Routledge
Taylor & Francis Group

Environmental Archaeology

The Journal of Human Palaeoecology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/yenv20

Wood in Pre-Columbian Funerary Rituals: A Case Study from El Caño (Panama, AD 880–1020)

María Martín-Seijo , Joeri Kaal , Carlos Mayo Torné & Julia Mayo Torné

To cite this article: María Martín-Seijo , Joeri Kaal , Carlos Mayo Torné & Julia Mayo Torné (2020): Wood in Pre-Columbian Funerary Rituals: A Case Study from El Caño (Panama, AD 880–1020), Environmental Archaeology

To link to this article: https://doi.org/10.1080/14614103.2020.1829301

Published online: 13 Oct 2020.

ENVIRONMENTAL ARCHAEOLOGY
https://doi.org/10.1080/14614103.2020.1829301

Wood in Pre-Columbian Funerary Rituals: A Case Study from El Caño (Panama, AD 880–1020)

María Martín-Seijo [a], Joeri Kaal [b], Carlos Mayo Torné[a,c,d] and Julia Mayo Torné[c]

[a]Grupo de Estudos para a Prehistoria do NO Ibérico-Arqueoloxía, Antigüidade e Territorio. GEPN-AAT (GI-1534), Departamento de Historia, Universidade de Santiago de Compostela, Santiago de Compostela, Spain; [b]Instituto de Ciencias del Patrimonio (Incipit), Santiago de Compostela, Spain; [c]Centro de Investigaciones Arqueológicas del Istmo, Fundación El Caño, Panamá, República de Panamá; [d]Dirección Nacional de Patrimonio Histórico, Panamá, República de Panamá

ABSTRACT
This research presents for the first time a comprehensive study of charcoal directly related to the multiple burials interred in Tomb 2 of El Caño (Coclé province, Panama). This funerary context, which dates to between AD 880 to AD 1020, contained three different burial levels accompanied by substantial ceramic offerings and rich mortuary assemblages. The challenge of taxonomically identifying charcoal from tropical areas was addressed by combining standard procedures in tandem with chemical analysis (Py-GC-MS) of archaeological charcoal and fresh wood from the reference collection. Nine charcoal types were identified at the genus level: Avicennia spp., Rhizophora spp., Handranthus/Tabebuia, cf. Copaifera spp., Inga spp., Guettarda spp., Roupala spp., Allophylus spp. and cf. Ryania spp. Charcoal of cf. Copaifera spp., Roupala spp., Guettarda spp., and probably Handroanthus/Tabebuia might be related to their use as firewood for producing smoke. The presence of *Copaifera* and *Roupala* indicates the selection of odorous woods for burning in the *sahumerios*. Diverse habitats, such as coastal mangroves, riverine and dry forests, were exploited to obtain wood, highlighting the complex management of wild plant resources developed by the hierarchical societies of the Isthmo-Colombian area.

ARTICLE HISTORY
Received 9 April 2020
Revised 5 August 2020
Accepted 25 August 2020

KEYWORDS
Charcoal analysis; Py-GC-MS; firewood; censer; mortuary rituals; Neotropics

Introduction

The complex societies that emerged in Panama *c.* AD 750–800 developed a diversified management of natural resources (Linares 1977; Cooke 2004; Cooke et al. 2003; Dickau 2010; Mayo and Carles 2015), including wild plant resources such as wood (Martín-Seijo et al. 2016, 2018) and resins (Kaal et al. 2018, 2020), amongst others (Dickau 2010). El Caño (Coclé province, Panama) is an archaeological site including a ceremonial area and a necropolis with multiple burials (Mayo and Carles 2015, Mayo et al. 2016, 2020) similar to those of Sitio Conte (Lothrop 1934, 1937). Inside the large tombs of El Caño, different burial episodes have been identified, more specifically the interment of multiple individuals to accompany elite in their afterlife (Mayo et al. 2016, 2020). The high-ranking individuals were accompanied by rich mortuary assemblages such as pectorals, ear ornaments, pendants, belts and bracelets made of *tumbaga* or gold, as well as other objects made of resin, copper, stone and bone, massive amounts of ceramics and perishable goods (Guinea and Mayo 2013; Mayo and Carles 2015, Mayo et al. 2016; Kaal et al. 2020; Mayo et al. 2020, 2021a, 2021b).

The perishable nature of wood and other plant remains conditions their preservation in archaeological contexts. They only survive in very humid (waterlogged) or very dry contexts, at very low temperatures, or when preserved by carbonisation in the absence of oxygen, by charring (limited air supply causing incomplete combustion) (Braadbaart and Poole 2008), or by mineral replacement in contact with metal (Cartwright 2015). In addition to preservation problems, scarce representation of plant remains is often exacerbated due to their poor visibility compared to other materials (bone, shells, etc) or non-perishable objects (pottery, metal or lithics), and a lack of recording if recovery processes (dry or water sieving, floating) are not implemented during excavation (Hastorf 1999).

Wood and other plant remains recovered from funerary contexts can originate from the remains of wooden structures, goods and offerings associated with graves, or other kinds of features (Dussol et al. 2016). Research on plant macro-remains have the potential to facilitate reconstruction of funerary rituals, sometimes even revealing symbolic aspects of the worldview and self-conceptualization of past societies (Dussol et al. 2016). Previous archaeobotanical studies in the area have highlighted the role of plants in funerary contexts; in line with recent multidisciplinary studies in Central America which

CONTACT María Martín-Seijo maria.martin.seijo@gmail.com Grupo de Estudos para a Prehistoria do NO Ibérico-Arqueoloxía, Antigüidade e Territorio. GEPN-AAT (GI-1534), Departamento de Historia, Universidade de Santiago de Compostela, Praza da Universidade 1, 15782, Santiago de Compostela, Spain

emphasised the diversity of plant resources and their multiple uses, and highlighted the importance of fibre and wood processing (Helms 1979; Morell-Hart et al. 2019).

Wood was probably burnt during the mortuary rite for producing smoke, and timber was used for building structures and crafting implements (Helms 1979). Other plant resources such as resins have been described in the ethnohistorical sources and attested recently in the archaeological record (Kaal et al. 2018, 2020). Burning wood as small offerings to zoomorphic or anthropomorphic carved wooden figures has been reported amongst indigenous groups from the Isthmo-Colombian area belonging to the Chibchan language family (Martínez-Mauri 2020). The lexicon of speakers of Chibchan or Chocoan linguistic families also reflects the importance of plants and their products in the cultural and physical world of these communities (Paché 2016; Velásquez-Runk 2017; Martínez-Mauri 2020).

This paper explores the usage patterns of wood in funerary rituals of hierarchical societies in the Isthmo-Colombian area, by studying plant macroremains recovered from Tomb 2 (AD 880–1020) at El Caño. For this purpose, the taxonomic identification of the plant remains was undertaken, including a pilot study combining anthracological analysis with molecular composition data obtained by pyrolysis-GC-MS. The second aim of this research is to define wood procurement areas and forest management strategies developed by these societies, and to understand the role of wood during the mortuary rituals.

Material and Methods

Site and Present-day Vegetation in the Study Area

El Caño (Coclé Province) is located at 50 m.a.s.l. on the Pacific side of Panama, in the alluvial plain of the Río Grande river, which flows from the mountains of the Cordillera Central to Parita Bay (Figure 1). It is in the Pacific dominion, Guatuso-Talamanca province of the Neotropical biogeographical region (Morrone 2017). This is an area of tropical climate (*Awi*), with average temperatures ranging from 26.4–29.3°C, and a maximum annual rainfall of 1,216 mm and several months with less than 30 mm precipitation. Current vegetation patterns at El Caño are highly modified by intensive agriculture and gardening, and the archaeological area itself is currently a park. In its immediate surroundings there are pastures, fields dedicated to intensive cultivation of sugar cane, rice, and onion, as well as small orchards.

Tropical dry forests are the climax vegetation in this area. These forests, of smaller stature and lower basal area than tropical rain forests, are composed mainly of deciduous trees accompanied by thorny shrubs (Murphy and Lugo 1986; Pennington, Lavin, and Oliveira-Filho 2009), and they tend to occur on richer soils than savannahs (Linares-Palomino, Pennington, and

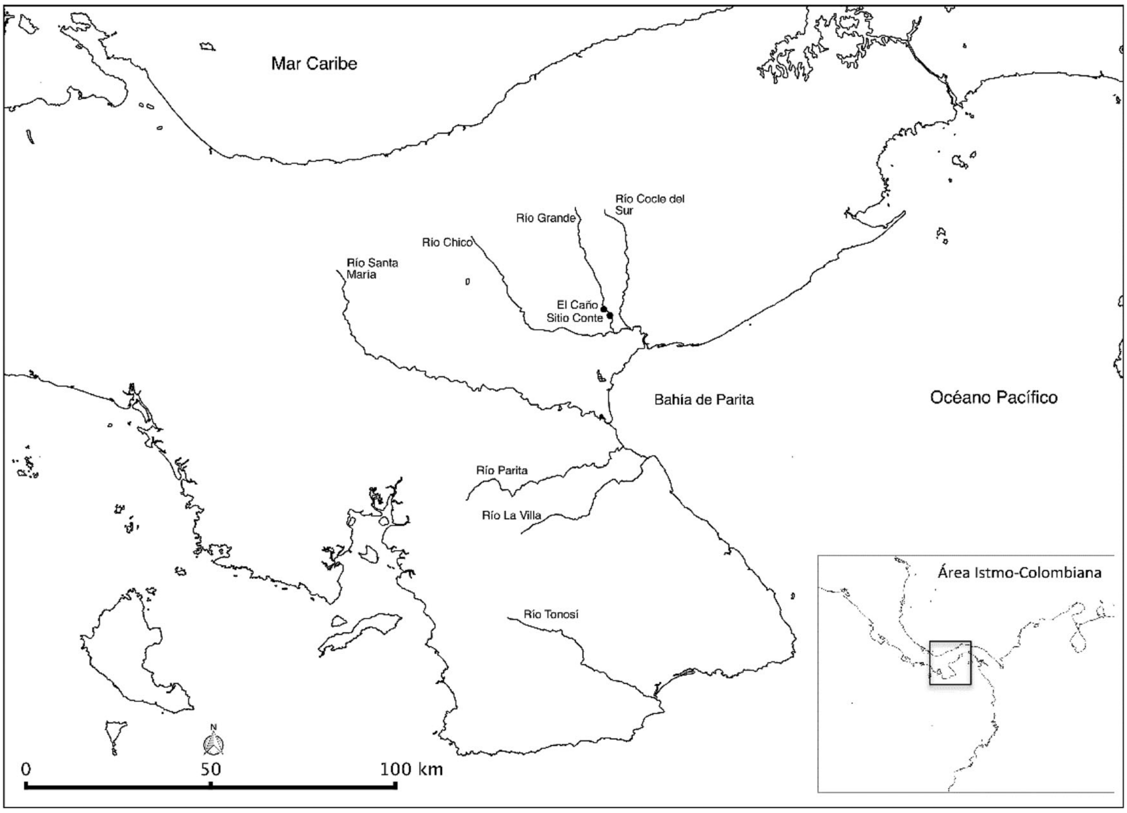

Figure 1. Location of El Caño in the Isthmo-Colombian area of America.

Bridgewater 2003). Woody vegetation is dominated by arborescent species belonging to the Fabaceae family, whilst the Bignoniaceae dominates the liana flora. Other families such as Anacardiaceae, Flacourtiaceae, Euphorbiaceae, Myrtaceae, Rubiaceae and Sapindaceae are also well-represented (Linares-Palomino, Pennington, and Bridgewater 2003; Pennington, Lavin, and Oliveira-Filho 2009; Condit, Pérez, and Daguerre 2011). Mangroves in estuaries and coastal areas of the Pacific include species such as red mangrove (*Rhizophora* spp.) with monospecific stands of this tree along deltas and rivers where tides oscillate between 2 and 6 metres. Mixed communities of red mangroves and mangle piñuelo (*Pelliciera rhizophorae*), as well as communities of white mangrove (*Laguncularia racemosa*) and black mangrove (*Avicennia germinans, A. bicolor*) are also present (ANAM-ARAP 2013).

Archaeological Context and Samples

The complex site of El Caño (Gran Coclé archaeological tradition) comprises a ceremonial area and a cemetery (Figure 2). The ceremonial area contains stone structures including a cobblestone pathway, two alignments of basalt columns and a group of 37 stone sculptures, two altars and two carved columns (Verril 1972; Zelsman 1959; Doyle 1960; Cooke 1976; Mayo and Mayo 2013a, 2013b; Mayo et al. 2020). Inhumations of multiple individuals, buried to accompany the high-ranking members of the society in their afterlife, have been recorded inside the tombs (Guinea and Mayo 2013; Mayo and Carles 2015, Mayo et al. 2016, 2020, 2021a, 2021b) Figure 3.

Tomb 2 is one of the most complex funerary contexts of this archaeological site, in which the latest funerary event has been dated to cal. AD 880–990 (Beta-294052, 1120 ± 30 BP), and the earliest to between cal. AD 900 to cal. AD 1020 (Beta-303193, 1070 ± 30 BP) (Mayo and Mayo 2013a, Guinea and Mayo 2013; Mayo et al. 2020). This sunken feature was probably covered with a wood structure and a roof made of plant material. It is a stepped tomb, dug during three levels of burials that were identified during the archaeological excavation. Five individuals were buried in the first burial level, three in the second level, and nineteen in the third. The highest-rank individual (I7) was an adult male (Mayo et al. 2020). He was buried in the centre of the third level with his head oriented to the east and his arms crossed over his body. Identification of lipids and series of sesquiterpenes (an important constituent of essential oils in plants) by gas chromatography-mass spectrometry (GC-MS) suggests that the corpse had been treated with Fabaceae (*Copaifera* or *Hymenaea*) resins (Kaal et al. 2020). This individual was adorned with four embossed pectorals, four bracelets and two earrings made of gold, a belt made of feline teeth with gold cases, several gold-bead necklaces, pendants made of stone, resin, bone and gold (Guinea and Mayo 2013). A package of multiple gold and *tumbaga* objects was placed on top of the body, as well as copper, stone and bone artefacts, a pyrite mirror, and a bundle

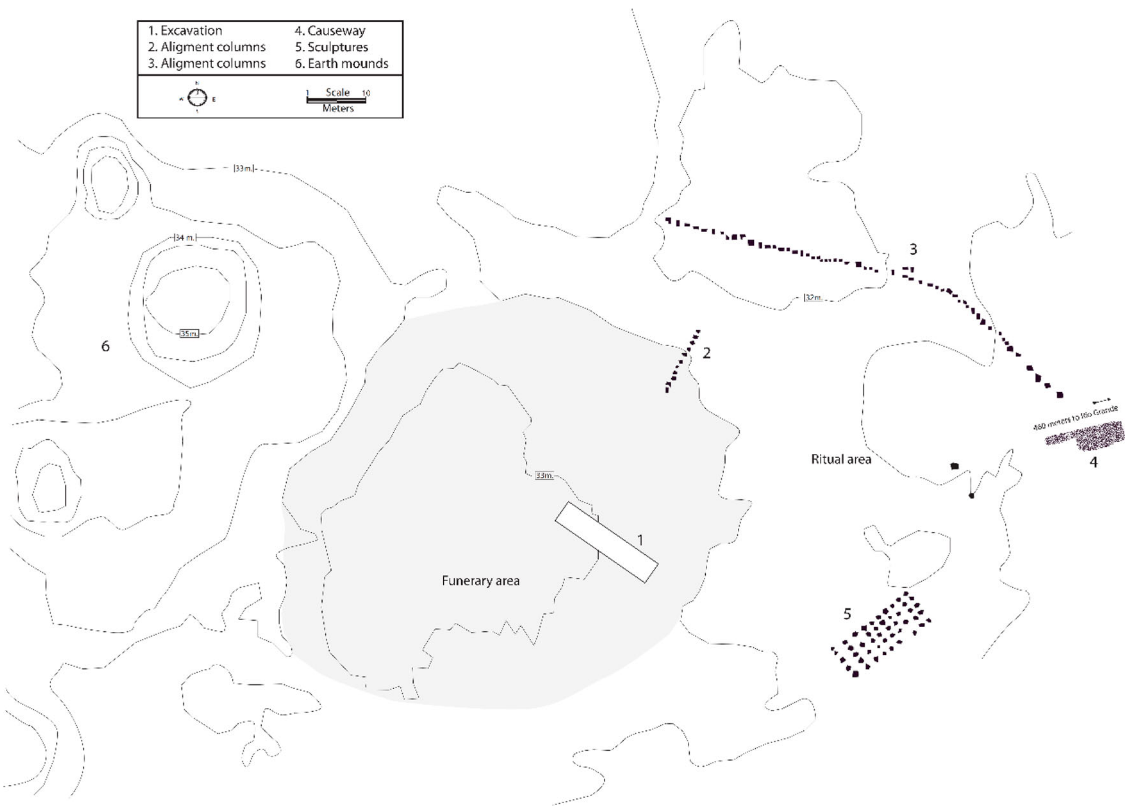

Figure 2. Main structures identified at the El Caño complex and position of the excavation area.

Figure 3. View of archaeological deposits SU131 and SU107 (a) a censer from SU104 (b) and a broken pottery vessel from SU107 (c).

of fish bones of the order Rajiformes (Guinea and Mayo 2013).

Handpicked samples ($N = 21$) of plant material were recovered during the excavation of the tomb. These samples include wood charcoal and other kinds of plant material not preserved by carbonisation. In total, 127 charcoal fragments were studied. The samples were gathered from ten stratigraphic units (Table 1), including samples from the three burial levels previously mentioned, and other deposits associated with offerings composed mostly of ceramics amongst other kinds of goods.

Charcoal Analysis

Each charcoal fragment was broken manually following the three anatomical sections of wood: cross, tangential, and radial. Taxonomic identifications were made following standard procedures (Cartwright 2015). Charcoal fragments were observed under a reflected-light microscope (Olympus CX40) and photographs were obtained using a stereoscopic microscope (Olympus SZX7) and a Scanning Electron Microscope (ZEISS EVO LS 15, RIAIDT-Universidade de Santiago de Compostela). The SEM was equipped with an energy-dispersive X-ray (EDX) spectroscopy device, which allowed both the detailed observation of anatomical features at high magnifications as well as the identification of chemical elements (Carlquist 2013; Hubau et al. 2013).

Table 1. Description of the Stratigraphic Units (SU) and chronology of provenance of archaeobotanical samples.

SU	Description	14C Dates (2 Sigma Calibration)
088	First burial level. Deposit. Burial of 5 individuals.	Cal AD 880–990 (Cal BP 1070–960)
104	Second burial level. Collapsed platform over SU106.	
106	Second burial level. Deposit. Burial of 3 individuals.	
107	Broken ceramic with charcoal remains.	
128	Deposit interpreted as burial/offering.	
130	Deposit with material slip from tomb 6.	
131	Deposit with massive ceramic offerings.	
134	Third burial level. Burial of 19 individuals and secondary burials.	Cal AD 900–1020 (Cal BP 1050–930)
135	Deposit. Offerings.	
136	Deposit with massive ceramic offerings	

The complexity of tropical wood identification is related to the large biodiversity of the area, in addition to the scarcity of anatomical studies and identification keys in comparison with temperate areas (Wheeler and Baas 1998; Höhn and Neumann 2018). These difficulties are increased by the alterations produced by the combustion process on anatomical features of wood, which are already poorly known especially for tropical woods, e.g. significant reduction in the tangential diameter of vessels (Prior and Gasson 1993; Gonçalves, Marcati, and Scheel-Ybert 2011) due to heat shrinkage (Braadbaart and Poole 2008). Therefore, absolute measurements need to be interpreted with caution (Hubau et al. 2012). Some diagnostic features of hardwood (IAWA Committee 1989) are hard to recognise in charcoal, e.g. growth rings, arrangement of intervessel pits, vestured pits, vessel-ray pitting, druses, other crystal types and silica (Hubau et al. 2012). Given these difficulties, the four-step process described by Höhn and Neumann (2018) was followed in the current study.

Firstly, the microscopic characteristics described by the IAWA Committee (1989) as well as other publications that follow the IAWA standards (León and Espinoza 2001; García-Esteban et al. 2003; Crivellaro and Schweingruber 2015) were observed and the charcoal types were classified and assigned a numerical code; all fragments with similar characters were grouped together. The charcoal types were then allocated to taxa from the Isthmo-Colombian area, using the InsideWood database (InsideWood 2004-onwards), which uses the descriptors in the IAWA hardwood list (IAWA Committee 1989), atlases and papers of tropical wood anatomy (Espinoza and Melandri 2000; Espinoza and León 2001; Miller and Détienne 2001; León 2002; Carpio 2003; Ogata et al. 2008; Carreras et al. 2012, 2013; Scheel-Ybert and Gonçalves 2017), as well as the modern reference collection of tropical woods available at the GEPN-AAT Archaeobotany Lab (Universidade de Santiago de Compostela) collected in El Caño and its surroundings since 2008. The third step was the differential diagnosis that separated the respective charcoal types. Finally, the charcoal type was named indicating the highest taxonomic level reached of species, genus, family, or sub-family. The genus name with the suffix 'spp.' indicates that several species of this genus must be considered. When a type matched the anatomy of two species or genera, both names were given, separated by a slash. The names of charcoal types are given in small capitals to discriminate them form the botanical taxa (Höhn and Neumann 2018). In the case of poorly preserved charcoal fragments, the absence of sufficient diagnostic features and/or their alteration due to combustion or taphonomical processes, hampered their taxonomic identification. Such fragments were classified under the label 'unknown' taxonomic groups with the number of the charcoal type assigned during the identification process as described previously (i.e. Unknown 01, Unknown 02, etc.).

In tandem with the taxonomic identification, dendrological and taphonomical features were registered to characterise the kind of wood resources managed (part of the plant, calibre and maturity of wood), the combustion process (vitrification, cracks), the condition of the wood before burning (biodeterioration), and the depositional and post-depositional processes (fragmentation, erosion) (Théry-Parisot 2001; Marguerie and Hunot 2007; Schweingruber 2007; Braadbaart and Poole 2008; Schweingruber, Börner, and Schulze 2008; Lancelotti et al. 2010; McParland et al. 2010; Moskal del Hoyo, Wachowiak, and Blanchette 2010; Théry-Parisot, Chabal, and Chrzavzez 2010; Théry-Parisot and Henry 2012; Martín-Seijo 2013; Chrzazvez et al. 2014).

Pyrolysis-GC-MS Analysis

As this was a pilot study to improve charcoal identification, Py-GC-MS was applied to identify the chemical composition of the archaeological charcoal, as well as fresh wood and resin of the reference collection deposited at the GEPN-AAT Archaeobotany Lab (Universidade de Santiago de Compostela). Archaeological charcoals identified as CF. COPAIFERA SPP. and ROUPALA SPP. were selected from sample 9133, along with wood and resin samples from the reference collection, which were gathered in the surroundings of the site of El Caño (Panama): *Roupala montana* fresh wood and *Copaifera aromatica* resin. The sample material was introduced into quartz tubes and pyrolysed at 650°C for 20s by means of a CDS Pyroprobe 5000. The pyrolysis products were separated and identified using a gas chromatograph and mass selective detector of Agilent Technologies (model 5975). The methodology is described in detail in Kaal et al. (2020).

Results

Charcoal Assemblage

Results are summarised in Table 2. Of 127 charcoal fragments, 77.8% have been assigned to charcoal types at genus level. The presence of poorly preserved (vitrification, cracks, mineral coatings, etc.) and small size charcoal fragments (0.3–3 cm.) prevented identification in several cases (Table 2, Figure 4), and some of them were classified as Unknown 1–7, and dicots. The main alterations related

Table 2. Charcoal analysis results from Tomb 2.

Family	Taxon/SU	088	104	106	107	128	130	131	134	135	136
Acanthaceae	AVICENNIA SPP.	1		2		6	1			1	
Bignoniaceae	HANDROANTHUS/TABEBUIA		3								
Fabaceae-Caesalpinoideae	CF. COPAIFERA SPP.				48						
Fabaceae-Mimosoideae	INGA SPP.					5					
Proteaceae	ROUPALA SPP.				7						
Rhizophoraceae	RHIZOPHORA SPP.	4									
Rubiaceae	GUETTARDA SPP.				14						3
Salicaceae	CF. RYANIA SPP.										1
Sapindaceae	ALLOPHYLUS SPP.					1					
-	UNKNOWN 01	5									
-	UNKNOWN 02								3		
-	UNKNOWN 03							8			
-	UNKNOWN 04										1
-	UNKNOWN 05					1					
-	UNKNOWN 06					3					
-	UNKNOWN 07								3		
-	DICOT			2	3						
TOTAL		**10**	**3**	**4**	**72**	**16**	**1**	**8**	**6**	**1**	**5**

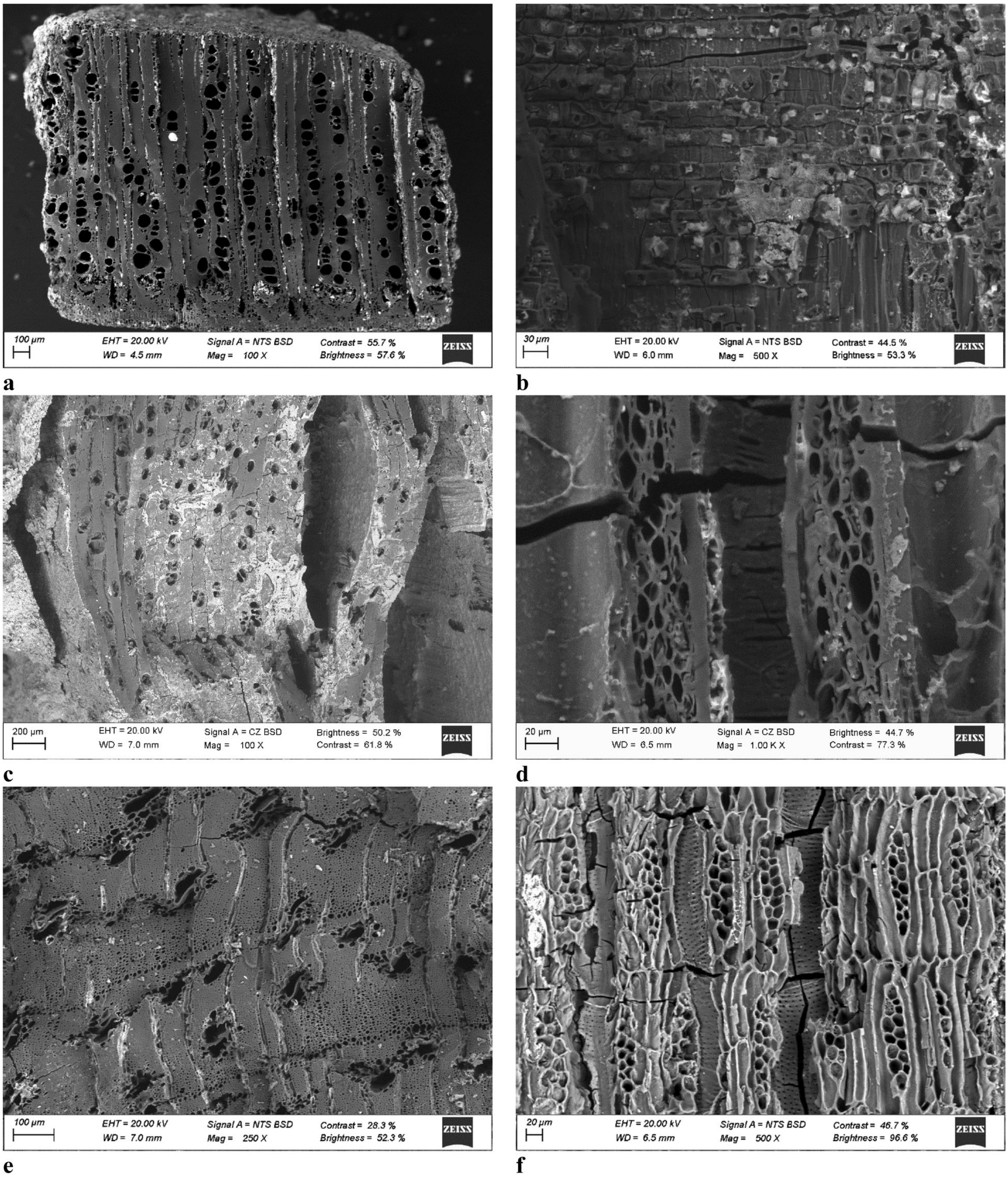

Figure 4. **a-b Avicennia spp.** a: TS. wood diffuse-porous with vessels in radial multiples of ≥4 vessels, included phloem concentric, fibres very thick-walled, b: RS. body ray cells procumbent with one to 4 rows of upright and/or square marginal cells, and prismatic crystals present in upright and/or square ray cells and in procumbent ray cells. **c-d. Rhizophora spp.** c: TS. wood diffuse-porous, fibres very thick-walled and tyloses common, d: TLS. vessels with scalariform perforation plates, intervessel pits scalariform, larger rays commonly 4–10 seriate, ray height > 1 mm and sheath cells. **e-f Handroanthus/Tabebuia**. e: TS. diffuse-porous wood, with solitary vessels and in short radial multiples, fibres thick-walled to very thick-walled, paratracheal parenchyma aliform, confluent or unilateral paratracheal, marginal (or seemingly marginal) banded parenchyma present with very fine bands mostly uniseriate. f: rays homocellular, typically procumbent with 2–3 cells wide, all rays, axial parenchyma, vessel elements and fibres storied.

with the combustion process identified in the charcoal assemblage were vitrification (60.6%), radial (18.9%) and tangential cracks (4.7%). Evidence of wood decay prior to charring, such as xylophagous' galleries (11.02%) and fungal hyphae (0.78%) were also observed. Under the reflected light microscope, presence of hyphae was under-represented compared to the SEM in which it was observed more frequently.

Two mangrove genera have been identified: Avicennia spp. and Rhizophora spp. (InsideWood

2004-onwards, León 2014, 219–220) (Figure 4a to d, Table 2). AVICENNIA SPP. is the most ubiquitous taxa in the charcoal assemblage and it has been identified in SU088 -together with RHIZOPHORA SPP.-, SU106, SU128 and SU130. Although both AVICENNIA and RHIZOPHORA presented a high degree of vitrification, they preserved diagnostic features. It is worth noticing that approximately 50% of the charcoal fragments from AVICENNIA showed evidence of vitrification.

HANDROANTHUS/TABEBUIA charcoal has been identified only in SU104 (Figure 4e to f, Table 2). In SU107, 48 charcoal fragments were classified as CF. COPAIFERA SPP. (Fabaceae-Caesalpinoideae) (Figure 5a to d, Table 2). Even though, these fragments are poorly preserved, they present anatomical features similar to those described for *Copaifera* genus (León and Espinoza 2001, 219; Marcati, Angyalossy-Alfonso, and Benetati 2001; InsideWood 2004-onwards, Melandri and Espinoza 2009, 306; Albuquerque 2012, 103–104; Nisgoski et al. 2012; Santini 2013, 106–107; Bhikhi et al. 2016, 102; Gonçalves et al. 2016). Species of *Copaifera* genus have wood resin with a volatile fraction containing few labdatriene diterpenoids, which polymerise to form hard copals (Langenheim 2003). In SU107, ROUPALA SPP. (Proteaceae) (Chattaway 1948; InsideWood 2004-onwards, Bhikhi et al. 2016, 130–131) and GUETTARDA SPP. (Rubiaceae) (Welle et al. 1983; Jansen et al. 2002; InsideWood 2004-onwards, León 2011) were also identified (Figure 7a to d, Table 2). This charcoal type was also identified in SU136, as well as CF. RYANIA SPP. (Salicaceae) (Bannan 1943; InsideWood 2004-onwards) (Figure 7e and f, Table 2). Five fragments from SU128 were classified as INGA SPP. (Fabaceae-Mimosoideae) (Baretta-Kuipers 1973; Miller and Détienne 2001; InsideWood 2004-onwards, León 2008, 2014) (Figure 6a to d, Table 2), together with ALLOPHYLUS SPP. (Sapindaceae) (Carreras and Dechamp 1995, InsideWood 2004-onwards, León 2013) (Figure 7g and h, Table 2).

Molecular Characterisation of Selected Samples

Archaeological charcoal classified as CF. COPAIFERA SPP. was analysed several times applying Py-GC-MS analysis. This charcoal was consistently productive of not only benzene, toluene and PAHs, which originate from the condensed polyaromatic structures of char (Kaal et al. 2008) but also of a series of sesquiterpenoid and diterpenoid derivatives (mostly alkylhydronaphthalenes and

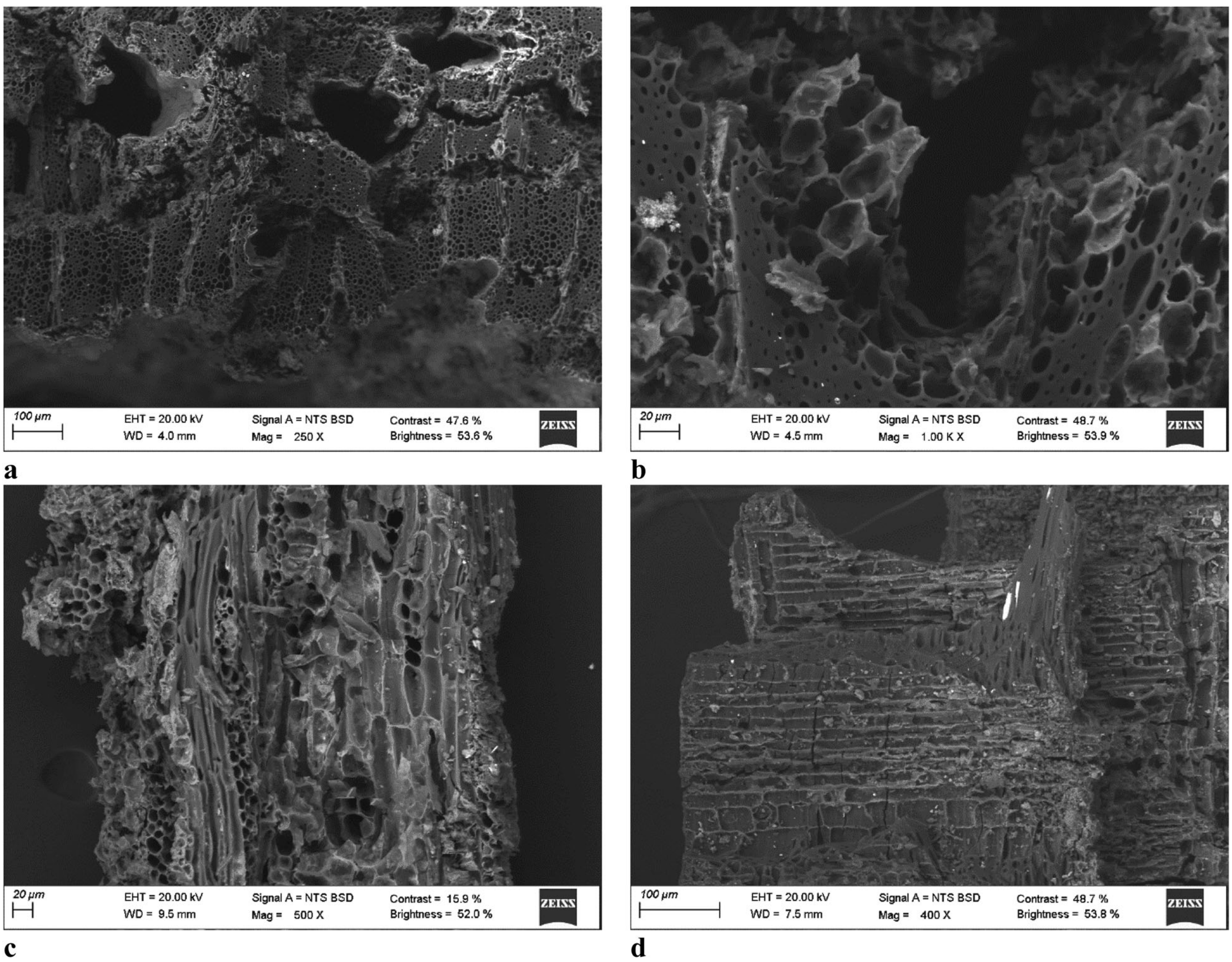

Figure 5. **CF. COPAIFERA SPP.** a: TS. diffuse-porous wood, b: TS solitary vessels, parenchyma paratraqueal vasicentric, c: TLS. rays 1–4 cells wide composed of procumbent ray cells with one row of upright and/or square marginal cells, d: RS. rays with one row of square marginal cells.

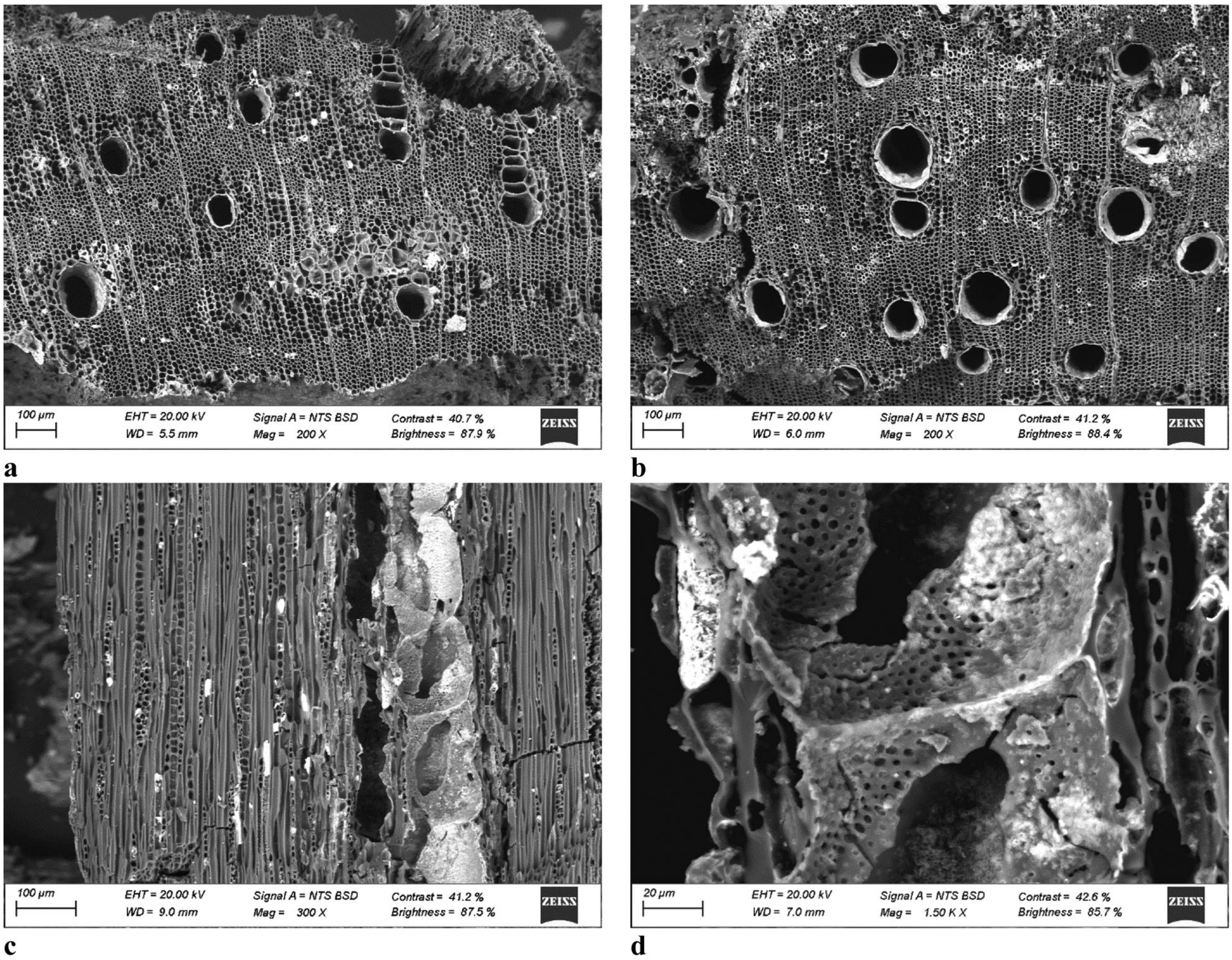

Figure 6. **Inga spp.** a: TS. wood diffuse-porous with solitary vessels and in short radial multiples of 2–4, occasionally in clusters, sometimes in small clusters, axial parenchyma vasicentric, aliform, lozenge-aliform, winged-aliform and/or confluent, b: TS. growth ring boundaries in most species indicated by crystalliferous fibres, often linked to some terminal parenchyma, wood diffuse-porous with solitary vessels, axial parenchyma vasicentric, aliform, lozenge-aliform, winged-aliform and/or confluent, c: TLS. ray width 1–3 cells, all ray cells procumbent; prismatic crystals in chambered axial parenchyma cells, septate fibres, d: TLS. vessels with simple perforation plates and circular or oval intervessel pits.

dimethyl-isopropyl-naphthalene) (not shown). These compounds probably originate from remains of labdanoid diterpene resins (in the same way that retene is formed from incomplete combustion of abietane diterpernes in pine resin). The same compounds were found in the resin of *Copaifera aromatica* (Kaal et al. 2020) from the reference collection but an unequivocal identification at the taxon level is impossible as charring affected the distribution of formed products, and other species may form similar patterns, especially after thermal alteration. Either way, the analysis supports an origin in *Copaifera aromatica* or a species with a similar resin composition and shows that biomarkers may be preserved in archaeological charcoal.

A sample of uncharred (fresh) wood of *Roupala montana* produced a Py-GC-MS chromatogram in which peaks of lignin products prevailed (not shown), with the peculiarity of a very dominant syringyl lignin. The main products were syringol, 4-methylsyringol, syringic aldehyde, $C_{3:1}$-syringols [4-(prop-1-enyl)syringol, *cis* 4-(prop-2-enyl)syringol and *trans* 4-(prop-2-enyl)syringol] and sinapaldehyde. Guaiacyl lignin groups were represented by minor peaks 4-vinylguaiacol and $C_{3:1}$-guaiacols. Polysaccharide products were also abundant (furans, furaldehydes and pyrans). Resinous substances were not detected. Unfortunately, the archaeological charcoal sample produced a chromatogram with only traces of benzene, toluene, and polycyclic aromatic hydrocarbons (PAHs), indicative of strongly charred biomass (Suárez-Abelenda, Kaal, and McBeath 2017). Hence, this material had been subjected to intense heating and all the diagnostic features of the *Roupala* wood had been lost.

Discussion

Taxonomic Identification

There are multiple constraints in charcoal analysis applied in tropical areas with species-rich environments because a large number of woody taxa share similar and overlapping wood anatomical features and the identification to family, species or genus is not always feasible

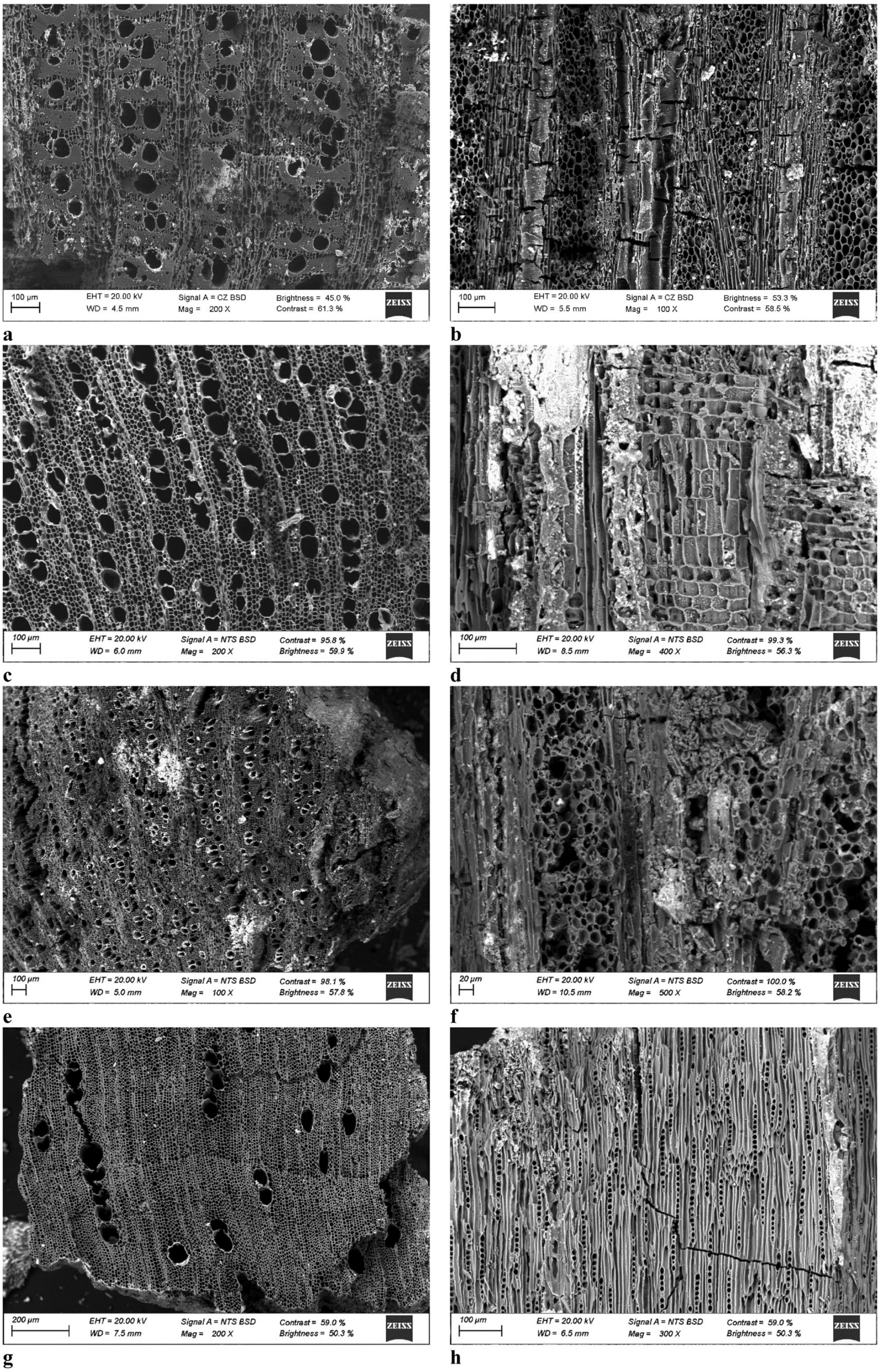

Figure 7. **a-b. Roupala spp**. a: TS. wood diffuse-porous with vessels in tangential bands and vessel clusters common, fibres very thick-walled, axial parenchyma in narrow bands or lines up to three cells wide, b: TLS. larger rays commonly > 10-seriate, ray height > 1 mm, rays of two distinct sizes, body ray cells procumbent with one up to 2–4 rows of upright and/or square marginal cells, sheath cells, **c-d. Guettarda spp**. c: TS. wood diffuse-porous, vessels in radial multiples of ≥4 and clusters common, solitary vessel outline angular, d: TR. body ray cells procumbent with ≥4 rows of upright and/or square marginal cells, prismatic crystals present in upright and/or square ray cells and crystal sand, e-f. **cf. Ryania spp**. e: TS. wood diffuse-porous, solitary vessel outline angular, f: TLS. larger rays commonly 4–10-seriate or more than 10-seriate, body ray cells procumbent with ≥4 rows of upright and/or square marginal cells, **g-h. Allophylus spp**. g: TS. wood diffuse-porous, fibres thin to thick walled, axial parenchyma absent or extremely rare, h: TLS. rays exclusively uniseriate and all ray cells procumbent.

(Wheeler and Baas 1998; Gasson 2011; Höhn and Neumann 2018). Within the charcoal assemblages from El Caño, other constraints on identification relate to the preservation of the material, and the difficulty in observing diagnostic features: coatings on vessel walls that originate from non-wood related deposits such as minerals, intense vitrification, presence of radial and tangential cracks, small size, brittleness. The abundance of vitrification and cracks, as well as fractures affecting the parenchyma cell walls in tropical wood after charring has been widely attested (Prior and Gasson 1993; Gonçalves, Marcati, and Scheel-Ybert 2011, 2016; Nisgoski et al. 2012).

The specificity of wood anatomical features of *Rhizophora* spp. (scalariform perforation plates and intervessel pits) and *Avicennia* spp. (conspicuous growth rings, alternation of bands of xylem and phloem tissue) (León 2001, 2008; Robert et al. 2009; Tomlinson 2016) has facilitated their classification in the charcoal types of AVICENNIA SPP. and RHIZOPHORA SPP. even when affected by vitrification and cracks. In the case of HANDROANTHUS/TABEBUIA, quantitative and qualitative similitudes identified in wood anatomical features of *Tabebuia* and *Handroanthus* (Pace et al. 2015; Pace and Angyalossy 2013) have conditioned their classification in the same charcoal type. *Tabebuia* alliance include 14 genera, although the archaeological samples presented features described specifically for *Handroanthus serratifolius* (Miller and Détienne 2001, 182–183; InsideWood 2004-onwards, Albuquerque 2012, 75–76; León 2014, 52–53; Bhikhi et al. 2016, 36).

In the case of Fabaceae family – the second largest family of trees in Panama (including 234 species; Condit, Pérez, and Daguerre 2011) – their taxonomic identification is problematic (Höhn 1999). In the present study, it has even been more challenging because charcoal fragments were in a poor state of preservation (Figure 5) or small in size (Figure 6). Forty-eight charcoal fragments were classified as CF. COPAIFERA SPP. (Fabaceae-Caesalpinoideae), combining both microscopic features observed in the SEM with chemical markers identified through Py-GC-MS analysis. The presence of *Copaifera aromatica* and *C. rufescens* has been reported in the Pacific area of the country (López, Pérez, and Mariscal 2015; Condit, Pérez, and Daguerre 2011). The subfamily Mimosoideae is represented by the charcoal type INGA SPP., which is one of the largest tree genera in tropical America, with 55 species in Panama (Condit, Pérez, and Daguerre 2011). Within the genus *Inga* there is much variation in wood anatomy (Baretta-Kuipers 1973; Espinoza and Melandri 1999–2000; Evans, Gasson, and Lewis 2006), which inhibits identification at species level Figure 8.

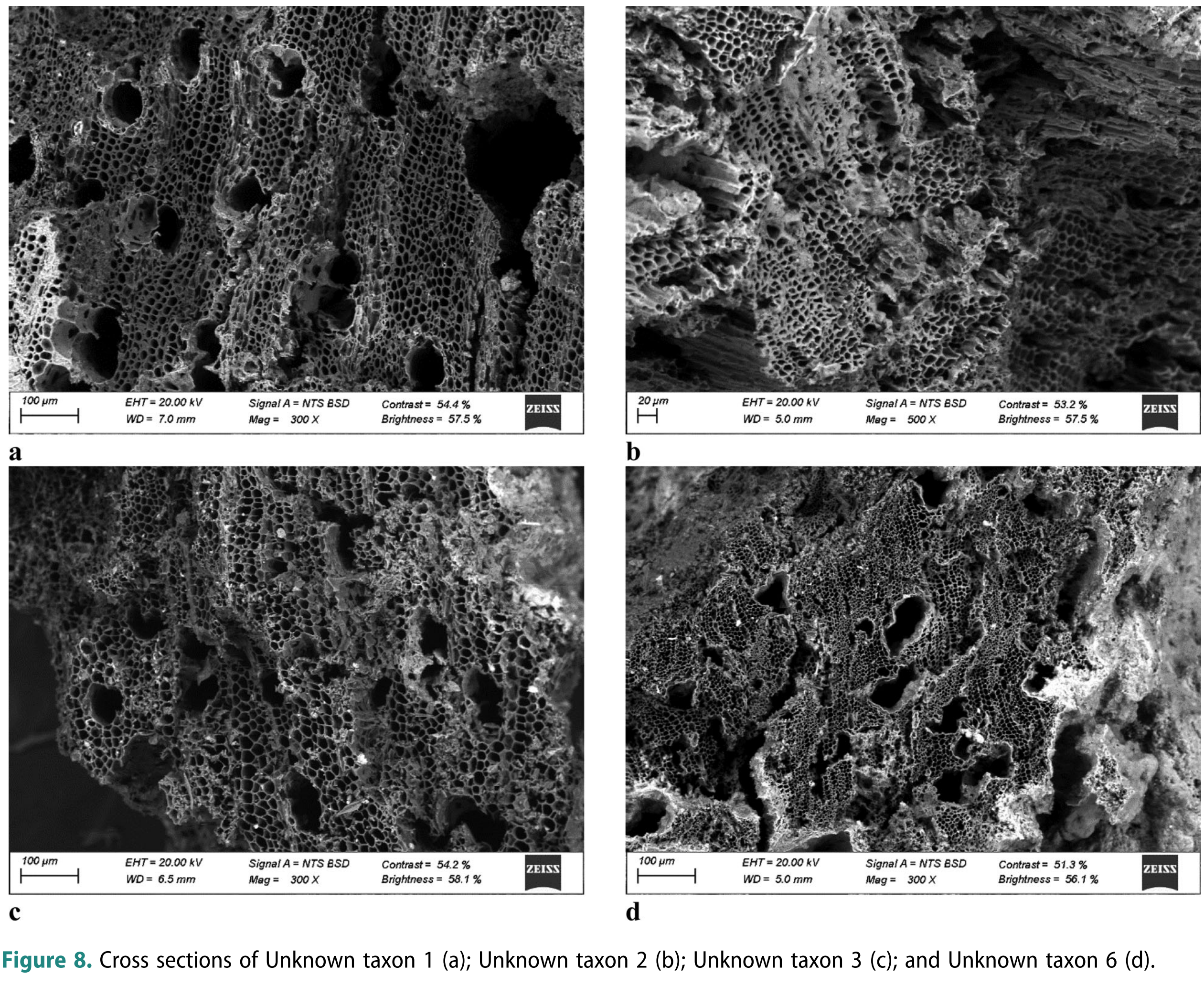

Figure 8. Cross sections of Unknown taxon 1 (a); Unknown taxon 2 (b); Unknown taxon 3 (c); and Unknown taxon 6 (d).

In the case of ROUPALA SPP. (Proteaceae), combined charcoal analysis with Py-GC-MS was also carried out, but the latter technique only provided chemical products of charred biomass. Nevertheless, it is interesting to note that ROUPALA SPP., CF. COPAIFERA SPP. and GUETTARDA SPP. were burnt together but chemical markers similar to those in *Copaifera* resin were not identified in ROUPALA SPP. This excludes the possibility that the presence of *Copaifera* resin markers associated with CF. COPAIFERA SPP. were related to the burning of *copal* obtained from this genus. The differentiation between different species of the *Roupala* genus is not possible because they present a very similar wood anatomy structure (Chattaway 1948). In the analysis of archaeological charcoal, it would be an advantage to select charcoal samples that show visual evidence of charring at reduced temperatures, for instance interior uncharred cores, and that way avoid the analysis of samples which did not preserve precursors of Py-GC-MS markers such as terpenoids.

A total of 17 charcoal fragments have been classified as GUETTARDA SPP. (Rubiaceae). Recent research on Rubiaceae wood anatomy resulted in several subgroups of the family (Jansen et al. 2002) and within it, tribe Guettardaceae has been described as heterogeneous and morphologically rather isolated (Welle et al. 1983 Jansen et al. 2002; León 2011). The identification of CF. RYANIA SPP. (Salicaceae) was based on microscopic features (Bannan 1943), but differentiation between *Ryania* species is difficult because diagnostic features overlap (Bannan 1943). Finally, the ALLOPHYLUS SPP. charcoal type (Sapindaceae) has been identified by anatomical features (InsideWood 2004-onwards, León 2013).

Wild Plant Resources Procurement

Charcoal types identified at El Caño suggest that hierarchical societies of Panama isthmus procured wood from diverse ecological zones. The presence of AVICENNIA SPP. and RHIZOPHORA SPP. in Tomb 2 indicates that wood was procured in mangrove forests. The exploitation of mangals was previously attested by the presence of RHIZOPHORA SPP. in a post-hole in Tomb 7 (Martín-Seijo, Mayo, and Mayo 2018) and in six features in Assemblage 5, one of which also contained another mangrove species such as PELLICIERA RHIZOPHORAE (Martín-Seijo et al. 2016). The nearest mangals are located several kilometres downstream at the mouth of the Río Grande. Mangroves are the only vascular flowering trees that can live in the confluence of land, freshwater, and ocean, and these forests are regularly flooded in the intertidal zones of tropical and subtropical coasts (Kathiresan and Bingham 2001; Robert et al. 2009; López-Angarita et al. 2016; Tomlinson 2016). In the Pacific coast of Panama, the presence of *Avicennia bicolor* and *A. germinans*, *Rhizophora mangle, R. harrisonii* and *R. racemosa* has been reported (Condit, Pérez, and Daguerre 2011). Although *Avicennia* and *Rhizophora* are the two dominant mangrove genera, *Avicennia* is observed near the sea as well as in the more inland parts of the mangrove area, while *Rhizophora* only grows at the seaward end of the mangrove forest (Robert et al. 2009). *Pelliciera* also occupies the intertidal zone, commonly in association with *Rhizophora*, but typically in sheltered sites such as estuarine banks or protected beaches (Tomlinson 2016).

Mangrove forests, despite their low floristic biodiversity, provide numerous raw materials, such as timber for construction, fuel, fodder, and tannins (Tomlinson 2016). The mangal create unique ecological environments that host rich species assemblages (Kathiresan and Bingham 2001). Their exploitation by the hierarchical societies has been demonstrated not only by the presence of wood charcoal of mangrove genera in funerary contexts (Martín-Seijo et al. 2016, 2018) but also by the identification of marine fish bones including many taxa that frequent mangroves (Cooke and Ranere 1999; Cooke and Jiménez 2004; Mayo et al. 2020). Within the tombs of El Caño, excavation has identified the remains of animals that inhabited the mangrove's shallow waters (e.g. sharpnose shark/*Rhizoprionodon longurio*, lemon shark/*Negaprion brevirostris*), its soft floor (e.g. bullseye puffer/*Sphoeroides annulatus*, spotted puffer/*Guentheridia formosa*), and its forests (e.g. raccoons/*Procyon lotor*) (Jiménez 2015; Mayo et al. 2020). There are also iconographic representations of animals that live in the mangal waters, such as the spiny lobsters (Guinea 2015) or the seahorse (Cobb, Beaubien, and Harrison 2015), in figurative *tumbaga* pendants.

Other charcoal types would be related to the exploitation of the plant resources of dry forests. This is the case of HANDROANTHUS/TABEBUIA. Its presence was also attested in three stratigraphic units of Tomb 7 (Martín-Seijo, Mayo, and Mayo 2018). Three main species are currently present in Panama: *Tabebuia guayacan* -currently named as *Handroanthus guayacan*-, *T. ochracea, T. rosea* and *T. palustris* (Correa, Galdames, and Stapf 2004; Condit, Pérez, and Daguerre 2011). *Handroanthus guayacan* is not common on Panama's dry Pacific side, whilst other two species, *T. ochraceae* and *T. rosea,* are distributed mostly in the dry zone of Panama, in pastures and dry forests (Condit, Pérez, and Daguerre 2011). *Tabebuia palustris* is a deciduous shrub or small tree mangrove associate with a strictly Pacific distribution, in a limited range from Costa Rica to Colombia, which grows in the drier marginal parts of mangrove swamps (Tomlinson 2016). Its presence was reported in the swamps of Río Grande (Correa, Galdames, and Stapf 2004). ROUPALA SPP. charcoal type refers to *Roupala* species which are present in shrublands, savannas and rainforests in tropical South and Central America (Weston 2007). In Panama, the presence of *Roupala montana, R. percoriaceae* and *R. panamensis* is reported (Condit, Pérez, and Daguerre 2011), with *R. montana* common in the extremely dry areas (Condit, Pérez, and Daguerre 2011; Pérez and Condit 2020).

The GUETTARDA SPP. and ALLOPHYLUS SPP. charcoal types are related to species found in dry and wet forests. Seven species of *Guettarda* genus, which includes shrubs and trees occurring in the Neotropics, are found in Panama, including species from dry forests (Condit, Pérez, and Daguerre 2011, 394), whilst *Allophylus psilospermus* is widespread in Panama and *A. racemose* is present in very dry areas (Condit, Pérez, and Daguerre 2011, 426). Other charcoal types, such as CF. COPAIFERA SPP. and INGA SPP., might be related to wood procurement on riparian forests. *Copaifera aromatica* grows in the dry zone near the Pacific, especially along streams (Condit, Pérez, and Daguerre 2011; Pérez and Condit 2020); in this area another species, *Copaifera panamensis*, is rare and endemic (D'Arcy 1987). All species of the large genus *Inga* are well developed trees that prefer a humid habitat (Baretta-Kuipers 1973), non-inundated primary and secondary forest, marsh forest, savannah forest, riparian forest, and is widely distributed throughout the Neotropics (Bhikhi et al. 2016, 130). In the area of El Caño the presence of at least 10 species is reported: *Inga chocoensis, I. cocleensis, I. goldmanii, I. marginata, I. oerstediana, I. pezizifera, I. punctate, I. thibaudiana, I. venusta* and *I. vera* (Condit, Pérez, and Daguerre 2011, 190–207). Previous research also identified the exploitation of *Hymenaea* trees, which also grows in riparian forests (Condit, Pérez, and Daguerre 2011), to obtain resin for producing figurines and beads deposited as grave goods in Tombs 2 and 7 (Kaal et al. 2020). The exploitation of moist to wet forests was registered in Tomb 7 by the presence of CHRYSOPHYLLUM SPP. (Martín-Seijo, Mayo, and Mayo 2018). Eight *Chrysophyllum* species (Sapotaceae) are found in Panama, all of them large forest trees that exudate white latex from broken leaves or cut bark, while one of the species, *Chrisophyllum cainito,* produces an edible fruit (Condit, Pérez, and Daguerre 2011; Pérez and Condit 2020). Finally, CF. RYANIA SPP. charcoal type could be related to *Ryania speciosa,* which is an understory tree present in lower montane sites, always within mature forest, and rare or absent in the dry forests of the Pacific side of the Panama (Condit, Pérez, and Daguerre 2011; Pérez and Condit 2020).

Wood and Funerary Rituals

The results obtained point to wood playing diverse roles during the mortuary rites. In Tomb 2 most samples were recovered from burial contexts (SU088, 104, 106 and 134), deposits of massive offerings (SU128, 130, 131, 135 and 136) and within a broken ceramic vessel probably used as incense burner (SU107) (Table 1). The presence of charcoal remains in relation to burials and offerings was probably related to the use of wood as firewood in different episodes at the time of burial -kindling for censers, burning resins, torches, etc.- or even timber for making ephemeral structures or implements that were partially burnt. The burning of plants during funerary rituals has been attested in the Mesoamerican area since at least the Late Classic period (*ca.* A.D. 600–900) and have continued through colonial and modern times (Morehart 2011; Morehart, Lentz, and Prufer 2005; Dussol et al. 2016).

Charcoal fragments recovered from SU107 were remains of firewood burnt inside a broken ceramic vessel, probably used as a censer (Figure 3a and c). The presence of CF. COPAIFERA SPP., GUETTARDA SPP., ROUPALA SPP. and DICOT wood was identified (Table 2). These charcoals were probably part of a *sahumerio* (perfuming with smoke), in which wood was burnt for producing aroma, as part of the funerary ritual. The burning of plant materials for producing fragrant smoke has been reported for different kinds of rituals (Pennacchio, Jefferson, and Havens 2010), and it is widely attested in El Caño and other sites of the Gran Coclé cultural area such as Sitio Conte by the presence of ceramic censers (Figure 3b). Three charcoal types (CF. COPAIFERA SPP., ROUPALA SPP. and GUETTARDA SPP) are related to plants that produce odour. The aroma of the smoke probably was a symbolic offering, as in other areas of Central America, it represented the 'breath-soul' (Houston and Taube 2000; García González 2015). The *cabimo* (*Copaifera aromatica*) is a resin-producing tree with fragrant resinous sap, exuded from cut bark (Prance and Nesbitt 2005). The fresh wood and crushed leaves or branchlets of *carne asada* or *árbol ratón* (*Roupala montana*) produce a strong odour described as ground fish, tuna fish or meat odour (Condit, Pérez, and Daguerre 2011). Several species of the *Guettarda* genus produce hard and durable wood, which was used traditionally for making tools and poles, and burnt as firewood, while dead wood is used to smoke objects, and the essential oil produced by the flowers is used for scenting (Condit, Pérez, and Daguerre 2011; Thaman et al. 2017).

Three ceramic censers were recovered from SU103, 104 and 218 within Tomb 2 (Figure 3b). In SU104, charred remains of HANDROANTHUS/TABEBUIA wood (Table 2) were identified; this charcoal type was previously reported in Tomb 7 of El Caño (Martín-Seijo, Mayo, and Mayo 2018). *Handroanthus* produces an incredibly hard wood, whilst *Tabebuia* wood is not particularly hard or heavy (Condit, Pérez, and Daguerre 2011). In both Tomb 2 and Tomb 7, HANDROANTHUS/TABEBUIA was probably burnt as firewood because the wood produces long-lasting embers. It must also be considered that these trees might have been selected for their symbolism. *H. guayacan* has one of the most extensive flowering responses to precipitation after the dry season in the tropics. These trees are leafless when they flower and their crowns are completely covered in yellow (*H. guayacan, T. ochraceae*), pink or white (*T. rosea*) (Carpio 2003; Condit, Pérez, and Daguerre 2011).

For the other contexts, it is more difficult to establish the role played by wood, which could be related to the burning of torches or firewood, or with the partial or complete burning of wooden objects. *Avicennia* and *Rhizophora* produce heavy and durable wood, difficult to manipulate. Wood from both genera has been traditionally used for making posts and also for producing charcoal (Carpio 2003). *Rhizophora* is recognised as an ideal firewood with high calorific content, burning well even when freshly cut, while its bark also makes an excellent fuel (National Research Council 1980; Prance and Nesbitt 2005). In Assemblage 5 of El Caño, it was possible to recognise the use of RHIZOPHORA SPP. type as poles through the presence of charred wood within post-holes (Martín-Seijo et al. 2016, 2018). Regarding other charcoal types, the wood obtained from *Inga* spp. has been traditionally used as firewood (Zamora, Jiménez, and Poveda 2000), and *Allophylus* spp. for making implements and poles (Condit, Pérez, and Daguerre 2011).

Finally, *Ryania* spp. is a highly toxic plant that contains the alkaloid Ryanodine which is used to produce a poison for humans and animals (fish, caiman) by macerating the bark and the leaves; the stems of *Ryania speciosa* were used for producing insecticide (Prance, Campbell, and Nelson 1977; Gupta et al. 2003). The inhalation of the smoke produced by this wood is considered fatal (von Reis and Lipp 1982; Pennacchio, Jefferson, and Havens 2010). The presence of charred CF. RYANIA SPP. wood could be linked to other toxic substances identified in Tomb 2 such as fish specimens belonging to the family Tetraodontidae that could have been used for their toxin in sacrificial acts (Mayo et al. 2020).

Conclusions

Archaeobotanical research in tropical areas is challenging. The usual methods used to recover plant remains (dry and wet sieving, flotation, hand collection) have not always been implemented during excavations, and for charcoal analysis the tropical wood taxa are extensive and poorly known with overlapping or similar diagnostic features. The pilot study presented has demonstrated that the combination of standard charcoal identification methods and chemical characterisation using Py-GC-MS is useful not only for the identification of traces of resins to species of the Fabaceae family, but also for the characterisation of the combustion process. In future studies, samples with morphological features indicating a relatively low charring temperature will be selected, increasing the likelihood of identifying chemical markers and therefore the benefit/cost ratio of the Py-GC-MS analyses.

Charcoal recovered from funerary contexts of the complex societies of the Isthmo-Colombian area offer a glimpse into the performance of their mortuary rituals. The practice of ritual *sahumerios* involving the burning of resins was already known by the presence of ceramic censers within the tombs, and by written sources (Gonzalo Fernández de Oviedo 1853, IX, XXX, 357), but in two different stratigraphic units in Tomb 2, burning of odorous wood, probably for producing smoke, was identified (Mayo et al. 2020). Taxa used included wood of *Ryania* genus, which produces a fatal smoke, and might be related to the use of other toxic substances during the sacrificial acts.

Charcoal types identified in the archaeobotanical assemblage of Tomb 2, together with those identified previously in El Caño (Martín-Seijo et al. 2016, 2018), have provided evidence for the complex strategies of wood procurement in diverse ecological zones. Plant materials were obtained from mangrove forests for providing raw material for perishable constructions linked to the tombs, or even as firewood, as attested previously, together with resources from riparian areas and the dry forests of the Pacific side of Panama (Martín-Seijo et al. 2016, 2018; Kaal et al. 2020).

Acknowledgements

This research has been funded by Secretaría Nacional de Ciencia y Tecnología (SENACYT) (Contrato de Mérito n° 80-2014-4-col12-005 signed between Julia Mayo and SENACYT). María Martín-Seijo was funded by a postdoctoral grant Plan I2C mod. B with the project 'MATERIAL-Materiality and Material Culture: Wood and Other Plant-based Materials in Archaeological Contexts'. The authors are grateful to Clíodhna Ní Lionáin for reviewing the English version of the text and to the anonymous reviewers for their valuable comments.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by Xunta de Galicia: [Grant Number ED481D 2017/016].

Notes on contributors

Dr María Martín-Seijo is Postdoctoral Researcher in the Department of History, Universidade de Santiago de Compostela. She has been the Principal Investigator of the

project "MATERIAL-Materiality and Material Culture: Wood and Other Plant-based Materials in Archaeological Contexts" (2017-2019). She specialises in archaeobotany (wood and charcoal analysis) combined with experimental and ethnoarchaeological approaches to the study of plant-based crafts. She is currently co-chair of the EAA Community of Research on Wild Plant Resources (ARCHWILD).

Dr Joeri Kaal is managing director of Pyrolyscience.com, based in Madrid, Spain. He is associated with the Institute of Heritage Sciences of the Spanish National Research Council (Incipit-CSIC) in Santiago de Compostela (Spain) as an invited researcher, in the context of which he participiated in the present study. He is specialized in the use of analytical pyrolysis techniques to characterize macromolecular organic constituents in archaeological artefacts, soils and sediments.

Carlos Mayo Torné Ph.D. Candidate, currently works as researcher at Ministry of Culture of Panama. He is part of the team of the El Caño Archaeological Project. His main interest is the study of the craft production and uses of ceramics in the ancient Coclé, Panama.

Dr Julia Mayo Torné is an archaeologist specialised in pre-Hispanic hierarchical societies of the Isthmo-Colombian Area. Her field of interest is social organization and funerary rituals. Julia has worked for the last 20 years in Panama. She is the director of the El Caño Archaeological Project since 2008 and president of the El Caño Foundation. She is also a member of the National Research System of the National Secretariat of Science, Technology and Innovation (SENACYT) of the Republic of Panama.

ORCID

María Martín-Seijo http://orcid.org/0000-0003-2924-7763
Joeri Kaal http://orcid.org/0000-0002-0177-5911

References

Albuquerque, AR. 2012. "Anatomia comparada do lenho e do carvão aplicada na identificacão de 76 espécies da floresta Amazónica, no estado do Pará, Brasil. PhD Thesis." São Paulo: Universidade de São Paulo.

ANAM-ARAP / Autoridad Nacional del Ambiente y Autoridad de los Recursos Acuáticos de Panamá. 2013. *Manglares de Panamá: importancia, mejores prácticas y regulaciones vigentes*. Panamá: Editora Novo Art.

Bannan, M. W. 1943. "Wood Structure of Ryania." *American Journal of Botany* 30 (5): 351–355.

Baretta-Kuipers, T. 1973. "Some Aspects of Wood-Anatomical Research in the Genus Inga (Mimosaceae) From the Guianas and Especially Suriname." *Acta Botanica Neerlandica* 22 (3): 193–205.

Bhikhi, Ch.R., P. J. M. Maas, J. Koek-Noorman, and T. R. van Andel. 2016. *Timber Trees of Suriname–an Identification Guide*. Volendam: LM Publishers.

Braadbaart, F., and I. Poole. 2008. "Morphological, Chemical and Physical Changes During Charcoalification of Wood and its Relevance to Archaeological Contexts." *Journal of Archaeological Science* 35: 2434–2445.

Carlquist, S. 2013. *Comparative Wood Anatomy: Systematic, Ecological, and Evolutionary Aspects of Dicotyledon Wood*. Berlin: Springer.

Carpio, I. M. 2003. *Maderas de Costa Rica: 150 especies forestales*. Costa Rica: Editorial Universidad de Costa Rica.

Carreras, R., A. Cuza, L. R. González, and J. Teruel. 2012. *Árboles y maderas de Baracoa, Cuba. Fichas anatómicas para su identificación*. Tarragona: Publicitat Tafaner.

Carreras, R., A. Cuza, L. R. González, and J. Teruel. 2013. *Árboles y maderas. Reserva de Biosfera de Guanacahibes (Pinar del Río, Cuba). Fichas anatómicas para su identificación*. Tarragona: Publicitat Tafaner.

Carreras, R, and Dechamps R. 1995. "Anatomía de la madera de 157 especies forestales que crecen en Cuba y sus usos tecnológicos, históricos y culturales." Ter vuren, Musé e Royal de l'Afrique Centrale.

Cartwright, C. R. 2015. "The Principles, Procedures and Pitfalls in Identifying Archaeological and Historical Wood Samples." *Annals of Botany* 116 (1): 1–13.

Chattaway, M. M. 1948. "The Wood Anatomy of the Proteaceae." *Australian Journal of Biological Sciences* 1 (3): 279–302.

Chrzazvez, J., I. Théry-Parisot, G. Fiorucci, J. F. Terral, and B. Thibaut. 2014. "Impact of Post-Depositional Processes on Charcoal Fragmentation and Archaeobotanical Implications: Experimental Approach Combining Charcoal Analysis and Biomechanics." *Journal of Archaeological Science* 44: 30–42.

Cobb, K. C., H. Beaubien, and A. Harrison. 2015. "Los orfebres de El Caño. Los Coclé, maestros en el manejo de los metales." In *Guerreros de Oro: Los Señores de Coclé*, edited by J. Mayo, and J. A. Carles, 184–214. Panamá: Ed. Caribe.

Condit, R., R. Pérez, and N. Daguerre. 2011. *Trees of Panama and Costa Rica*. New Jersey: Princeton Field Guides.

Cooke, R. 1976. Rescate arqueológico en El Caño (NA-20), Coclé. Actas del IV Simposium Nacional de Arqueología, Antropología y Etnohistoria de Panamá, 447–482. Panamá, Instituto Nacional de Cultura de Panamá.

Cooke, R. G. 2004. "Rich, Poor, Shaman, Child: Animals, Rank, and Status in the 'Gran Coclé'culture Area of pre-Columbian Panama." In *Behaviour behind Bones. The Zooarchaeology of Ritual, Religion, Status and Identity*, edited by S. O'Day, W. Van Neer, and A. Ervynck, 271–284. Oxford: Oxbow Books.

Cooke, R. G., I. Isaza, J. C. Griggs, B. Desjardins, and L. A. Sánchez. 2003. "Who Crafted, Exchanged, and Displayed Gold in Pre-Columbian Panama?" In *Gold and Power in Ancient Costa Rica, Panama and Colombia*, edited by J. Quilter, and J. W. Hoopes, 91–158. Washington: Dumbarton Oaks.

Cooke, R. G., and M. Jiménez. 2004. "Teasing out the Species in Diverse Archaeofaunas: Is it Worth the Effort? An Example From the Tropical Eastern Pacific." *Archaeofauna* 13: 19–35.

Cooke, R. G., and A. J. Ranere. 1999. "Precolumbian Fishing on the Pacific Coast of Panama." In *Pacific Latin America in Prehistory: The Evolution of Archaic and Formative Cultures*, edited by M. Blake, 103–121. Washington: Washington State University Press.

Correa A.M.D., Galdames, C. and Stapf, M. 2004. *Catálogo de las Plantas Vasculares de Panamá*. Panamá: Smithsonian Tropical Research Institute.

Crivellaro, A., and F. H. Schweingruber. 2015. *Stem Anatomical Features of Dicotyledons. Xylem, Pholem, Cortex and Periderm Characteristics for Ecological and Taxonomical Analysis*. Remagen-Oberwinter: Verlag Kessel.

D'Arcy, W. G. 1987. "Flora of Panama. Checklist and Index. Part 1: The Introduction and Checklist." *Monographs in*

Systematic Botany From the Missouri Botanical Garden 17–18: 1–328.

Dickau, R. 2010. "Microbotanical and Macrobotanical Evidence of Plant use and the Transition to Agriculture in Panama." In *Integrating Zooarchaeology and Paleoethnobotany*, edited by A. M. VanDerwarker, and T. M. Peres, 99–134. Berlin: Springer.

Doyle, G. 1960. "Metal and Pottery Associations." *Panama Archaeologist* 3: 48–51.

Dussol, L., M. Elliott, G. Pereira, and D. Michelet. 2016. "The Use of Firewood in Ancient Maya Funerary Rituals: A Case Study from Río Bec (Campeche, Mexico)." *Latin American Antiquity* 27 (1): 51–73.

Espinoza, N., and W. J. León. 2001. *Atlas para la Identificación Microscópica de Maderas Latifoliadas*. Mérida: Universidad de los Andes.

Espinoza, N., and J. L. Melandri. 1999–2000. "Estudio Anatómico del Leño de Cinco Especies Comerciales de la Subfamilia Mimosoideae en Venezuela." *Pittieria* 29–30 (1): 75–88.

Espinoza, N., and J. L. Melandri. 2000. *Anatomía del Tallo de las Monocotiledóneas*. Mérida: Universidad de los Andes.

Evans, J. A., P. E. Gasson, and G. P. Lewis. 2006. "Wood Anatomy of the Mimosoideae (Leguminosae). IAWA Journal." *Supplement* 5: 1–116.

Fernández de Oviedo, G. 1853. Historia general y natural de las Indias, Islas y Tierra-Firme del Mar Océano. Madrid: Imprenta de la Real Academia de la Historia.

García-Esteban, L., A. Guindeo, C. Peraza, and P. de Palacios. 2003. *La madera y su anatomía*. Madrid: Ed. Mundi Prensa.

García González, M. 2015. "Efluvios mensajeros: el copal y el yauhtli en los sahumadores del Templo Mayor." *Arqueología mexicana* 23 (135): 44–49.

Gasson, P. 2011. "How Precise can Wood Identification be? Wood Anatomy's Role in Support of the Legal Timber Trade, Especially CITES." *IAWA Journal* 32 (2): 137–154.

Gonçalves, T. A., C. R. Marcati, and R. Scheel-Ybert. 2011. "Wood and Charcoal Anatomy in Species of the Brazilian Cerrado: Effect of Carbonization on Wood Structure." *SAGVNTVM Extra* 11: 51–52.

Gonçalves, T. A., S. Nisgoski, J. S. Oliveira, C. R. Marcati, A. W. Ballarin, and G. I. Muñiz. 2016. "A Contribution to the Identification of Charcoal Origin in Brazil II-Macroscopic Characterization of Cerrado Species." *Anais da Academia Brasileira de Ciências*, 1–10. doi:10.1590/0001-3765201620150322.

Guinea, M. 2015. "El calamar volador. El mundo sobrenatural de los Coclé." In *Guerreros de Oro: Los Señores de Coclé*, edited by J. Mayo, and J. A. Carles, 126–156. Panamá: Ed. Caribe.

Guinea, M., and J. Mayo. 2013. "La armadura dorada de un cacique coclé: los pectorales de oro del ajuar del individuo principal de la Tumba 2 de la necrópolis de El Caño (900–1020 d.C.)." *Revista Española de Antropología Americana* 43 (2): 307–327.

Gupta, M. P., S. S. Handa, G. Longo, and D. D. Rakesh. 2003. *Compendium of Medicinal and Aromatic Plants: The Americas*. Vienna: UNIDO.

Hastorf, C. 1999. "Recent Research in Paleoethnobotany." *Journal of Archaeological Research* 7 (1): 55–103.

Helms, M. W. 1979. *Ancient Panama. Chiefs in Search of Power*. Austin and London: University of Texas Press.

Höhn, A. 1999. "Wood Anatomy of Selected West African Species of Caesalpinioideae and Mimosoideae (Leguminosae): A Comparative Study." *IAWA Journal* 20 (2): 115–146.

Höhn, A., and K. Neumann. 2018. "Charcoal Identification in a Species-Rich Environment: The Example of Dibamba, Cameroon." *IAWA Journal* 39 (1): 87–S47.

Houston, S., and K. Taube. 2000. "An Archaeology of the Senses: Perception and Cultural Expression in Ancient Mesoamerica." *Cambridge Archaeological Journal* 10 (2): 261–294.

Hubau, W., J. Van den Bulcke, P. Kitin, L. Brabant, J. Van Acker, and H. Beeckman. 2013. "Complementary Imaging Techniques for Charcoal Examination and Identification." *IAWA Journal* 34 (2): 147–168.

Hubau, W., J. Van den Bulcke, P. Kitin, F. Mees, J. Van Acker, and H. Beeckman. 2012. "Charcoal Identification in Species-Rich Biomes: A Protocol for Central Africa Optimised for the Mayumbe Forest." *Review of Palaeobotany and Palynology* 171: 164–178.

IAWA COMMITTEE. 1989. "List of Microscopic Features for Hardwood Identification." *IAWA Bulletin* 10 (2): 219–332.

Insidewood. 2004-onwards. Accessed 2019 March. http://insidewood.lib.ncsu.edu/search.

Jansen, S., E. Robbrecht, H. Beeckman, and E. Smets. 2002. "A Survey of the Systematic Wood Anatomy of the Rubiaceae." *IAWA Journal* 23 (1): 1–67.

Jiménez, M. 2015. "La explotación de los recursos faunísticos." In *Guerreros de Oro: Los Señores de Coclé*, edited by J. Mayo, and J. A. Carles, 100–107. Panamá: Ed. Caribe.

Kaal, J., M. Martín-Seijo, C. Oliveira, E. Wagner-Wysiecka, V. E. McCoy, M. M. Solórzano Kraemer, A. Kerner, P. Wenig, C. Mayo, and J. Mayo. 2020. "Golden Artefacts, Resin Figurines, Body Adhesives and Tomb Sediments From the pre-Columbian Burial Site El Caño (Gran Coclé, Panamá): Tracing Organic Contents Using Molecular Archaeometry." *Journal of Archaeological Science* 113: 105045.

Kaal, J., A. Martínez Cortizas, P. Buurman, and F. Criado Boado. 2008. "8000 Years of Black Carbon Accumulation in a Colluvial Soil From NW Spain." *Quaternary Research* 69: 56–61.

Kaal, J., C. Oliveira, M. Martín-Seijo, C. Mayo, and J. Mayo. 2018. Objetos de resina en Los Ajuares de El Caño (Panamá): diseño de un protocolo de análisis y primeros resultados. In ICA 2018, 56th International Congress of Americanists.

Kathiresan, K., and B. L. Bingham. 2001. "Biology of Mangroves and Mangrove Ecosystems." *Advances in Marine Biology* 40: 84–254.

Lancelotti, C., M. Madella, P. Ajithprasad, and C. A. Petrie. 2010. "Temperature, Compression and Fragmentation: An Experimental Analysis to Assess the Impact of Taphonomic Processes on Charcoal Preservation." *Archaeological and Anthropological Science* 2 (4): 307–320.

Langenheim, J. H. 2003. *Plant Resins: Chemistry, Evolution, Ecology, and Ethnobotany*. Portland-Cambridge: Timber Press.

León, H. W. 2001. "Anatomía del leño, aspectos ecológicos y filogenia en mangles de Venezuela." *Revista Forestal Venezolana* 45 (2): 191–203.

León, W. J. 2002. *Anatomía e Identificación Macroscópica de Maderas*. Mérida: Universidad de los Andes.

León, W. 2008. Anatomía *de Madera en 31 Especies de la Subfamilia Mimosoideae (leguminosae) en Venezuela." Colombia Forestal* 11: 113–136.

León, W. J. 2011. “Anatomía de la madera de 31 especies de Rubiaceae en Venezuela.” *Acta Botanica Venezuelica* 34 (2): 347–379.

León, W. J. 2013. “Anatomía de la madera de 27 especies de Sapindales en el estado Barinas (Venezuela). Aspectos taxonómicos.” *La Revista Forestal Venezolana* 57 (1): 9–28.

León, W. J. 2014. “Anatomía de Maderas de 108 Especies de Venezuela.” *Pittieria* número especial: 1–267.

León, W. J., and N. Espinoza. 2001. *Anatomía de la madera*. Mérida: Universidad de los Andes.

Linares-Palomino, R., R. T. Pennington, and S. Bridgewater. 2003. “The Phytogeography of the Seasonally dry Tropical Forests in Equatorial Pacific South America.” *Candollea* 58 (2): 473–499.

Linares, O. F. 1977. “Ecology and the Arts in Ancient Panama: on the Development of Social Rank and Symbolism in the Central Provinces.” *Studies in Pre-Columbian Art and Archaeology* 17: 1–86.

López-Angarita, J., C. M. Roberts, A. Tilley, J. P. Hawkins, and R. G. Cooke. 2016. “Mangroves and People: Lessons From a History of use and Abuse in Four Latin American Countries.” *Forest Ecology and Management* 368: 151–162.

López, O. R., R. Pérez, and E. Mariscal. 2015. “Diversidad de árboles y arbustos en fragmentos de bosque seco tropical en rio Hato, Panamá.” *Colombia forestal* 18 (1): 105–115.

Lothrop, S. 1934. “Archaeological Investigation in the Province of Coclé, Panamá.” *American Journal of Archaeology* 38: 207–211.

Lothrop, S. 1937. “Coclé: An Archaeological Study of Central Panama. Historical Background Excavations at the Sitio Conte: Artifacts and Ornaments.” Part 1. Memoirs of the Peabody Museum of Archaeology and Ethnology 7, Cambridge.

Marcati, C. R., V. Angyalossy-Alfonso, and L. Benetati. 2001. “Comparative Wood Anatomy of Copaifera Langsdorffii Desf. (Leguminosae-Caesalpinoideae) in Forest and “Cerradão”.” *Brazilian Journal of Botany* 24 (3): 311–320.

Marguerie, D., and J. Y. Hunot. 2007. “Charcoal Analysis and Dendrology: Data From Archaeological Sites in North-Western France.” *Journal of Archaeological Science* 34 (9): 1417–1433.

Martín-Seijo, M. 2013. “A xestión do bosque e do monte dende a Idade do Ferro a época romana no noroeste da península Ibérica: consumo de combustibles e produción de manufacturas en madeira.” PhD Thesis. Santiago de Compostela: University of Santiago de Compostela.

Martín-Seijo, M., J. Mayo, and C. Mayo. 2018. “Madera para acompañar la muerte: antracología en los contextos funerarios de El Caño (Coclé, Panamá).” ICA 2018 56th International Congress of Americanists, 566–574.

Martín-Seijo, M., R. Piqué, J. Mayo, C. Mayo, and E. Abad. 2016. “Madera carbonizada en contextos funerarios de la jefatura de Río Grande, Panamá: antracología en el sitio de El Caño.” *Chungará. Revista de Antropología Chilena* 48 (2): 277–294.

Martínez-Mauri, M. 2020. “Things, Life, and Humans in Guna Yala (Panama): Talking About Molagana and Nudsugana Inside and Outside Guna Society.” In *Amerindian Socio-Cosmologies between the Andes, Amazonia and Mesoamerica Toward an Anthropological Understanding of the Isthmo-Colombian Area*, edited by E. Halbmayer, 257–278. London: Routledge.

Mayo, J, and Mayo C. 2013a. “El descubrimiento de un cementerio de élite en El Caño: indicios de un patrón funerario en el valle del Río Grande, Coclé, Panamá.” *Arqueología Iberoamericana* 20: 3–27.

Mayo, J, and Mayo C. 2013b. "La escultura precolombina del Área Intermedia. Aproximación al estudio estilístico, iconográfico y espacial del grupo escultórico de El Caño." In *Producción de bienes de prestigio ornamentales y votivos de la América Antigua*, edited by J. Mayo and C. Mayo, 12–21. Florida: Syllaba Press.

Mayo, J., and J. A. Carles. 2015. *Guerreros de Oro: Los Señores de Coclé*. Panamá: Ed. Caribe.

Mayo, J., C. Mayo, and M. Guinea. 2021a. “Funerary Rituals among the Elite of the Río Grande Chiefdom, Panama: Preparations for the Final Journey of a Powerful Coclé Warrior.” In *Central American and Colombian Art at Dumbarton Oaks*, edited by C. McEwan, B. Cockrell, and J. W. Hoopes. Washington: Dumbarton Oaks Research Library and Collection. In press.

Mayo, J., C. Mayo, M. Guinea, M. A. Hervás, and J. Herrerín. 2020. “Approach to the Study of the Phenomenon of Multiple Burials at El Caño, Panama.” *Latin American Antiquity* 31 (1): 20–39.

Mayo, J., C. Mayo, M. Guinea, M. A. Hervás, and J. Herrerín. 2021b. “Social Order at El Caño.” In *Towards an Archaeology of “Greater” Central America*, edited by C. McEwan, B. Cockrell, and J. W. Hoopes. Washington: Dumbarton Oaks Research Library and Collection. In press.

Mayo Torné, J, Mayo Torné C, Bueno M, Hervás Herrera M, and Herrerín López J. 2016. “La tumba T7 de la necrópolis de El Caño, tradición arqueológica Gran Coclé, istmo de Panamá.” Arqueología Iberoamericana 30: 30–43.

Mcparland, L, Collinson M, Scott A, Campbell G, and Veal R. 2010. “Is Vitrification in Charcoal a Result of High Temperature Burning of Wood?.” *Journal of Archaeological Science* 37 (10): 2679–2687.

Melandri, J. L., and N. Espinoza. 2009. “Wood Anatomy of Tribe Detarieae and Comparison with Tribe Caesalpinieae (Leguminosae, Caesalpinioideae) in Venezuela.” *Revista de Biología Tropical* 57 (1–2): 303–319.

Miller, R. B., and P. Détienne. 2001. *Major Timber Trees of Guyana. Wood Anatomy*. Wageningen: Tropenbos International.

Morehart, C. T. 2011. *Food, Fire and Fragrance: A Paleoethnobotanical Perspective on Classic Maya Cave Rituals. BAR International Series 2186*. Oxford: Archaeopress.

Morehart, C. T., D. L. Lentz, and K. M. Prufer. 2005. “Wood of the Gods: The Ritual Use of Pine by the Ancient Lowland Maya.” *Latin American Antiquity* 16 (3): 55–74.

Morell-Hart, S., R. A. Joyce, J. S. Henderson, and R. Cane. 2019. “Ethnoecology in Pre-Hispanic Central America: Foodways and Human-Plant Interfaces.” *Ancient Mesoamerica* 30 (3): 535–553.

Morrone, J. J. 2017. *Neotropical Biogeography: Regionalization and Evolution*. Boca Raton: CRC Press.

Moskal del Hoyo, M., M. Wachowiak, and R. A. Blanchette. 2010. “Preservation of Fungi in Archaeological Charcoal.” *Journal of Archaeological Science* 37: 2106–2116.

Murphy, P. G., and A. E. Lugo. 1986. “Ecology of Tropical Dry Forest.” *Annual Review of Ecology and Systematics* 17: 67–88.

National Research Council. 1980. “Firewood Crops: Shrub and Tree Species for Energy Production: Report of an Ad Hoc Panel of the Advisory Committee on Tecnhology Innovation Board on Science and Technology for International Development, Commission on International Relations, National Research Council.” National Academy of Sciences.
Nisgoski, S., G. I. B. Muñiz, R. F. França, and F. R. R. Batista. 2012. “Anatomia do lenho carbonizado de Copaifera cf. langsdorfii Desf. e Dipteryx odorata (Aubl.) Wild.” *Revista Ciência da Madeira (Brazilian Journal of Wood Science)* 3 (2): 10–12953.
Ogata, K., T. Fujii, H. Abe, and P. Baas. 2008. *Identification of the Timbers of Southeast Asia and the Western Pacific*. Holzforschung: Kaiseisha Press.
Pace, M. R., and V. Angyalossy. 2013. “Wood Anatomy and Evolution: A Case Study in the Bignoniaceae.” *International Journal of Plant Sciences* 174 (7): 1014–1048.
Pace, M. R., L. G. Lohmann, R. G. Olmstead, and V. Angyalossy. 2015. “Wood Anatomy of Major Bignoniaceae Clades.” *Plant Systematics and Evolution* 301 (3): 967–995.
Paché, M. 2016. “The Grammaticalization of Plant-Part Terms in Chibchan Languages.” *International Journal of American Linguistics* 82 (4): 425–452.
Pennacchio, M., L. Jefferson, and K. Havens. 2010. *Uses and Abuses of Plant-Derived Smoke: Its Ethnobotany as Hallucinogen, Perfume, Incense, and Medicine*. Oxford: Oxford University Press.
Pennington, R. T., M. Lavin, and A. Oliveira-Filho. 2009. “Woody Plant Diversity, Evolution, and Ecology in the Tropics: Perspectives From Seasonally Dry Tropical Forests.” *Annual Review of Ecology, Evolution, and Systematics* 40: 437–457.
Pérez, R., and R. Condit. 2020. “Tree Atlas of Panama.” Accessed 2020 March. http://ctfs.si.edu/webatlas/maintreeatlas.php.
Prance, G. T., D. G. Campbell, and B. W. Nelson. 1977. “The Ethnobotany of the Paumarí Indians.” *Economic Botany* 31 (2): 129–139.
Prance, G., and M. Nesbitt. 2005. *The Cultural History of Plants*. Abingdon: Routledge.
Prior, J., and P. Gasson. 1993. “Anatomical Changes on Charring six African Hardwoods.” *IAWA Bulletin New Series* 14: 77–86.
Robert, E. M., N. Koedam, H. Beeckman, and N. Schmitz. 2009. “A Safe Hydraulic Architecture as Wood Anatomical Explanation for the Difference in Distribution of the Mangroves Avicennia and Rhizophora.” *Functional Ecology* 23 (4): 649–657.
Santini, L. 2013. “Descricão macroscópica e microscópica da madeira aplicada na identificacão das principais espῦcies comercializadas no estado de São Paulo.” PhD Thesis. São Paulo: Universidade de São Paulo.
Scheel-Ybert, R., and T. A. P. Gonçalves. 2017. *Primeiro Atlas Antracológico de Espécies Brasileiras*. Rio de Janeiro: Museu Nacional, Série Livros Digital 10.
Schweingruber, F. H. 2007. *Wood Structure and Environment*. Berlin-Heidelberg: Springer Berlag.
Schweingruber, F. H., A. Börner, and E. D. Schulze. 2008. *Atlas of Woody Plant Stems. Evolution, Structure and Environmental Modifications*. Berlin-Heidelberg: Springer Berlag.
Suárez-Abelenda, M., J. Kaal, and A. V. McBeath. 2017. “Translating Analytical Pyrolysis Fingerprints to Thermal Stability Indices (TSI) to Improve Biochar Characterization by Pyrolysis-GC-MS.” *Biomass and Bioenergy* 98: 306–320.
Thaman, R. R., W. Clarke, H. I. Manner, B. G. Decker, and I. Ali. 2017. *Agroforestry in the Pacific Islands: Systems for Sustainability*. Tokyo: United Nations University Press.
Théry-Parisot, I. 2001. *Économie des combustibles au Paléolithique: Expérimentation, taphonomie, anthracologie*. Paris: CNRS.
Théry-Parisot, I., L. Chabal, and J. Chrzavzez. 2010. “Anthracology and Taphonomy, from Wood Gathering to Charcoal Analysis. A Review of the Taphonomic Processes Modifying Charcoal Assemblages, in Archaeological Contexts.” *Palaeogeography, Paleoclimatology, Palaeoecology* 291 (1–2): 142–153.
Théry-Parisot, I., and A. Henry. 2012. “Seasoned or Green? Radial Cracks Analysis as a Method for Identifying the use of Green Wood as Fuel in Archaeological Charcoal.” *Journal of Archaeological Science* 39: 381–388.
Tomlinson, P. B. 2016. *The Botany of Mangroves*. Cambridge: Cambrigde University Press.
Velásquez-Runk, J. 2017. *Crafting Wounaan Landscapes: Identity, art, and Environmental Governance in Panama’s Darién*. Tucson: University of Arizona Press.
Verril, H. 1972. A Mistery of the Vanished Past in Panama: Newly Discovered Relics of a Vanished Civilization Destroyed by Earthquake or Volcanic Eruption. *Illustrated London News* 173: 15–18.
von Reis, S., and F. J. Lipp, Jr. 1982. *New Plant Sources for Drugs and Foods From the New York Botanical Garden Herbarium*. Cambridge: Harvard University Press.
Welle, B. J. H., A. Loureiro, P. L. B. Lisboa, and J. Koek-Noorman. 1983. “Systematic Wood Anatomy of the Tribe Guettardeae (Rubiaceae).” *Botanical Journal of the Linnean Society* 87 (1): 13–28.
Weston, P. H. 2007. “Proteaceae.” In *Flowering Plants*, edited by K. Kubitzki, 364–404. Berlin- Heidelberg: Springer.
Wheeler, E. A., and P. Baas. 1998. “Wood Identification-a Review.” *IAWA Journal* 19: 241–264.
Zamora, N., Q. Jiménez, and L. Poveda. 2000. *Árboles de Costa Rica. Vol. II*. Costa Rica: INBio.
Zelsman, J. 1959. “A Río Grande burial.” *Panama Archaeologist* 2: 85–90.