues or secondary cortex; scale bar is 2mm.

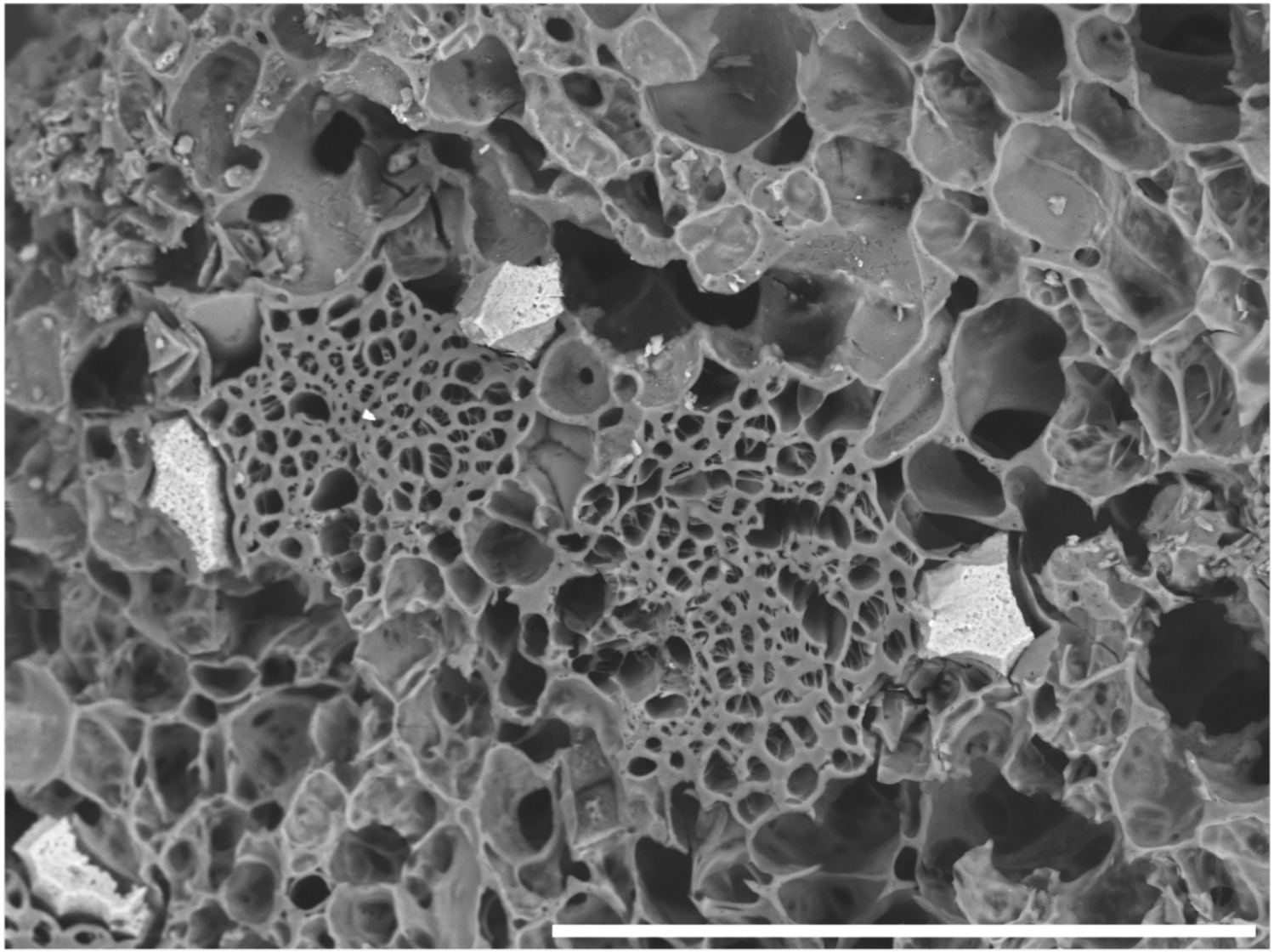

Figure 12: Scanning electron micrograph of a transverse section of unidentified archaeological monocot USO stem tissue, displaying two closed collateral vascular bundles and associated phytoliths; scale bar is 200µm.

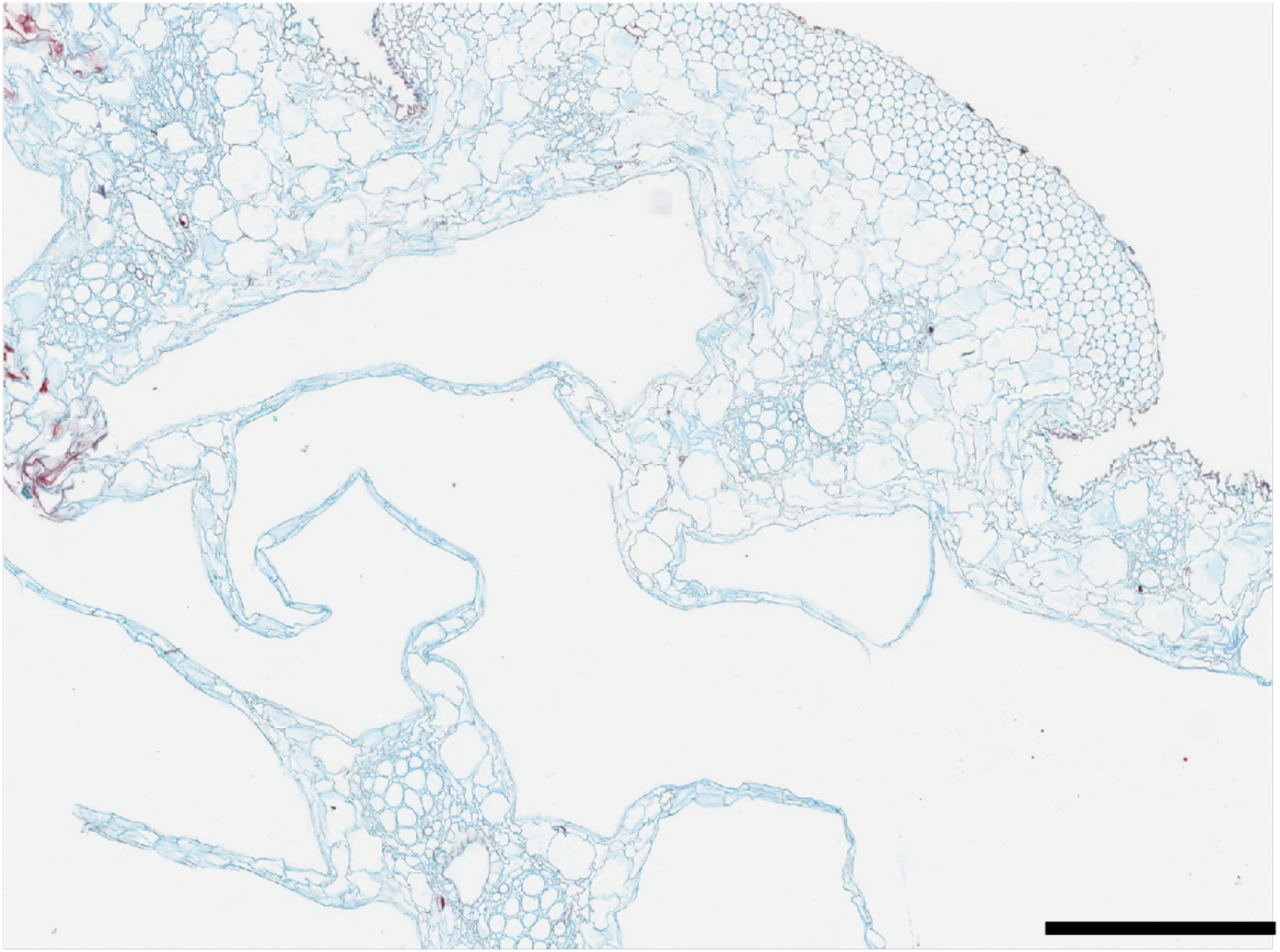

Figure 13: Thin section of the transverse section of a *Nymphaea violacea* (wayuk or waterlily) stem, displaying vascular bundles spaced within aerenchyma (parenchyma, which form continuous intercellular spaces); scale bar is 600µm.

Further to this, mineral inclusions found in vegetative parenchyma such as raphides, druses, phytoliths and cystoliths can also be diagnostic (see Fig. 12). These inclusions form from surplus calcium or silica present in the plant system and serve a range of purposes from defensive to structural. Alone, phytoliths especially can be identifiable to genus- and even species-level. However, many of those found within USOs are taxonomically redundant (i.e., they are common across many plant Families). Their presence within a particular plant structure alongside other identification criteria may, however, allow for high-level identification.

Finally, alongside other features, parenchyma itself can also be helpful in the identification process. Aerenchyma is parenchymatous tissue with continuous intercellular spaces, that is spaces between the cells that link up within the plant tissue (see Fig. 13). Aerenchyma is common within aquatic plant tissue. It helps permanently submerged organs, such as USOs, receive oxygen, and allows for buoyancy in stem and leaf tissue. If aerenchyma is present in archaeological vegetative parenchyma it allows for the identification of the plant as aquatic or semi-aquatic, even if there are no further diagnostic features.

The general shape and size of parenchyma relative to other features in a USO may also be diagnostically helpful. However, caution must be used here as, as parenchyma is by nature a pliable packing tissue. Its dimensions can often change under different developmental phases and growth environments. Further, the process of charring may also distort parenchymatous tissues in different ways dependent on the state the USO was charred in (i.e., fresh or dried) and even the season it was harvested in, which will likely vary the amount of sugar present within the USO and, therefore, its 'fuel load'.

When present, a mixture of these features, and others, allow for identification of vegetative parenchyma to a vegetation community, Family, genus or, even, species. These identifications are limited primarily by the anatomical and morphological features of the USOs and other botanical structures represented in the archaeological assemblage, and whether they vary by Family, genus or species. However, they are also greatly limited by the representativeness of the modern plant reference collection used for identification and the nature of the archaeological preservation.

Looking for vegetative parenchyma and other non-woody plant tissues

Probably the best way to identify the presence of vegetative parenchyma and other non-woody plant tissues (e.g., palm stem, endocarp) in a charred plant macrofossil assemblage is to individually analyse each fragment of charcoal >1mm in size. Looking at the individual fragment across multiple plains (e.g., transverse, tangential, radial), consider if the fragment shows the characteristics of wood charcoal. This may require you to fracture the fragment to create clean sections, if they are not already present. If this is the case store the fragments together, so future analysis does not count them as two, or more, individual fragments. Some non-woody tissues can mimic the anatomy of wood charcoal. For example, the transverse view of closely spaced vascular bundles towards the cortex of monocotyledonous stem tissue can look like vessels at low magnification, and secondary root tissues can easily be mistaken for wood charcoal and parenchyma for wood pith. Be careful to check across at least two plains, as the non-woody nature of such vessels will

often become apparent in longitudinal plains. Bottom line, if a fragment doesn't look quite right, put it to one side for further analysis at higher magnifications.

References

Hather, J. G. (1993). *An Archabotanical Guide to Root and Tuber Identification: Europe and south west Asia* (Vol. 1). Oxbow Books.

Hather, J. G. (2000). *Archaeological Parenchyma*. Archetype Publications.

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