WOOD OF THE WEST HOUSE, AKROTIRI, SANTORINI (GREECE)

J.N. BOTTEMA-MAC GILLAVRY
Norgerweg 129, 9494 PB Yde, the Netherlands

ABSTRACT: Samples of charred wood, collected during the excavation of the West House in Akrotiri, Santorini, were analysed and identified. Olive (*Olea europaea*) dominated the samples, especially inside the West House, suggesting regular pruning of olive trees and use of the branches as firewood. The findings included sweet chestnut (*Castanea sativa*), almond (*Prunus dulcis*), alder (*Alnus* sp.), pear (*Pyrus amygdaliformis*), terebinth or mastic tree (*Pistacia* sp.), juniper (*Juniperus* sp.), pine (*Pinus* sp.) and tamarisk (*Tamarix* sp.). *Castanea* and *Alnus* were not known before from Bronze Age Santorini. The find of *Castanea* is the earliest registered find of wood of *Castanea* in Greece. Also it is shown that domesticated almond trees grew on the island itself and already were cultivated as early as the Middle Cycladic period. The range of species in pre-eruption Santorini reflects intensive human habitation. The inhabitants of Akrotiri tended orchards of olive (*Olea europaea*) and other fruit trees. The environment had a typical Mediterranean maquis vegetation, the result of years of cattle grazing. The occurrence of alder and tamarisk may indicate that a stream, as depicted in one of the wall paintings in the West House, was present on the island in reality.

KEYWORDS: Cyclades, Santorini, Thera, Akrotiri, Bronze Age, archaeobotany, charcoal, wood species analysis.

1. INTRODUCTION

1.1. The vegetation in the West House wall paintings

Delightful wall paintings cover the walls of two rooms on the first floor of the West House, one of the houses in the Bronze Age settlement, near Akrotiri on the Aegean island Santorini (Thera[1]). This settlement was abandoned after severe earthquakes and subsequently covered by a thick layer of ash (tephra) as a result of the volcanic eruption that followed. The tephra layer concealed and preserved the settlement, until Professor Spyridon Marinatos started excavations in the second half of the 20th century AD. After his death the excavations have been continued under the direction of Professor Christos Doumas. The murals from the West House show a mountainous landscape with multicolored layers, streams, wild animals and several kinds of trees: monocotyl (palm) trees and dicotyl trees, as well as conifers. At the entrance of an enclosure for flocks of sheep and goats, two trees are depicted that seem to be pollarded, an indication that in those days men already practised tree cultivation (fig. 1). The question arises if these images are a true representation of the vegetation on Santorini before the volcanic eruption, or whether they are ingredients of an artistic style used in paintings all over the Aegean world in the Late Cycladic Bronze Age. In other words, is it possible that the depicted trees grew on the island in fact?

1.2. Modern vegetation

Not many species of trees are growing on Santorini at present. Next to one small specimen of (presumably wild) kermes oak (*Quercus coccifera*; fig. 2), some straggling *Juniperus phoenicea*[2], one finds tamarisk (*Tamarix* sp.), dwarf fan palm (*Chamaerops humilis*), cypress (*Cupressus sempervirens*), eucalyptus (*Eucalyptus* sp.) and other cultivated plants like fig (*Ficus carica*), carob (*Ceratonia siliqua*), extensive fields of grapevine (*Vitis vinifera*) and very few olive trees (*Olea europaea)*. Eucalyptus, an Australian tree, certainly is a recent acquisition, but except for the oak and juniper, all the other tree species may have been introduced quite recently as well.

1.3. Evidence of past vegetation

1.3.1. *Fossilized remains*

Geological layers formed during earlier volcanic eruptions[3], already show fossilized leaves and fruits of olive (*Olea europaea*), the base of a leaf of dwarf fan palm (*Chamaerops humilis*)[4] and from about 50.000 years ago remains of *Tamarix*, *Pistacia lentiscus* and *Phoenix theophrasti* (Velitzelos, 1990). Therefore, it is plausible that these trees are native to Santorini. The more recognizable palm trees, depicted in the murals of the West House, more or less resemble date palms (*Phoenix dactylifera*) or *Phoenix*

Fig. 1. Pastoral scene, part of the Miniature Frieze from the north wall of first floor room 5 (Morgan, 1988: plate A). The trees at the entrance of the enclosure seem to be pollarded. The left tree is a reconstruction, the right tree for the greater part original.

theophrasti, the last one a relic in Crete and Turkey nowadays.

1.3.2.   *Pollenanalysis*

Plant pollen is resistant to degradation and can give information about past vegetations, provided that it is preserved under moist conditions. For this very reason, pollen information is extremely scarce on Santorini. In the dry, porous tephra it only survived in exceptional situations, for instance in a rodent coprolite in which a small percentage of pine and juniper pollen was preserved (Sarpaki, 1987). As pine pollen can travel long distances in the air, it is no proof of the occurrence of pine on Santorini. Juniper pollen settles more locally, but can only be identified at family level and not to the species. Besides, identification of juniper pollen often is not very secure.[5] Nevertheless, as some *Juniperus phoenicea* still grows on the island[6], the find of juniper pollen could be an indication of its past occurrence.

1.3.3.   *Macroremains*

Conservation of organic material

Due to the porosity of the cover of the tephra layer, wooden structures have not been preserved. The availability of oxygen during the millennia before the excavation of the West House virtually erased all traces of organic material, with the exception of charred material and seeds preserved in closed pots. Seeds of almond (*Prunus*), fig (*Ficus carica*), olive (*Olea europaea*) and grapevine (*Vitis vinifera*) have been found in storage jars in several houses (Friedrich *et al*., 1990; Sarpaki, 1990). As these fruits can be dried or preserved and shipped, these findings do not guarantee that the trees have been growing on the island itself.

Parts of plants (wood, seeds) that are heated in an anaerobic environment become charred and resistant to oxidative, bacterial and fungal attack. Thanks to this process, charred pieces of wood have been preserved and could be recovered during the excavations. According to the excavator, Chr. Doumas, the charcoal can not have been formed by the heat of descending tephra from the eruption, as this was already cooled when it settled (personal communication). Consequently, it must have been formed in fires dating from before the volcanic eruption. For the nature of these fires one can assume two possibilities:

1) Hearth or cooking fires: these can give information about plant species used for fire making. Presuming that most of the firewood will have been collected locally, the charred remains could give insight in the local woody vegetation. Of course, discarded imported timber may have been recycled as fire-

Fig. 2. Kermes oak (*Quercus coccifera*) growing on Santorini in 1996. (photograph by the author).

wood as well, but statistically it will have been in the minority;

2) Accidental fires. The charcoal resulting from these fires could give insight into the nature of building- and construction material, *i.e.* used for furniture, ceilings, door- and window frames. Beams, frames, posts and furniture may have been made from local as well as from imported timber.

Species identified in Akrotiri on wood charcoal

A recent study of charred macroremains recovered during the excavation of shaft 63A[7] showed a whole range of species: *Pinus* (pine), *Cedrus libani* (cedar), *Cupressaceae* (cypress or juniper), *Taxus baccata* (yew), *Olea* (olive), *Punica granatum* (pomegranate), *Arbutus* (strawberry-tree), *Maloideae* (pear or haw-thorn), deciduous and evergreen *Quercus* (oak), *Fagus* (beech), and probably *Rhamnus* (buckthorn), *Tamarix* (tamarisk), *Capparis* (caper), *Lonicera* (honeysuckle), *Lamiaceae* (mint family) and *Poaceae* (reeds?) (Asouti, 2003). The samples cover the periods of Early, Middle and Late Bronze Age, *i.e.* late 4th to mid-2nd millennium BC. Olive was best represented with 50% of sample composition, fol-lowed by pine with 20%. Beech, yew and cedar most likely were imported. These macroremains suggest a landscape varying from maquis to woodland and prob-ably point to a moister climate during the pre-eruption period in the Aegean region, than was assumed previ-ously (Asouti, 2003).

2. MATERIAL AND METHOD

Charred wood samples were collected in and around the West House during excavations between 1972 and 1985. The samples were hand collected or recovered by A. Sarpaki during water floating and sieving pro-cedures for the retrieval of macrobotanical material. The samples were studied under a Zeiss coaxial il-lumination microscope. Smaller magnifications (40× and 80×) were used in dark field and the larger ones (200× and 400×) in bright or dark field. Microscopic examination of the charcoal fragments was carried out on fracture surfaces of the transversal plane and two longitudinal planes. The anatomical features of the samples were compared with contemporary charcoal samples from charcoal collections of the author and of the Groningen Institute of Archaeology, with wood identification handbooks (Greguss, 1945; Fahn *et al.,* 1986; Schweingruber, 1990) and with Wheeler C.S. Computer-Aided Wood Identification (Wheeler *et al.*, 1986). Distribution of parenchyma, and features like the length of tracheids, fibres and vessel elements are often not distinguishable in charcoal. As the water-floated fragments often were very small (<0.5×0.5×0.5 mm) it was not possible or desirable to fracture them.

Table 1. Charcoal found inside the West House.

Location		Species					
First floor	3A	Olea					
	5	Olea					
	6			unidentifiable matlike material			
	area 7	Olea	Castanea	Juniperus			
Ground floor	3A	Olea					Tamarix
	3B	Olea					
	3C					Prunus	
	4			unidentifiable bark and conifer			
	5	Olea					
	6	Olea					
Drainage pipe		Olea					
Sewer		Olea	Castanea	Juniperus	Pinus	Prunus	Tamarix

In that case it sometimes was not possible to identify them with certainty. R. Neef of the Deutsches Archäologisches Institut in Berlin was consulted in the matter of questionable identifications. Digital photographs from charcoal samples were made with Zeiss KS 400 software in combination with a coaxial illumination microscope and photographed in either dark or bright field. As the charcoal surface mostly was not flat, the pictures often are of details that represent striking characteristics. Discernible anatomical features are described as comprehensively as possible in the appendix.

3. SPECIES IDENTIFICATIONS

3.1.   Species found inside the West House (table 1)

Inside the West House olive (Olea), sweet chestnut (Castanea), almond (Prunus), tamarisk (Tamarix) and juniper (Juniperus) were found. Olive was best represented (more than 90%) in all the samples. Olive even makes up 100% of the samples of groundfloor 5, 6 and 3B, first floor rooms 5 and 6 and earthenware drainage pipe. It was present in all the rooms inside the West House where charcoal was found, except for room 3C. There was no charcoal from first floor room 4, which is surprising as the clay pipe underneath the 'toilet' in this room contains olive charcoal exclusively. Rather mysterious was the find of four gnarled, relatively large olive fragments in blind room 3B[8] in the centre of the house. Area 7 on the first floor, next to olive, yielded some fragments of sweet chestnut and juniper. In room 3A (groundfloor) also a fragment of tamarisk was found and in a hollow under the floor of room 3C a rather large fragment (about eight growth rings)

of almond between pieces of pottery. In ground floor rooms 4 and 6 some pieces of unidentifiable bark were found, and from storage room 6 on the first floor some matlike material in a hollow in the wall was recovered by impregnation with glue. It was not possible to identify this material, as it disintegrated when the glue was dissolved.

3.2.   Species found in the sewer and drainage pipe (table 1)

The charcoal assemblages collected by A. Sarpaki from the sewer and from the underside of the earthenware drainage pipe that connected the sewer with room 4 (first floor) differed strikingly. The drainage pipe contained Olea exclusively, but the sewer showed a greater variety of species: Castanea, Olea, Prunus, Tamarix, Juniperus and Pinus. Except for Pinus all these species have been found in different rooms in the West House.

3.3.   Species found in the vicinity of the West House (table 2)

Several locations around the West House yielded next to the ubiquitous olive: Pistacia, Pinus and Tamarix. In the square between the West House and the House of the Ladies at depths varying from 2.30–2.40 metres were found Castanea, Juniperus, Olea, Pistacia, Pinus, Prunus, Pyrus, Tamarix, and – rather unexpectedly – alder (Alnus).

4. DESCRIPTION OF THE SPECIES

For anatomical descriptions see appendix I

Table 2. Dispersed charcoal found outside the West House.

Location		Species								
Area 1	0.69 m	*Olea*								
	2.35 m	*Olea*								*Tamarix*
	2.40 m	*Olea*	*Alnus*	*Castanea*	*Juniperus*	*Pinus*		*Prunus*	*Pyrus*	*Tamarix*
	2.55 m	*Olea*	*Alnus*		*Juniperus*		*Pistacia*		*Pyrus*	
Area 2		*Olea*				*Pinus*				
Area 3		*Olea*							*Pyrus*	
Area 4		*Olea*								

Area 1 = square between West House and House of the Ladies

Area 2 = square between West House and disturbed layer

Area 3 = area north of north wall of West House

Area 4 = area east of West House

4.1.   Juniper (*Juniperus phoenicea/oxycedrus*-type) (figs 3–10)

The juniper charcoal is identified as Phoenicean juniper (*Juniperus phoenicea* L.) and/or prickly juniper *(Juniperus oxycedrus* L.). *Juniperus* species belong to the Cupressaceae. They are distinguished from other conifers by the absence of resin ducts and ray tracheids, by the height and form of rays, ray cells and ray cell walls. According to Fahn *et al.* (1986: p. 56) the two juniper species here concerned are indistinguishable from each other on the basis of wood anatomy. In the reference collection, the charcoal of *Juniperus phoenicea* L. has distinct features (wide ray cells, large, iridescent ray-cell pits) that are lacking in *J. oxycedrus*. Some of the Akrotiri samples show J. *phoenicea* characteristics, and some samples resemble *J. oxycedrus*. However, because the charcoal of *J. phoenicea* is rather variable and these characteristics are not always expressed, the samples are identified as *Juniperus phoenicea/oxycedrus*-type.

   Juniperus oxycedrus L. (prickly juniper) is a widespread tree or shrub in the Mediterranean. The species is very drought-resistant, can stand long periods of severe cold and can grow up to 2500 m. It prefers calcareous soils or rocks, but can even grow on serpentine or pure sand (Rikli,1943: p. 242). At present the wood is used for the production of cade oil, cade being the French name for the prickly juniper. The Egyptians used the oil for embalming.

   Juniperus phoenicea (Phoenicean juniper) can grow as a shrub or tree up to 6 m high. It grows from sea level to 350 m (Davis, 1965: p. 82) or up to 1200 m in the European Mediterranean region and still may be growing on Santorini.

   These two juniper species are both called kedros in modern Greek, as well as in most of the classical literature. Homer, however, discerned two juniper species, kedros and thuion, and described their uses as firewood, for smoking and for charcoal production (Koch, 1884: pp. 38–39). Both species could have grown on classical Thera and have been used for the same purposes, but as the trees can become relatively large, the wood may have been exploited as timber as well.

4.2.   Pine (*Pinus halepensis/brutia*-type) (figs 11–32)

The samples were identified as *Pinus* by the presence of resin canals and ray-tracheids and as *P. halepensis/brutia*-type (figs 11–32) by the pinoid form of the cross-field pits (figs 13, 23 and 24) and the slightly dentate walls of the ray tracheids. The two relevant species, Aleppo pine (*Pinus halepensis* Mill.) and brutian pine (*Pinus brutia* Ten.) are closely related and according to Schweingruber (1990: p. 121) cannot be distinguished on the basis of their wood anatomy. Figures 11–32 represent two *Pinus* samples, that were found at different locations[9] and both answer better to *P. brutia* than to *P. halepensis* (see appendix). The dentate tracheid walls (fig. 19) and slitlike extended pits (fig. 21) of the second sample are characteristic of compression wood[10], which is often found on the underside of conifer branches. Therefore, it is likely that this sample is derived from branch wood.

   Pinus halepensis Mill. (Aleppo or Jerusalem pine), in contrast to its name, grows around the Peloponnesus, on the coast of mainland Greece, the western Aegean Islands, Italy, France, Spain, North Africa and Israel.

   Pinus brutia Ten. (brutian, Turkish or Cyprus pine) is distributed on the northeastern Aegean coast and

islands, Crete, Cyprus, Turkey, Syria, Iraq, Lebanon and more northeasterly (Frankis, 1993). The two species resemble each other in habitus as well as in wood anatomy. In habitus they are distinguished by the position of their cones: *P. brutia* has (almost) sessile, erect or forward pointing cones and in *P. halepensis* the cones always point to the base of the branch.

As Santorini is situated more or less on the dividing line between the present-day distribution range of the two species, both could have grown on the island, where they do not grow at present. Both are undemanding trees, growing on rock-beds, in the poorest and driest sandy locations, but with a preference for calcareous soils (Rikli, 1943: pp. 212–216). In classical times the trees were exploited for the collection of resin or pitch, which was used for the sealing of ships and amphorae and to flavour and preserve wine (Coppen, 1995; Ciesla, 1998). The bark was used for tanning. *P. brutia* (synonym *P. pityusa*), called 'pitys' by the ancient Greeks, also was widely planted for the harvest of 'pine honey'. This honey was (and still is) produced by honeybees from honeydew that was excreted by sap-sucking *Marchalina hellenica*, a scale insect (Frankis, 1993). The timber of both pines was used for ship, house and furniture building, and as firewood. *P. brutia* is straighter and the wood is stronger than that of *P. halepensis*. As Thera will have been too small for the production of large-scale construction wood, especially for shipbuilding, pinewood may have been imported for this purpose, *P. halepensis* from the Peloponnesus or from mainland Greece, *P. brutia* from Crete, Cyprus or Turkey. However, the compression wood in the second sample, most likely indicating branch wood, could signify that pine trees grew on the island itself, perhaps to provide shade around the houses.

4.3.   Pistache (*Pistacia* sp.) (figs 33–40)

The samples could belong either to *Pistacia lentiscus* L. (mastic tree) or *P. terebinthus* L. (terebinth or turpentine tree), but fit *P. terebinthus* best. Fossilized remains show that *P. lentiscus* L. was indigenous on Santorini (Velitzelos, 1990: pp. 406–409), but *P. terebinthus* may have grown on the island as well. Both species are drought tolerant Mediterranean maquis plants. The mastic tree is mainly coastal and grows from 0–700(–800) m (Zohary, 1972: pp. 299–300), in *Pinus brutia* woodland, on steep rocky banks and maritime sands (Jahn *et al.*, 1995: p. 36). The turpentine tree grows mainly on hills and mountains, in rocky woodland and on calcareous cliffs, from (0)–100–700

(–1100) m (Fahn *et al.*, 1986: pp. 64–65).

At present wood of the mastic tree and olive tree are used preferably as firewood by the Jabala in the Western Rif (Morocco) (Zapata *et al.*, 2003: pp. 165–168). Turpentine from terebinth and resin from the mastic tree (*P. lentiscus* var. Chia) are said to have been used in medicine by the ancient Greeks.

4.4.   Alder (*Alnus* sp.) (figs 41–47)

In the square between the West House and the House of the Ladies at a depth of 2.30 m two minute fragments of charcoal with scalariform vessel perforations were found. Personal and Computer-Aided Wood Identification (Wheeler *et al.,* 1986) led to alder (*Alnus*). Two alder species can be considered: common alder (*Alnus glutinosa* {L.} Gaertner) and oriental alder (*Alnus orientalis* Decne.). According to the *Flora Hellenica* (Strid *et al.*, 1997: pp. 36–37) the common alder can become 25 m tall, grows on riversides, damp mountain slopes and mixed deciduous forests, from 0–1500 m. Common alder is found on some of the larger Aegean isles, but does not grow on Crete (Turland *et al.*, 1993).

The oriental alder can reach 15 m and grows along streams, from sea level up to an elevation of 1000 m. At present, oriental alder is found only on Cyprus, where two populations occur (Davis, 1982: p. 693). Some wood anatomical features fit *Alnus orientalis*, for instance the few bars in the perforation plates and the frequent branching of these bars. The find of *Alnus* confirms Rackham's theory that *Alnus* grew in the Aegean before and during the Neolithic period. He concluded this on the basis of a reinterpretation of several pollen diagrams (Rackham, 1990). Supposing that alder occurred on Santorini itself, this would mean that at least one stream was present on the island and that the stream with wild animals and vegetation in the river mural was a true representation of a Theran situation.

4.5.   Sweet chestnut (*Castanea sativa* Miller) (figs 48–57)

4.5.1.   *Identification of* Castanea

According to the literature (Schweingruber, 1990: p. 397), *Castanea* and *Quercus* can only be distinguished by their rays: *Quercus* has two types of rays: 1-seriate and multiseriate. *Castanea* has 1–2-seriate rays, but no multiseriate rays. When samples are very small, one cannot be sure if the absence of multiseriate rays means that they are not represented in the

sample or that the sample belongs to a species lacking these rays. In the relatively big sample from area 7 (17×12×5 mm, figs 48–57) multiseriate rays are absent and a 12 mm wide sample of *Quercus* (with about 1 multiseriate ray per mm) would have shown several multiseriate rays. On this ground and on the presence of 2 – and even 3 – seriate rays, this sample was identified as *Castanea*. Other characteristics that point to *Castanea* are in transverse section: the straight and acute growth ring border, the closed circle of early-wood vessels immediately following this border, the uniformity of the ground tissue, with medium-wide lumina and thin-medium thick walls (fibres as well as parenchyma), and the oblique, elongated pits in the ray-cells. The tissue around the vessels often has tortuous cell walls, simple pits and (nearly) no bordered pits. Axial parenchyma is scarce (2–10/mm), with long cells and few pits. Fibres are thin to medium thick-walled, with few pits.

In contrast, most *Quercus* species appear crowded and irregular in transverse sections, owing to the differences in diameter and wall-thickness of the ground tissue. This consists alternately of groups of fibres with narrow lumina and thick to very thick walls, and groups of parenchyma tissue – especially around the vessels – with wide lumina and thin to very thin, often tortuous walls with lots of bordered pits. In transverse section the pits in ray-cells are round. Axial parenchyma is abundant (10–32/mm), with short cells and numerous pits. Fibres are thick – to very thick – walled, with slit-like pits. The European *Quercus* bearing the greatest likeness to the samples is *Quercus robur*, because it has a less pronounced difference between fibres and parenchyma, except around the vessels.

Because of the importance of the identification the sample from area 7 was sent to R. Neef in Berlin, who confirmed the identification as *Castanea*. The other samples of this type were identified as *Castanea* as well.

4.5.2. *First occurrence of* Castanea *wood in Greece*

The find of charcoal of sweet chestnut is surprising. It is the earliest occurrence of chestnut wood in Greece and the Aegean. Evidence from pollenanalysis suggests that before the Santorini eruption *Castanea* was a rare tree in the eastern Mediterranean and did not occur in southern Greece and south western Turkey (Bottema, 2000). Finds of early single pollen grains suggest that *Castanea* survived the Glacial period as a relic in the Eastern Macedonian plain and southwestern Bulgaria (Filipovitch, 1977). However, corroded

pollen grains of sweet chestnut are difficult to distinguish from other species and identifications of isolated grains may be dubious (Bottema, 2000). More reliable is the discovery of a relatively large amount of *Castanea* charcoal in an archaeological excavation near Goljamo Delčevo, which demonstrated that about 5840±100 BP sweet chestnut trees occurred at least in the most eastern part of the Stara Planina mountain range in Bulgaria.

In pollen cores from several sites in southwestern Turkey a sudden change in the vegetation was observed on top of a layer of tephra (Bottema, 2000). The tephra has been analysed and attributed to the Santorini eruption by Sullivan (1988). The change is called the Beyşehir Occupation Phase (B.O.P.) after the site on the shore of Lake Beyşehir where it was first observed. A combination of four pollen types that were lacking in the pollen sequence below the tephra layer suddenly appeared in continuous curves. The combination consisted of pollen of sweet chestnut (*Castanea sativa*), manna-ash (*Fraxinus ornus*), walnut (*Juglans regia*) and plane (*Platanus orientalis*). All these species apparently were introduced by man and the sudden appearance indicate a change in farming economy immediately after the occurrence of the Santorini eruption. In about the same period an identical change in the vegetation took place in northern Greece (Bottema, 2000). In the West House of Akrotiri sweet chestnut does not occur in combination with the other three species of the B.O.P. combination, namely walnut, manna ash and plane tree. These are absent from the charcoal samples of the West House, as well as from the charcoal assemblage of shaft 63A (Asouti, 2003). On Santorini, before the eruption, the husbandry evidently differed from that of the B.O.P.

Sweet chestnut provides good timber and may have been imported, just like beech was imported (Asouti, 2003). As sweet chestnut often grows in a belt beneath the beech zone, the two species may have been imported together. The region where imported sweet chestnut originated, would have been the Stara Planina mountains of Bulgaria or northern Turkey. On the other hand, in theory *Castanea* could have grown on Santorini itself, as it grows on deep, well-drained, acid and mineral rich soils (Bottema, 2000), from 30–1500 m (Davis, 1982: p. 659). As volcanic soil is an excellent substratum for sweet chestnut, pre-eruption Thera would have met its needs perfectly. The nuts may have been imported together with the wood and planted on the island. The tree can stand pollarding well (Rackham *et al.*, 1996: pp. 81–83) and the branches may have been used as firewood.

4.6. Olive (*Olea europaea* L.) (figs 58–64)

Olive was the predominant species of the identified samples from the West House and its environment. It was also the only species to be found in relatively big formats. The samples mostly originated from branches. The often whorled or gnarled structure suggests that the trees or shrubs were pruned or coppiced. It is likely that the cut branches were used as firewood, as is customary today. To deduce from this that the Therans used cultivated olives is rather premature, as Terral (2000) showed that olive branches already were collected from wild shrubs from the Mesolithic onwards.

Terral (1997) developed a method to discriminate between wild and cultivated olive on charcoal samples, based on the assumption that genotypical and phenotypical alterations would take place in the course of domestication. He found that growth ring width and number of vessels per group could discriminate between wild and cultivated olives in modern samples from different habitats. Based on these characteristics he classified charcoal samples as wild type and cultivated type (wider growth rings, less vessels per group), and applied this principle to archaeological charcoal samples from a French cave. Charcoal from Mesolithic layers in this cave exclusively showed wild type characteristics. During the Neolithic and Chalcolithic, a constant 8–10% of the olive charcoal could be classified as cultivated type. In the Early Bronze Age *c.* 30% of the charcoal was of the cultivated type. During the Neolithic and Chalcolithic, habitats were favourably changed for the olive by man's activities as well as by climatic changes, resulting in a constant increase of olive trees or shrubbery, that had its maximum in the Bronze Age.

Terral (1997) proposed distinguishing two domestication phases during this period of olive increase:

1) *Unintentional selection*, giving rise to the low percentage of cultivated type charcoal during Neolithic and Chalcolithic, caused by the influence of man on the environment (genetic variability in increasing population in combination with phenotypic effects);
2) *Intentional selection* during the Bronze Age by human action (selection and propagation of trees with good qualities), leading to 30% cultivated type olive charcoal.

He also distinguished three different phases in olive exploitation, based on anatomical differences in mature and immature wood:

1) Mesolithic-Early Neolithic: exclusive collection of immature wood (twigs, young branches);
2) Neolithic: increase in use of mature wood (mature branches, trunks);
3) Bronze Age: increase in use of immature wood (young branches).

He explained the difference between the first two phases by the difference in technology: Mesolithic tools were not adequate for cutting whole trees, in contrast to the Neolithic stone axes. On the other hand although the cutting material during the Bronze Age (phase 3) was even superior, the preference for cutting branches might reflect a policy of tending and pruning, *i.e.* domestication of trees.

In pre-eruption Akrotiri the Bronze Age already was in an advanced phase (Bunimovitz, 1996). Therefore, we can accept the fact that olive had been domesticated for a long time. From the combined findings of olive stones and wood we can assume that on Thera olives were grown and exploited for their fruits and probably for the production of oil. The predominant finds of branch wood fit this picture. However, to be sure, we have to wait until the first oil press is found.

4.7. Almond tree (*Prunus dulcis* {Miller} D.A. Webb.) (figs 65–73)

Imprints of almonds have been found in a storage jar in the West House (Friedrich *et al.*, 1990: pp. 190–191) and are found in other Bronze Age sites in Greece as well. This raised the questions whether the nuts in the jar had been imported or harvested on Thera itself, and whether they were produced by wild or domesticated almond trees.

It appears to be difficult to distinguish between the wild and domesticated species, based on almond nuts alone (Zohary *et al.*, 2000: pp. 176–178). According to Davis (1972: pp. 22–24) the wild almond tree in the Aegean region is Webb's almond tree (*Prunus webbii* {Spach} Vierh.). This tree grows from 50–1100 m on rocky limestone slopes, whereas the domesticated almond tree (*P. dulcis*) grows from 150–1800 m on dry slopes and in calcareous gorges. The wood anatomical difference is small: both can be distinguished from other *Prunus* species by ring porous wood and ground tissue of mainly fibre-tracheids. Furthermore both have rays of two sizes: 1(2)-seriate and multiseriate rays, the main difference being the width of the multiseriate rays. Those of *P. dulcis* are 3–8-seriate (Fahn *et al.,* 1986: p.146) and those of *P. webbii* are 2–5-seriate (Schweingruber, 1990: pp. 631–639).

As the large sample from room 3C consisting of 14

Table 3. Comparison of tamarisk sample with reference data.

Character	This article	Friedrich et al. (1990)
Tangential vessel diameter	15-110 μm	12 - 90 μm
Vessel member length	(40-)85-130 μm	60 - ? μm
Parenchyma cells length	90-100 μm	50 - 80 μm
Ray width	(1-)3-10 cells	4 - 16 cells

growth rings (figs 65–73) and two samples from the sewer all have 3–7-seriate rays, they are identified as *Prunus dulcis*, the domesticated almond tree.

The above questions now can be answered in the affirmative. Almond trees grew on Thera and the almonds that made the imprints in the storage jar could have been harvested in Akrotiri's own orchards. As regards the second question, the almond trees on Thera most likely were domesticated.

The sample of almond charcoal from room 3C was found in connection with a MC pot and appears therefore to date back to the Middle Cycladic period. The samples from the sewer presumably date to the last habitation phase prior to the eruption. This means that domesticated almond trees had already been cultivated over a long period of time on Thera before the eruption took place.

4.8. Pear (*Pyrus amygdaliformis* Vill.)

This sample is identified as belonging to the Maloideae by the numerous solitary vessels, many rays and type of vessel-ray pitting, and as *Pyrus* sp. on account of the medium thick-walled fibres. Due to the 2–3-seriate rays the sample is identified as probably almond-leaved pear (*P. amygdaliformis*). This pear grows as a prickly shrub or small tree (up to 6 m) and produces little pears (2–3 cm). It grows in maquis and open forests from 80–1500 m (Davis, 1972: pp. 163–164). As a species native to the Aegean basin (Zohary *et al.*, 2000: pp. 185–188), it is the most likely pear to have grown on Thera. Small carbonized fruits have been found in several Neolithic and Bronze Age sites in Europe and in Greece (Kastanas) (Zohary *et al.*, 2000), but not yet in Bronze Age Thera.

4.9. Tamarisk (*Tamarix* sp.) (figs 74–81)

The characteristics of the tamarisk samples agree more or less with those described by Friedrich *et al.* (1990: pp. 192–193; table 3). According to Schweingruber (1990: p. 709), wood anatomical differentiation between the tamarisk species is not possible. Species with an Aegean distribution are *T. hampeana* Boiss.

& Heldr., *T. parviflora* DC. and *T. tetranda* Pall. ex Bieb., which all grow along river banks from sea level up to respectively 300 or 1300 m (Davis, 1967: pp. 349–350).

Together with alder, the occurrence of tamarisk is therefore an indication for the presence of one or more streams on Thera.

5. DISCUSSION

5.1. Dating and origin of the charcoal

The samples mostly consisted of dispersed charcoal, often scattered all over the rooms. For most of the charcoal samples, the archeological context is not mentioned in the excavation diaries. For the samples excavated in the surroundings of the West House the depth is given, but for most of the inside samples the exact description is lacking. Therefore, it is not clear to which occupation phase the wood belongs, to the latest occupation phase Late Cycladic I, to the period before the Early LC I destruction phase (late Middle Cycladic and Early LC I), or to an even earlier period.

Only in those cases where wood is found in connection with pottery, is it possible to have an indication about the period of use. An example are some fragments of almond charcoal, found in a small hollow in room 3C under the level of the West House together with a broken, closed shape of an Middle Cycladic pot. These presumably date back to the first habitation period. At this point, perhaps, it is good to stress the fact that even if samples have been found inside amphorae or pithoi, the possibility remains that they originated from higher-up floors or roofs.

In this context the charcoal found in room 3B is interesting. As 3B is a blind room without access, this charcoal presumably originated from upstairs. It consists of four rather large[11] gnarled fragments, identified as olive (*Olea europaea*). From the gnarled structure of the fragments it is deduced that the original trees probably had been pruned or pollarded, and from the blowing up of the rays that the wood had been burned

when it was fresh. This could mean that the fragments derived from firewood, which perhaps was stored on the terrace roof. The gnarls must have been part of rather thick branches and were perhaps more resistant to burning than other parts.

5.2.   Late Cycladic I destruction

In the beginning of LC I the settlement was destroyed by an earthquake. During the following reconstruction activities, debris from collapsed houses was got rid of by raising the level of the squares and streets between neighbouring houses and by the construction of platforms and dry walls (Marthari, 1984). A new entrance door at a higher level was built in the West House to accommodate the raised outside level. To overcome the difference of about 1.80 m between the level of the outside pavement and the lowest floor in room 4, the floor in room 3 next to the entrance was raised stepwise with rubble (Palyvou, 1984: pp. 135, 140 and 147).

   If during the Early LC I earthquake part or all of the first- and second-room floors and the roof construction burned down, the charred remains fell down into the lower rooms. The large fragments in room 3B may have been the result of such an event. During reconstruction activities, charcoal residues will have been incorporated into the newly piled up rubble floors inside the West House. The majority, presumably, will have ended up outside the house in the debris layers and retaining walls, *i.e.* on the South side in the Triangular Square and on the East side between the West House and the House of the Ladies. Charcoal found in the raised floors and the outside localities, consequently could be architectural construction material and fire wood dating to the first habitation phase, MC and Early LC I (before the LC I destruction). The charcoal found in the first floor rooms, which presumably were build after the LCI destruction, would date to the last habitation phase.

5.3.   Species found

Five species were found in rooms in the West House, one in the drainage pipe, six in the sewer and nine outside the West House (tables 1 and 2). Except for pine (*Pinus*), all the species found in the sewer may have come from inside the West House.

   In contrast, the drainage pipe of baked clay that connected the sewer with the toilet, merely yielded olive charcoal. How to explain the contrast between the contents of the drainage pipe and the sewer? The drainage pipe probably reflects the refuse from a pe-

riod shortly before the house was deserted, while the sewer collected charcoal during a longer period of time. However, the greatest species variety was found outside the West House. Charcoal fragments of *Alnus*, *Pistacia* and *Pyrus* were found between the West House and the House of the Ladies, but not inside the building or in the sewer. This means that the charcoal of these species at least must originate from outside the West House.

   Castanea and *Alnus* were not known from Bronze Age Santorini before. The find of wood of *Castanea* is exciting, as until now only some pollen corns from unknown origin had been found in Greece (Bottema, 2000). The find of this wood shows that *Castanea* either grew on Santorini, or that the wood was valued and imported as construction wood. The find of charcoal of almond (*Prunus*), is interesting, as the fact that they were found in combination with MC sherds not only shows that almond trees grew in Akrotiri, but also that they were cultivated already for a long time.

5.4.   Absent species

Wood of grapevine, fig and palms has not been found in the West House or anywhere else in Akrotiri. Either viticulture was not as important as today – in contrast with prevailing opinions –, or the vines were not used as firewood. Rackham (1990: p. 388) may be right in his assumption that the so-called "branches of vine interlaced with branches of olive in stone walls", found during the first excavation, were an error for juniper, as lots of fragments of juniper charcoal have been found, but no vine wood at all. If that is the case, it is possible that vine did not grow on Thera itself, and that grapes were imported. The same is applicable to fig (*Ficus*). Fig seeds have been found in pots, but as long as wood or especially pollen is not found, one cannot be sure that these trees grew on Santorini.

   Charcoal of evergreen and deciduous oaks has been identified in the samples from shaft 63A (Asouti, 2003), but not in or around the West House. It is also notable that no macroremains have been found of the phrygana shrubs that abound on Santorini today and were used as fuel in the Second World War.[12]

5.5.   Application of the species

As most charcoal fragments are very small, it is often difficult to conclude if the wood has been used as firewood, as construction wood or both. Whorled or gnarled fragments (olive, almond), compression wood (juniper, pine) and fragments with strongly

curved growth rings (*Pistacia*, almond, olive, tamarisk) are assumed by the author to have been derived from branches and to have been used as firewood. The same is the case for charcoal with puffed or blown up rays, which signifies that the wood was fresh when it was burned (olive, juniper). Even some fragments of sweet chestnut were derived from branch wood. It must be noted, however, that in spite of the occurrence of many such fragments in the West House no real hearths have been found. It could be that the domestic hearth was outside the house, as still is the habit in the Moroccan Jebala (Zapata *et al.*, 2003: pp. 165–168). On the other hand, fragments of pine, juniper, olive and sweet chestnut may have been the debris of burned architectural structures as well.

5.6. Local or imported?

If we presume that branch wood was used as firewood and that species providing these branches grew locally, it is likely that *Pinus, Juniperus, Olea, Pistacia, Prunus* (almond) and *Tamarix*, but also *Castanea* actually grew in or around Akrotiri. For most charcoal fragments, however, it is not possible to distinguish between branch wood and mature wood. Species like pine, juniper, alder, sweet chestnut, olive and pear may have been local, but may have been imported as well.

6. CONCLUSION

Although palm trees are missing in the charcoal assemblage of the West House, the river mural in room 5 of the West House probably gives a realistic representation of the surroundings of the people living in pre-eruption days. Even the stream on one of the wall paintings may represent an actual Theran situation, as may be gathered from the occurrence of alder (*Alnus*) and tamarisk (*Tamarix* sp.). In those days, the appearance of Santorini was strikingly different from that of today. Thera had a typical Mediterranean vegetation with stands of either brutian pine (*Pinus brutia*) or Aleppo pine (*P. halepensis*), tamarisk, prickly juniper (*Juniperus oxycedrus*) and/or Phoenicean juniper (*J. phoenicea*), mastic tree (*Pistacia lentiscus*) and/or turpentine tree (*P. terebinthus*), signs of long human habitation and intensive grazing. One can get an impression of this wild vegetation by visiting Europe's most southern island, Gavdos. This small and low (about 300 m high) island has *Pinus brutia* woods, relatively large detached trees of *Juniperus oxycedrus* and *J. phoenicea*, a maquis vegetation of browsed shrubs of both juniper species in combination with *Pistacia lentiscus* on inland plateaus, and tamarisk trees on sandy beaches.

The Therans cultivated orchards with domesticated almond and olive trees, pear and perhaps sweet chestnut. This is in accordance with the image on one of the wall paintings of flocks herded in the fields at daytime and locked up for the night, probably in order that they could do no damage to the orchard trees (fig. 1). Except for a small number of olives, none of these species grow on Santorini at present.

The fruit trees, olive, almond, pear and sweet chestnut, appear to have been pollarded or pruned on a regular basis. The branches of these trees were used as firewood and/or construction wood. Almond trees apparently were cultivated already in the first (Middle Cycladic) habitation period. The discovery of sweet chestnut is most striking, as it is the earliest find registered of wood of *Castanea* in Greece.

7. ACKNOWLEDGEMENTS

8. NOTES

1. Thera is the classical name for the island that is now called Santorini.
2. S. Katsipis, personal communication, 1996.
3. The last one c. 18,000 BP (Asouti, 2003).
4. Shown to the author by S. Katsipis, 1996.
5. S. Bottema, personal communication.

6. S. Katsipis found *Juniperus phoenicea* on Santorini on a steep rock overhanging the sea, but did not manage to find the small tree again in 1996 in its dangerous location.

7. This shaft was dug for the support of a new roof over the settlement.

8. Room 3B is a closed space in the centre of the house, without doors or windows.

9. Sample 1 (figs 11–18) was collected from the sewer, sample 2 (figs 9–32) from the square between the West House and a disturbed layer.

10. Thick-walled wood formed on the lower side of branches or on the lower side of leaning stems or trunks. (Kaennel *et al.*, 1995: p. 76).

11. 6.5×4.5×3; 5×4×2.5; 3.5×2.5×2 and 6×5×2 cm.

12. S. Katsipis, personal communication (1996).

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APPENDIX 1:
ANATOMICAL DESCRIPTIONS
(CHARRED MATERIAL)

TS = transverse section;
RLS = radial longitudinal section;
TLS = tangential longitudinal section.

N.B. Proportions change during charring. Therefore, measurements on charred material differ from those on fresh wood: tangential diameters often are larger than radial ones, reliable data for fibre length cannot be obtained; axial parenchyma is difficult to observe in transversal sections.

Cupressaceae

Juniperus phoenicea/oxycedrus type (figs 3–10)

Locations: Sewer, several minute fragments; square between West House and House of the Ladies, several small fragments, depth 2.35 and 2.55 m (figs 3–10).

Description: **TS**. Growth ring distinct. Transition from early- to latewood abrupt. Rays 3–9/mm. Ray cells in transversal section in earlywood 90–115 µm long, 7–9 µm wide; in latewood 75–115 µm long, 11–12.5 µm wide; in the growth ring border often shorter (25–30 µm long), with ridged walls, smooth to nodular end walls and thick ray cell walls over the unilateral pit apertures (figs 3, 4); **RLS**. Cross-field pits 1–4 per field (fig. 6), cupressoid, eye-shaped with elevated borders (figs 7, 8), included (not extending outside the pit-border) or sometimes extended (extending outside the pit-border). up to 7.5 µm in diameter, with *c.* 5 µm long apertures. Tracheids up to more than 1500 µm long, difficult to measure, with 1(–2) rows of bordered pits in radial walls. Tracheid pits up to 20 µm in diameter; pit apertures round to elliptic, up to 12.5 µm in diameter (fig. 5). Axial parenchyma cells up to 110 µm long, 20 µm wide, with smooth to nodular end walls and simple pits (12.5 µm in diameter); **TLS**. Rays 139(110–178)/mm² (n=5), 1–8(–11) (average=2) cells high (fig. 9, 10).

The narrow ray cells match the reference samples of *J. oxycedrus* better than those of *J. phoenicea* (fig. 4). The last species has very variable, often much wider ray cells (7–20 µm), with thin ray cell walls over pit apertures in transverse sections. The amount of rays/mm² is too high for both species according to Fahn *et al.* (1986: p. 56).

Pinaceae

Pinus halepensis/brutia type (figs 11–32)

Although according to Schweingruber (1990: p. 121) *P. halepensis* and *P. brutia* cannot be distinguished on the basis of their wood anatomy, Greguss (1955: pp. 229–232) separated them:
– on the size of the pits in the tangential walls of the last late tracheids: 10–12 µm wide in *P. halepensis* (while according to Phillips (1948: p. 34) tangential wall pits are absent in *P. halepensis*) and 5–7 µm in *P. brutia*;
– on the shape of the pit apertures in the radial walls: in *P. halepensis* they are circular, elliptic or eye-shaped, included or rarely reaching the border; in *P. brutia* in the latewood the outer pit apertures are elongated, eye-shaped or slitlike, as long as the pit diameter or extended, while the inner apertures stay circular or elliptic.

These distinctions do not work out in the charred specimens in the reference collection: both species have small pits in the latewood: 1.5–5 µm in *P. brutia* and 2.5–5 µm in *P. halepensis*. In the earlywood (radial and tangential) the size of the tracheid pits overlaps: 15–25 µm for *P. halepensis* (stem), 22.5–30 µm in *P. brutia* (stem) and 10–22.5 µm in *P. brutia* (branch). In the reference sample the radial tracheid pits in *P. brutia* are more often eye-shaped and elongated than those of *P. halepensis,* but not extended. Only in compression wood (see note 10) the pits are slitlike and extending outside the pit-borders. The most conspicuous differentiating features in the charred reference specimens are shape and size of the cross-field pits. *P. halepensis* has small, widely spaced pinoid cross-field pits, 1–2(–3) per cross-field, with 2.5–4(–12.5) µm wide apertures, while in *P. brutia* the cross-field pits often are close together or touching, pinoid to fenestrate, 1–3(–4–5) per cross-field, with narrow borders and small- to large apertures, 5–17.5 µm wide, variable in size and shape. Pit apertures in *P. brutia* are circular or lozenge shaped, single ones sometimes as large as the cross-field, 2 pits in one cross-field often form an 8-shape together. Furthermore, *P. brutia* has less dentate ray tracheids than *P. halepensis*, which has raised pit-borders forming horn-like projections on both sides of the pit aperture in cross section.

The figures represent two different *Pinus* samples, which both answer better to the description of *P. brutia* than of *P. halepensis*. As they were found on different locations they can date to different habitation periods.

1) *Pinus halepensis/brutia*-type (figs 11–18)

Location: Sewer (2.5×1×1 mm).

This sample agrees with *P. brutia*, due to the thick ray-cell walls (figs 14, 16), cross-field pits that are close together and have relatively large apertures (fig. 13) and tracheids with relatively small tangential pits (*c.* 13–15 µm, figs 17 and 18).

Description: **TS**. Fragment shows neither growth rings nor early to latewood transitions. Tracheids in transverse section regular, with thick walls (fig. 11); lumen rounded, hexagonal to oval, diameter up to 20×30µm, tangential diameter often larger than radial one (this may signify latewood). Axial resin ducts 65–170 µm wide, filled with yellow-brown resin (fig. 12); **RLS**. Ray tracheids present but indistinct, with dentate walls. Rays heterogeneous, composed of marginal ray tracheids and thick-walled central cells (up to 22 µm wide), with relatively large intercellular spaces between cells and tracheids. Cross-field pits 1(–2) per field, pinoid, round, 10–13 µm in diameter; apertures round, *c.* 6–9 µm in diameter, not exceeding the border (fig. 13). Tracheid pits few, uni-seriate, bordered, small, *c.* 13–15 µm in diameter, mostly in radial walls, with included circular to elliptic apertures (figs 15, 17, 18); **TLS**. Rays 1–(partly 2)-seriate, 1–18 cells high, tapering to the ends (fig. 16).

2) *Pinus halepensis/brutia*-type (figs 19–32)

Location: Square between West House and disturbed layer, several minute fragments.

These agree with *P. brutia*, due to the distinct growth rings, thick tracheid walls (figs 19, 20, 21), inconspicuously dentate ray tracheid walls (fig. 25), and thick ray-cell walls (figs 26, 28). The dentate tracheid walls (fig. 19) and slitlike extended pits (fig. 21) indicate compression wood, as can be found on the underside of conifer branches.

Description: **TS**. Growth ring distinct. Transition from early- to latewood gradual to abrupt. Tracheids in transverse section regular, with 2–6 µm thick, crenelated walls; lumen square, rectangular or lozenge shaped, up to 30×40 µm. Rays 5–7/mm (figs 19, 20). Axial resin ducts in transition zone; **RLS**. Ray tracheids present, with sometimes weakly dentate walls (fig. 25) and bordered pits (4.5–9 µm wide, figs 31, 32). Rays heterogeneous, composed of marginal ray tracheids in one to several rows and thick-walled (2–5.5 µm) central cells. Ray cells elliptic, up to 18 µm high and 10 µm wide. Cross-field pits 1–2(–4) per field, pinoid, elliptic, up to 9 µm in diameter, with apertures of 2–7 µm wide (figs 23, 24). Ray-parenchyma pits sim-

ple, 1–4 per cross-field, 4.5–9 µm wide. Tracheid pits 1- to rarely 2-seriate, bordered, mostly in radial walls, 13–20 µm in diameter. Pit apertures circular (fig. 27), elliptic or eye-shaped, 4.5–10 µm in diameter; circular to slitlike and small in compression wood (figs 21, 29, 30). Axial parenchyma in radial strings or sheets of up to 30 cells deep, with smooth horizontal walls, and 1–2-seriate, slanting, eye-shaped pits (fig. 22), up to 17.5 µm wide; **TLS**. Rays 1–(partly 2)-seriate, 3–17 cells high, tapering to the ends (figs 26, 28).

Anacardiaceae

Terebinth (*Pistacia* sp.) (figs 33–40)

Location: Square between West House and House of the Ladies (2 fragments, 4×2×2 and 4×4×3 mm).

Description: **TS**. Diffuse porous (fig. 33). Growth rings indistinct. Pores solitary, rounded in cross-section, tangential diameter 25–60 µm, gradually diminishing into latewood, walls up to 4 µm thick. Parenchyma scanty paratracheal. Rays *c.* 5–6/mm. Resin ducts not observed. **RLS**. Perforations simple (fig. 34). Rays composed of procumbent central cells and square or upright marginal ones (figs 36, 37, 38); cells 18–45 µm long (fig. 38), 10–25 µm wide; walls very thin (up to 3.5 µm), notched; intercellular spaces with irregular crosslinks. Marginal ray cells often with solitary, orange or ruby crystals. Inter-vessel and vessel-tracheid pits alternate or in horizontal rows, rounded-oval (figs 34, 35, 39), 2.5–5.5 µm long, between spirals sometimes clustered (2–3) in horizontal lenticular grooves (10–18 µm long), apertures round (fig. 40). Vessels (except for widest) and vascular tracheids with prominent spiral thickenings (4–4.5 per10 µm, figs 39, 40). Fibres thick- to very thick-walled; Parenchyma pits oval (3–7 µm long, 2–4.5 µm wide). **TLS**. Rays 1–3(–4) seriate, 5–11(–14) cells high, heterogeneous.

The obscurity or absence of the growth ring could fit mastic tree (*P. lentiscus*). On the other hand, the sometimes 3–4 seriate rays, the low number of rays/mm, the gradual decrease in vessel diameter and the numerous crystals match turpentine tree (*P. terebinthus* L.) better.

Betulaceae

Alder (*Alnus* sp.) (figs 41–47)

Location: Square between West House and House of the Ladies, depth 2.55 m, 2 fragments: 5×3×1.5 mm

(figs 41–47) and 2.5×1.5×1.5 mm.

Description: **TS**. Growth rings distinct, boundaries formed by about 6 flattened fibres. Pores diffuse, solitary, in groups (3–6) or in radial rows (up to 6, fig. 41), round to angular in cross section, tangential diameter 30–75 μm, not much difference between earlywood and latewood in vessel size. Parenchyma paratracheal or apotracheal. Rays 22–26/mm; ray cells 13–17.5 μm long, 6.5–11 μm wide, curving and following the contours of neighbouring fibres and vessels, crystalliferous, with crenellated walls (1–2 μm thick). **RLS**. Perforations scalariform, with 10–15 bars; bars often 2–3-furcate at the base (figs 43, 44). Rays homogeneous, composed of procumbent cells (fig. 42). Inter-vessel pits narrowly bordered, opposite in horizontal rows, 2–3 pits/10 μm in a row, 3–4 rows/10 μm, oval, *c*. 3–4×2 μm, with oval apertures. Vessel-ray pits round to oval, *c*. 2 μm in diameter, with round to oval apertures (fig. 45). Fibres with eye-shaped bordered pits (fig. 47), up to 9 μm in radial walls and up to 7 μm in tangential walls. Parenchyma in strands of 4 cells or more (fig. 46); cells 45–100 μm long, 9–15 μm wide, sometimes enlarged (20–26.5 μm wide),

TLS. Rays 1-seriate, up to 14 cells high; cells 10–20 μm long, 4.5–13 μm wide, sometimes with conspicuous intercellular spaces.

Fagaceae

Chestnut (*Castanea sativa* Gaertn.) (figs 48–57)

Locations: Area 7 on first floor of West House (17×12×5 mm, figures); sewer (1.5×1.5×1mm); square between West House and House of the Ladies at 2.40 m depth (1×1×0.5 mm).

Description: **TS**. Growth rings distinct, boundary formed by several rows of flattened fibres. Ring-porous. Earlywood pores solitary, in 1–2 more or less closed rows, *c*. 24/mm², rounded in cross-section, tangential diameter 214(175–325) μm, radial diameter 175(150–250) μm (fig. 50), gradually diminishing into the latewood. Latewood pores in dendritic or radial patterns or groups, 30–42/mm², tangential diameter 60(20–100) μm (figs 48, 49). Parenchyma sparse, scanty paratracheal and apotracheal diffuse, diffuse-in-aggregates. Rays 4–13(–16)/mm, ray cells 30–45(–65) μm long, 10–30 μm wide, with square or rounded ends, thin walls (1–3 μm) and many oval pits (2.0×6.5 μm) in horizontal grooves (fig. 50). Ground tissue (fibres) in regular radial rows; lumen oval, triangular or hexagonal in cross section, tangential diameter 33(12.5–44) μm, radial diameter 33(19–56) μm; **RLS**. Perforations simple. Rays homogeneous (figs

51, 52). Vessel member length 270(62–394) μm long. Vessel-tracheid pits in longitudinal waving lines, bordered, with horizontal up to *c*.17 μm long apertures (fig. 56). Tyloses present. Fibres 330–550 μm long, thin-walled; fibre pits bordered, 4.5–6.5 μm in diameter, with lenticular, slanting, 3–4 μm long apertures (fig. 54); Parenchyma in strands of about 4 cells; cells 55–144 μm long, 10–18 μm wide, with simple, circular pits (fig. 53, 57);

TLS. Rays 1(–2–3) seriate, (3–)9–20 cells high (11.5 average) (figs 55, 57). White or orange crystals in fibres and vessels.

Oleaceae

Olive (*Olea europaea* L.) (figs 58–64)

Found at all locations, except in both rooms 4 (ground floor and first floor) and room 6 (first floor): in total more than 500 fragments, most of which are less than 0.5×0.5×0.5 cm. Room 3B, 6.5×4.5×3.0 cm; 5×4×2.5 cm; 3.5×2.5×2 cm; 6×5×2 cm. Room 3A, 7×6, 5×5 cm, 10 growth rings (figs 58–64); room 5 first floor, 18 fragments: parts of branches of 1.5–5 cm Ø, some including bark, some with gnarls, 0.8×2.6×1.9 cm up to 4×4×3.5 cm.

Fragments with blown up rays are considered to have been fresh when burned and fragments with whorled or gnarled structures to have been derived from pruning of trees.

Description: **TS**. Growth rings distinct in immature branches (fig. 58), indistinct in mature wood. Diffuse porous. Pores (fig. 58, 59), numerous, up to 190/mm², solitary, in radial multiples of 2–4(–15) or in clusters; angular to rounded in cross section, radial and tangential diameter 38(17–63) μm, walls 5–6 μm thick. Rays 10–14/mm; **RLS**. Perforations simple. Rays heterogeneous, with procumbent central cells, and large upright and square marginal cells (figs 61, 62). Vessel member length 330(100–530) μm. Inter-vessel pits bordered, alternate, rounded, minute (1.5–4 μm in diameter). Vessel-ray pits numerous, circular, 2.5–4 μm in diameter (fig. 62). Fibres 460(200–660) μm long (difficult to measure, therefore not certain), medium thick- to very thick-walled. Parenchyma in 2–4-celled strands (fig. 64); **TLS**. Rays 1–3(4) seriate, 7–12(–16) cells high often with large top cells (fig. 63). Crystals white, amber, greenish or red, minute, clustered.

The species is very variable and sometimes difficult to identify. These data, especially the amount of pores/mm² (branch wood), differ somewhat from the description of Fahn *et al.* (1986: pp. 136–137).

Rosaceae

Almond tree (*Prunus dulcis* {Miller} D.A. Webb.) or Webb's almond tree (*P. webbii* {Spach}Vierh.) (figs 65–73)

Locations: Room 3C, lower level, 15×15×6 mm, 14 growth rings (figs 65–73), 7 flat fragments: 10×10×0.5 mm to 18×18×0.5 mm and some granules; sewer 6×3×2 mm; square between West House and House of the Ladies, depth 2.40m, *c*.1.0×0.5×0.5 mm.

Description: **TS**. Growth rings distinct. Semi-ring to ring-porous (fig. 65). Pores 55–475/mm², mostly solitary or in radial, tangential or oblique multiples of 2–3(–6) or small clusters; rounded to angular in cross-section, tangential diameter 47(12–120) µm, radial diameter 48(9–106) µm. Rays 7/mm; **RLS**: Perforations simple (fig. 70). Rays heterogeneous, composed of procumbent central cells and square to upright marginal cells (figs 69, 70). Vessel member length 108(31–250) µm. Inter-vessel pits alternate, rounded, 2.5–9 µm in diameter (figs 67, 68). Vessel-ray pits, alternating, 2.5–10 µm in diameter (fig. 69). Vessel walls with spiral thickenings (fig. 66). Fibres thick- to very thick-walled, with bordered pits, 2.5 µm in diameter (fig. 66). Parenchyma in 2–4 celled strands (fig. 73); **TLS**. Rays 1(2)- and 3–7-seriate; 1-seriate 1–9 cells high, multiseriates up to 28 cells high. White crystals.

Pear (*Pyrus amygdaliformis* Vill.)

Location: Area north of north wall of West House, *c.* 2×2×1.5 mm; square between West House and House of the Ladies, depth 2.40 and 2.55 m.

Description: **TS**. Growth rings indistinct, boundary formed by about 3 flattened fibres. Diffuse porous. Pores *c.* 240/mm²(one count), almost exclusively solitary, rarely in pairs or small clusters; round to angular in cross section, diameter 5–20 µm, walls thin. Parenchyma paratracheal, up to 2 cells thick. Rays 12–18/mm; ray cells curving around vessels; **RLS**. Perforations simple. Rays predominantly homogeneous, composed of procumbent cells. Inter-vessel pits bordered, round *c.* 6.5–9 µm in diameter. Vessel-parenchyma pits rounded. Vessel-ray pits numerous, diagonal, lanceolate, with reduced borders, *c.* 6.5–9 µm long, often accumulated in transverse bands on vessel walls. Fibres medium thick-walled (2–3 µm), with eye-shaped, slanting, elongated pits. Parenchyma cells 30–70 µm long, 10–15 µm wide, with many round to oval pits; walls thin, undulating, end walls thick (up to 4.5 µm); **TLS**. Rays *c.* 125/mm² (one count), (1–)2–4-

seriate, sometimes with uniseriate wings up to 4 cells, up to 16(30) cells high. Crystals white, yellow, blue or red, in vessels and ray-cells.

Tamaricaceae

Tamarisk (*Tamarix* sp.) (figs 74–81)

Locations: Described sample in square between West House and House of the Ladies depth 2.40 m, 2×4×3 mm (figs 74–81). Other finds: same location depth 2.35, 7 small fragments and 2.40 m, 4×3×2 mm; Room 3A, 8×6×0.5 mm; Sewer, granule.

Description: **TS**. Growth ring indistinct or not present in sample. Diffuse porous (figs 74, 75). Pores 25/mm² (2 counts), mostly solitary, in multiples of 2 or in clusters of 3–4; rounded in cross-section, tangential diameter 15–110 µm, radial diameter 15–90 µm, walls *c.* 2–3 µm. Parenchyma paratracheal. Rays 5–6/mm; **RLS**: Vessel member length (40–)85–130 µm. Perforations simple. Rays heterogeneous, composed of procumbent, square, upright, circular or oval cells (fig. 76). Inter-vessel pits alternate, circular to oval, 2–4.5 µm long, 1–3 µm wide, with slit-like often coalescent apertures (fig. 79). Vessel-parenchyma pits numerous, circular, 1.5–2.5 µm in diameter (figs 77, 79). Vessel-ray pits few, circular, *c.* 1–3.5 µm in diameter. Parenchyma fusiform, storied (figs 77, 80, 81); storied together with vessel members only in some samples. Parenchyma cells about 90–120 µm long, 5–15 µm wide. Fibres numerous, thin- to medium thick-walled; pits simple, mainly in radial walls 3–4.5 µm in diameter, often in the center of slanting, pointed furrows (compression wood) (fig. 78); **TLS**. Rays (1–)3–10-seriate; 1-seriate 5–24 cells high, multiseriate up to *c.*1 mm high (figs 80, 81). Central ray cells often tortuous and small (4.5–9 µm wide), marginal cells large, oval (up to 25×15 µm) (fig. 81). Crystals white, in marginal ray cells.
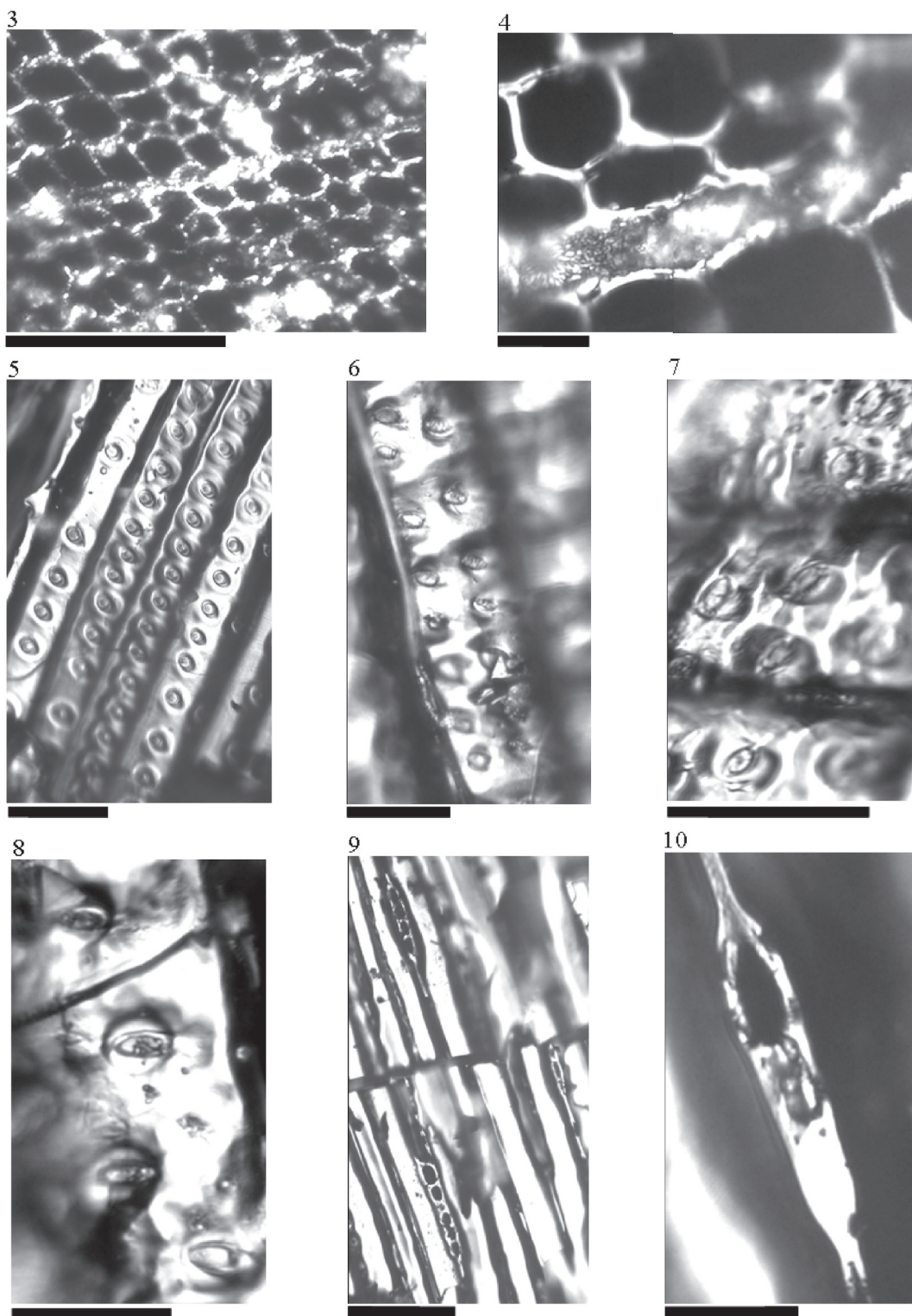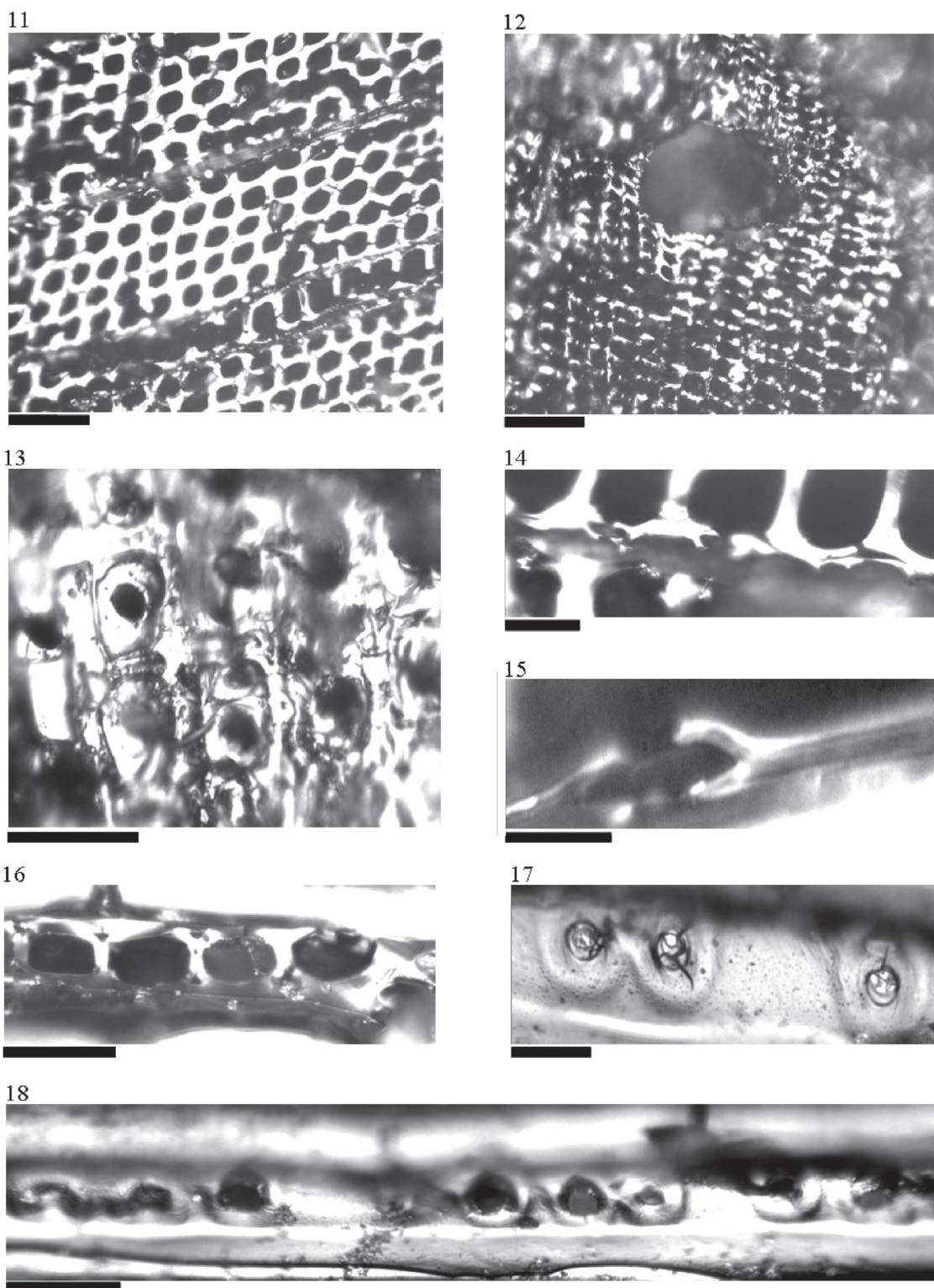
Figures 3–10. *Juniperus phoenicea/oxycedrus* type

Fig. 3. Tracheids, rays. TS. *Fig. 4.* Ray cell with pits and crystals. TS. *Fig. 5.* Tracheids, uniseriate pits in radial walls. RLS.

Figs. 6, 7, 8. Cross-field pits. RLS. *Fig. 9.* Rays. TLS. *Fig. 10.* Ray cells, tracheid-ray pits. TLS.

Figs. 3, 4, 6, 7, 8: *J. phoenicea*-type. Figs. 5, 9, 10: *J. phoenicea/oxycedrus*-type.

Scale: 3, 9 = 100 µm; 5 = 50 µm; 7, 10 = 25 µm; 6, 8 = 20 µm; 4 = 15 µm.

Figures 11–18. *Pinus halepensis/brutia* type I

Fig. 11. Tracheids, rays. TS. *Fig. 12*. Resin duct. TS. *Fig. 13*. Cross-field pits. RLS. *Fig. 14*. Tracheid-ray pits. TLS.

Fig. 15. Tracheid pit in radial wall. TLS. *Fig. 16*. Ray (partly), intercellular spaces. TLS. *Fig. 17*. Tracheid pits in tangential wall. TLS.

Fig. 18. Tracheid pits in tangential wall. TLS.

Scale: 12 = 100 µm; 11 = 50 µm; 13, 16, 18 = 25 µm; 14, 17 = 15 µm; 15 = 10 µm.
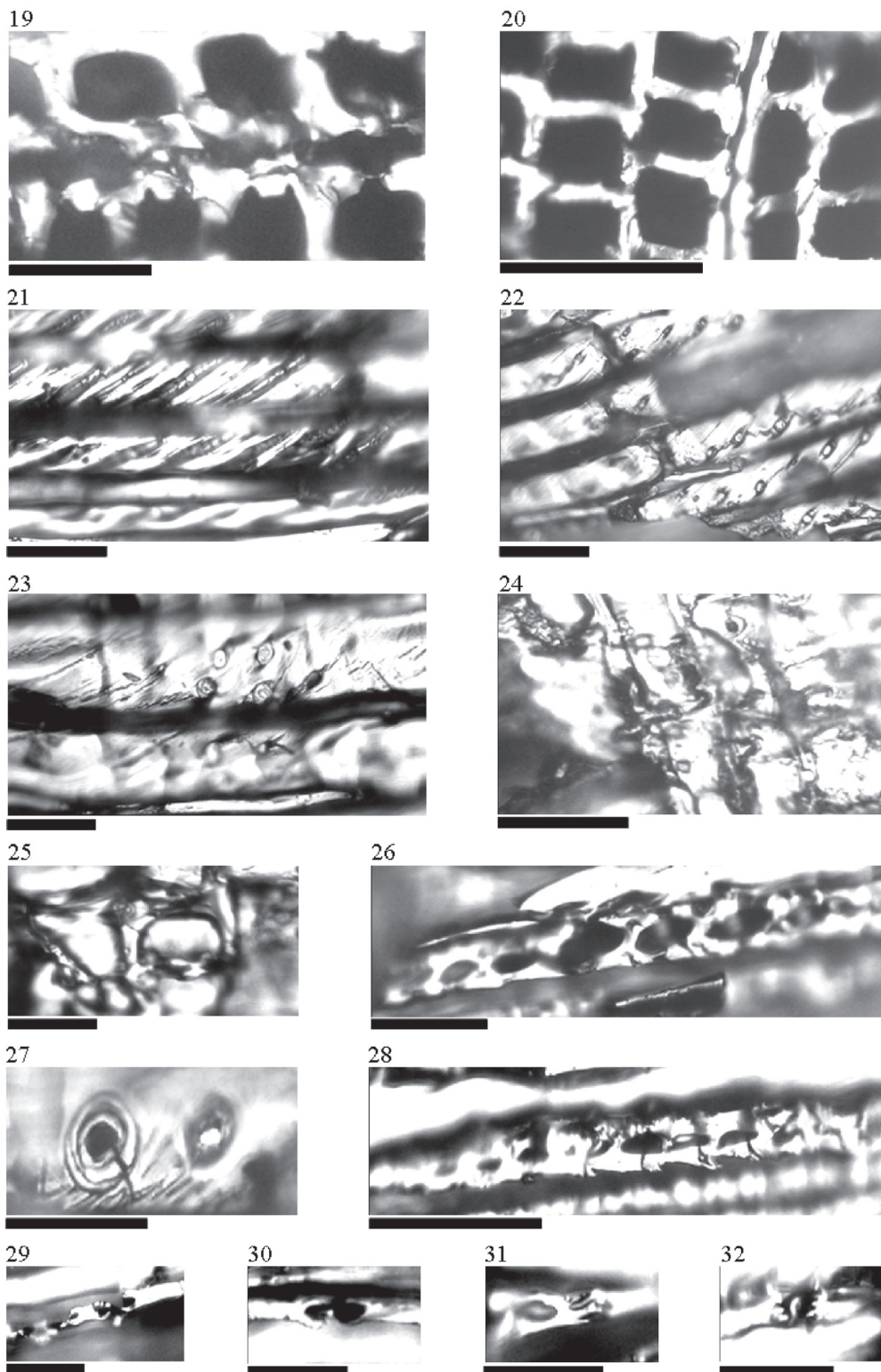
Figures 19–32. *Pinus halepensis/brutia* type II

Fig. 19. Ray, ray-pits, late wood. TS. *Fig. 20.* Tracheids, ray, ray-pits. TS. *Fig. 21.* Slit-like tracheid pits. RLS. *Fig. 22.* Parenchyma, pits. RLS. *Fig. 23.* Parenchyma-ray pits. RLS. *Fig. 24.* Ray cells, cross-field pits. RLS. *Fig. 25.* Raytracheid pits. RLS. *Fig. 26.* Ray. TLS. *Fig. 27.* Tracheid pits. TLS. *Fig. 28.* Ray, late wood. TLS. *Figs. 29, 30.* Tracheid pits in cross section. TLS. *Figs. 31, 32.* Raytracheid pits. TLS.

Scale: 21 = 25 μm; 20 = 20 μm; 22, 25 = 15 μm; 19, 23, 24, 26, 27, 28, 29, 30, 31, 32 = 10 μm.
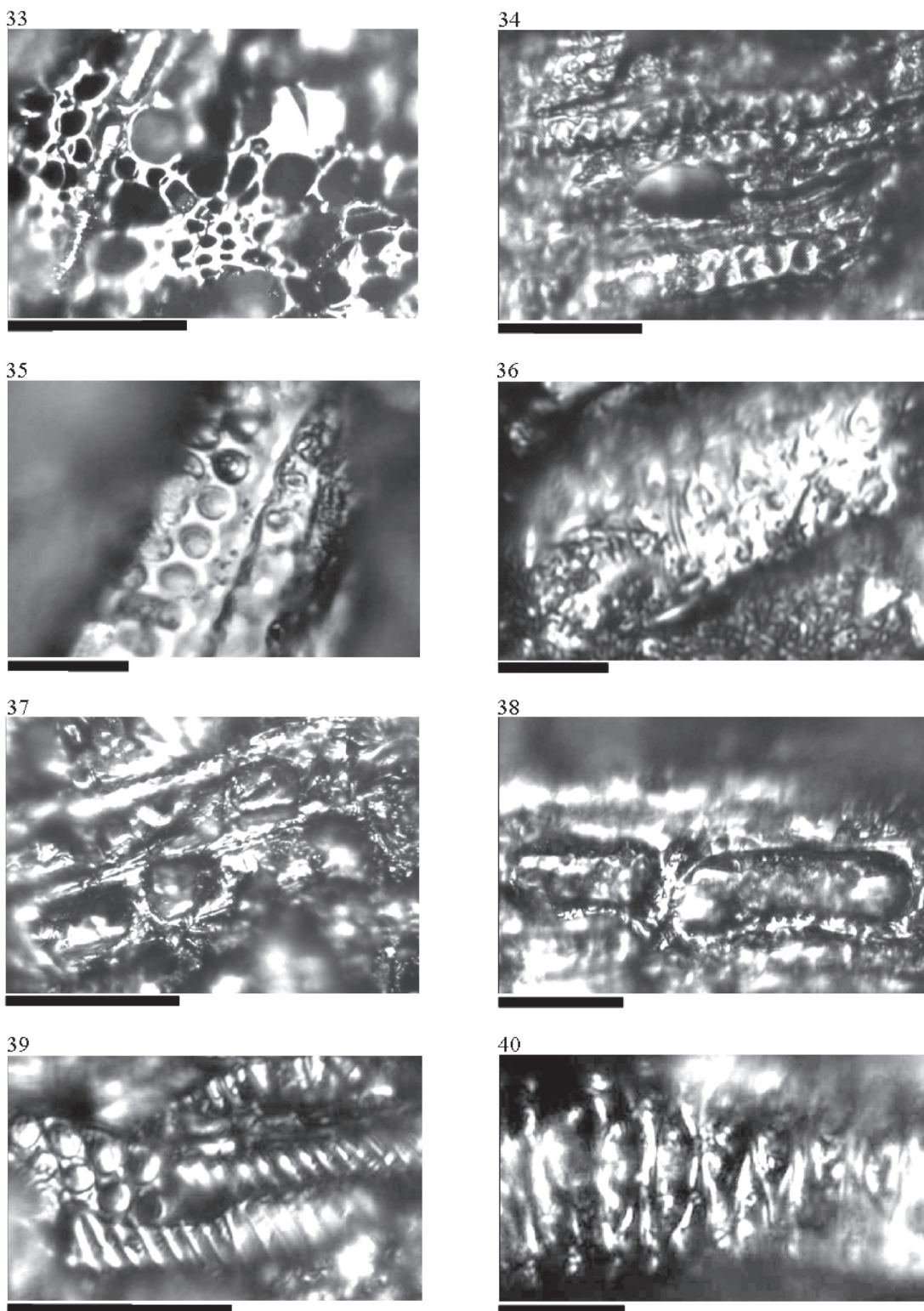
Figures 33–40. *Pistacia* sp.

Fig. 33. Vessels, ground tissue, ray. TS. *Fig. 34.* Vessels, perforation, inter-vessel pits. RLS. *Fig. 35.* Inter-vessel pits. RLS.

Fig. 36. Cross-field pits. RLS. *Figs. 37, 38.* Ray cells. RLS. *Fig. 39.* Vessels, inter-vessel pits, spirals. TLS. *Fig. 40.* Spiral thickenings, pits. TLS.

Scale: 33, 37 = 50 μm; 34, 38, 39, 40 = 25 μm; 35 = 15 μm; 36 = 10 μm.
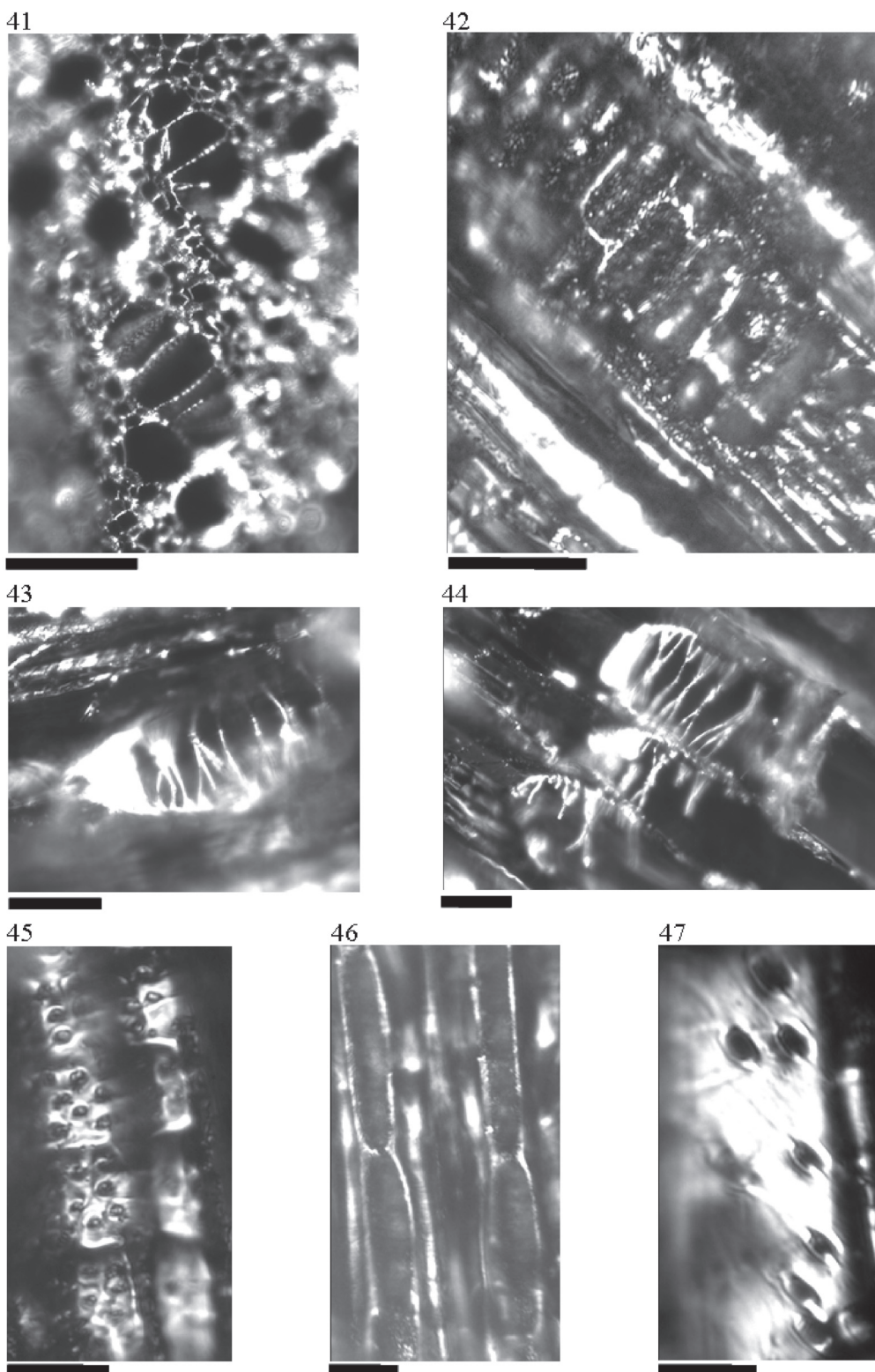
Figures 41–47. *Alnus* sp.

Fig. 41. Vessel distribution. TS. *Fig. 42*. Ray cells. RLS. *Fig. 43*. Scalariform perforation. RLS. *Fig. 44*. Scalariform perforations. RLS. *Fig. 45*. Cross-field pits. RLS. *Fig. 46*. Parenchyma. TLS. *Fig. 47*. Fibre pits. TLS.

Scale: 41 = 100 μm; 42, 43, 44, 46 = 25 μm; 45, 47 = 10 μm.
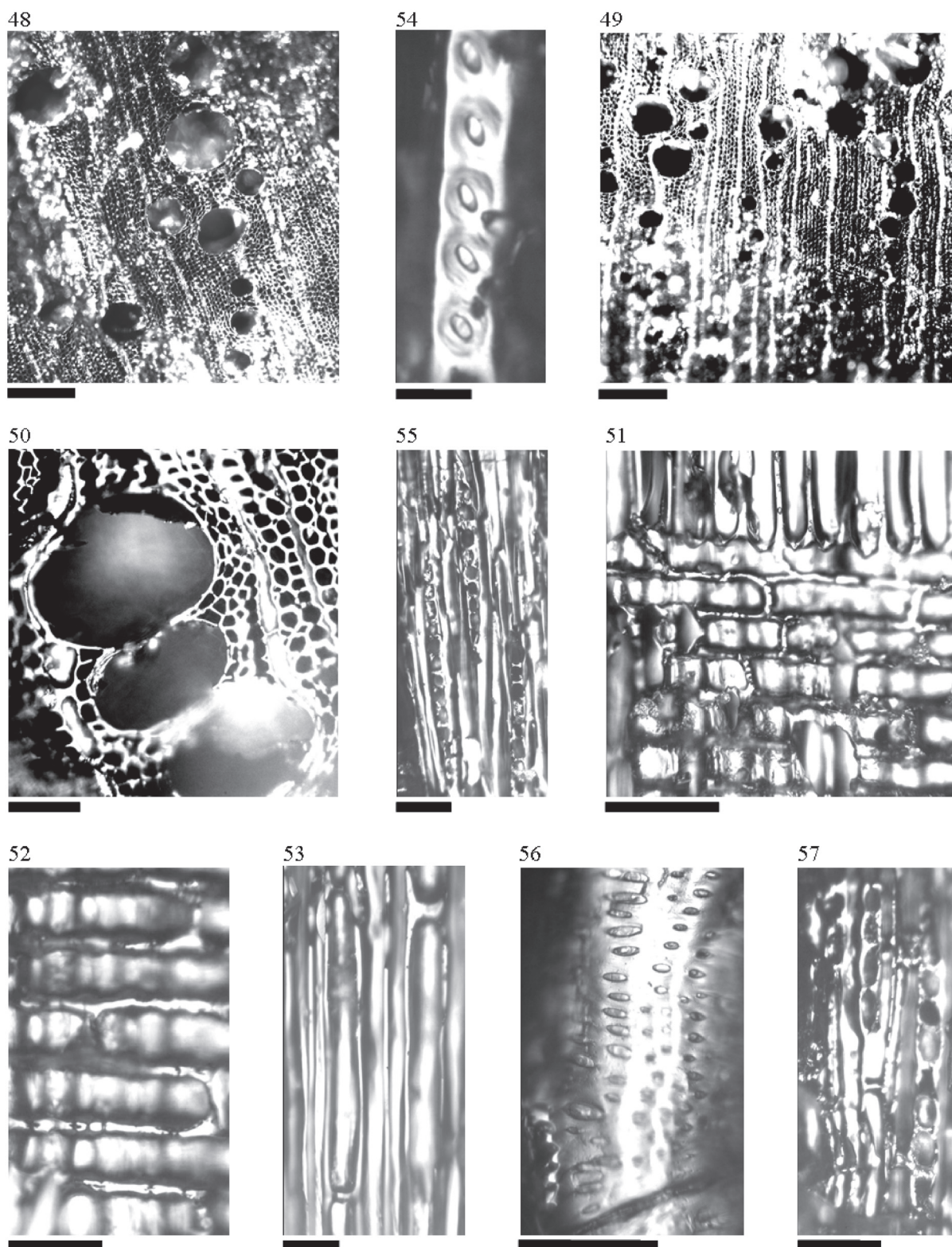
Figures 48–57. *Castanea sativa*
Figs. 48, 49. Ring-porous vessel distribution. TS. *Fig. 50.* Vessels, rays (detail). TS. *Fig. 51.* Ray-cells. RLS. *Fig. 52.* Ray-cells, pits. RLS.
Fig. 53. Parenchyma. RLS. *Fig. 54.* Fibre pits. TLS. *Fig. 55.* Rays. TLS. *Fig. 56.* Detail of *v*essel with pits. TLS. *Fig. 57.* Rays, parenchyma. TLS.
Scale: 48, 49 = 200 µm; 50, 51, 55, 56, 57 = 50 µm; 52, 53 = 25 µm; 54 = 10 µm.
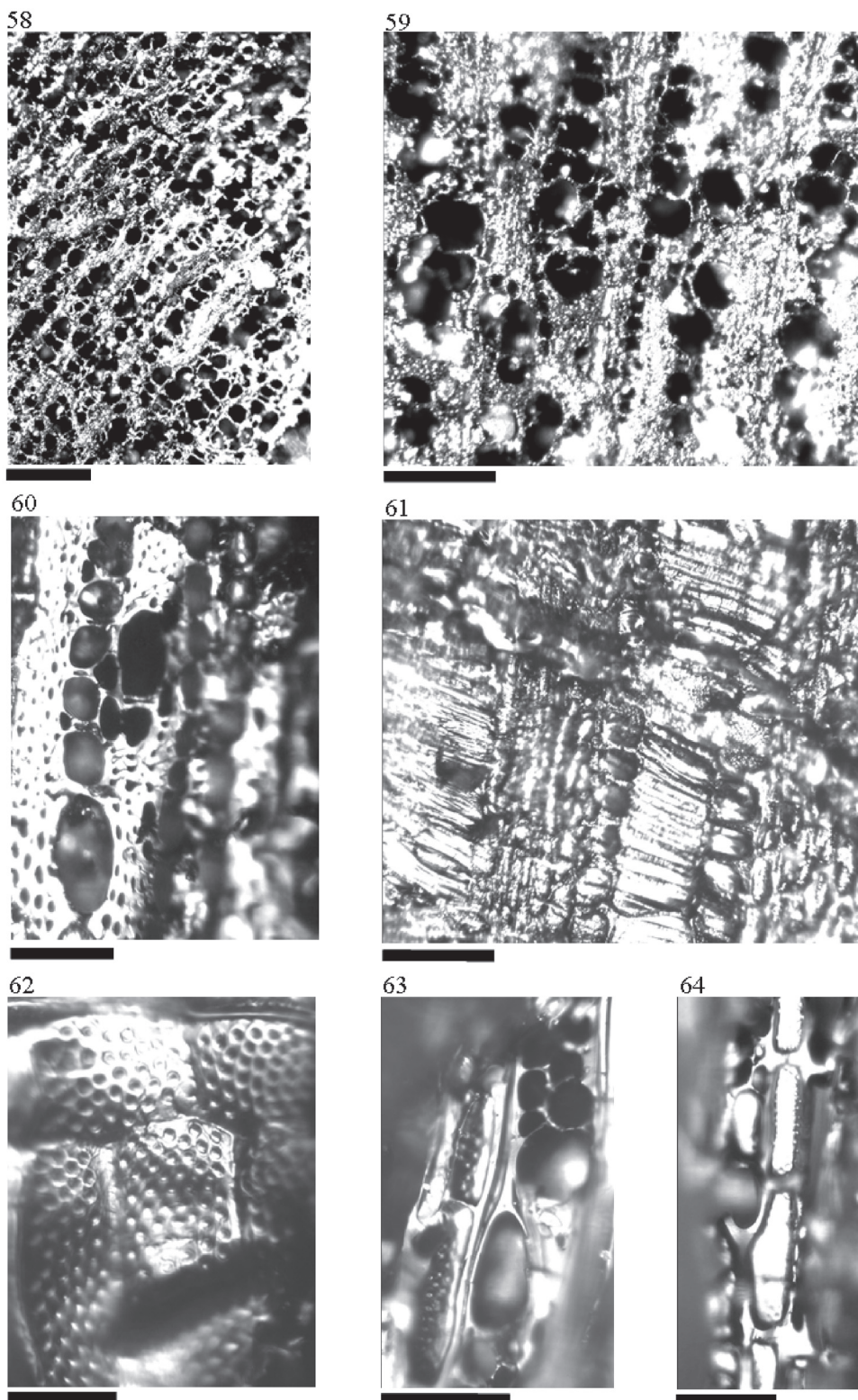
Figures 58–64. *Olea europaea*

Fig. 58. Growth ring. TS. *Fig. 59.* Vessel distribution, rays, parenchyma. TS. *Fig.60.* Vessels, ground tissue. TS. *Fig. 61.* Ray. RLS.
Fig. 62. Ray cells, cross-field pits. RLS. *Fig. 63.* Rays (partly). TLS. *Fig. 64.* Parenchyma. TLS.
 Scale: 58 = 200 µm; 59, 61 = 100 µm; 60, 62, 63, 64 = 50 µm.
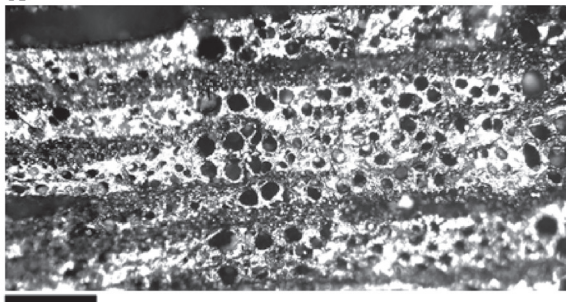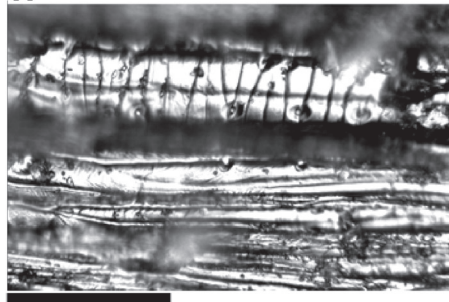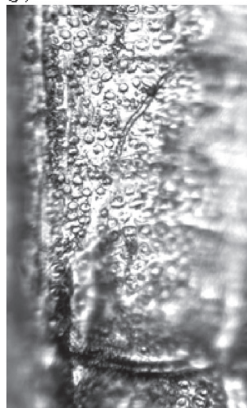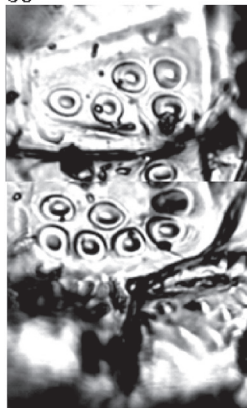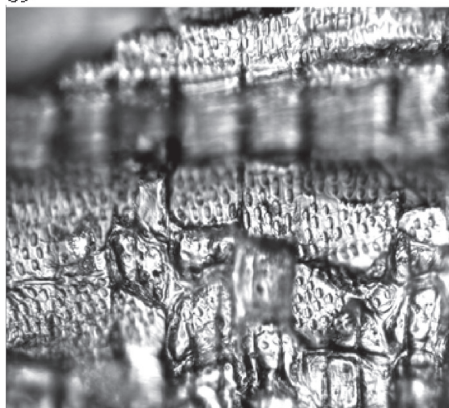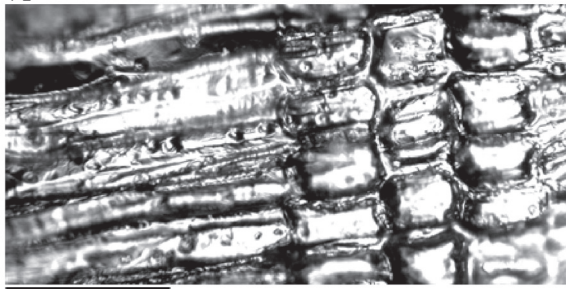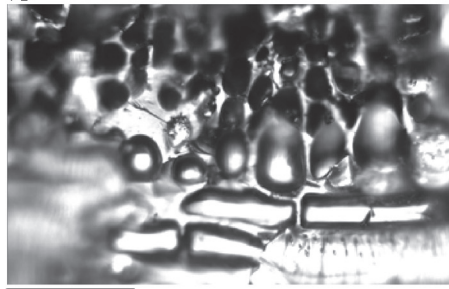
Figures 65–73. *Prunus dulcis*
Fig. 65. Growth ring. TS. *Fig. 66.* Vessel, spiral thickenings, inter-vessel pits*,* fibres. RLS. *Fig. 67.* Large vessel without spiral thickenings, inter-vessel pits. RLS. *Fig. 68.* Inter-vessel pits. RLS. *Fig. 69.* Ray cells, vessel-ray pits. RLS. *Fig. 70.* Vessel, simple perforation, vessel-ray pits. RLS. *Fig. 71.* Ray cells, fibres with bordered pits. RLS. *Fig.72.* Rays, vessel with spiral thickenings. TLS. *Fig. 73.* Heterogeneous ray, parenchyma strands. TLS.
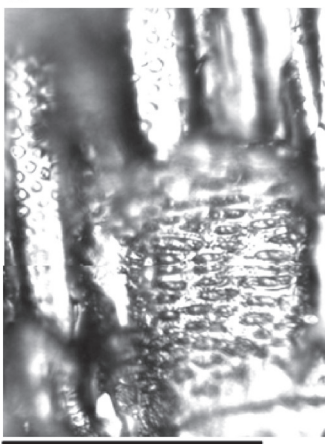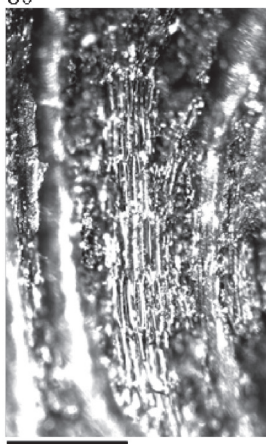Scale: 65 = 200 μm; 72 = 100 μm; 66, 67, 69, 70, 71, 73 = 50 μm; 68 = 25 μm.
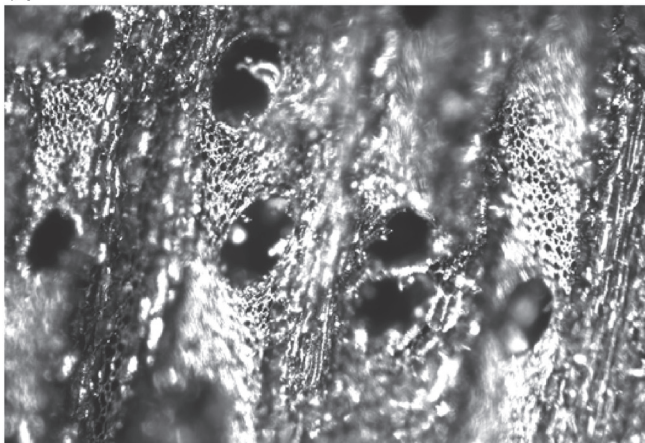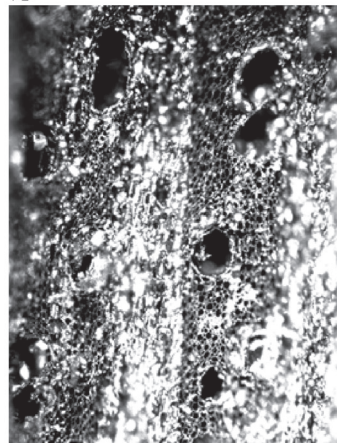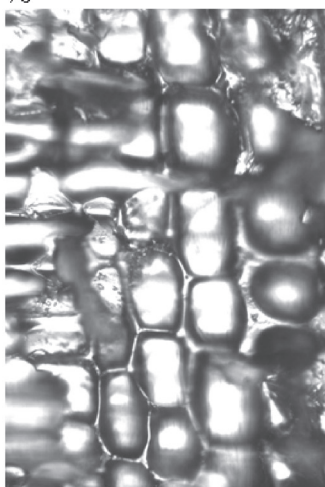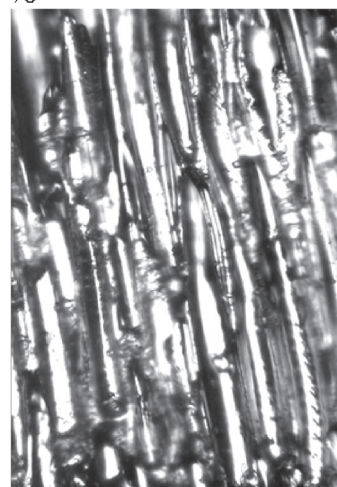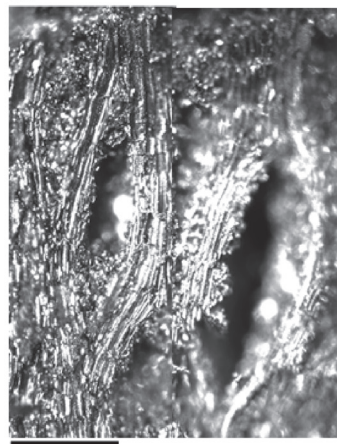
Figures 74–81. *Tamarix* sp.

Fig. 74, 75. Vessels, ground tissue, multiseriate rays. TS. *Fig. 76.* Ray cells. RLS. *Fig. 77.* Parenchyma. RLS. *Fig. 78.* Fibres. RLS. *Fig. 79.* Vessel, inter-vessel pits, parenchyma cells. TLS. *Fig. 80.* Storied parenchyma. TLS. *Fig. 81.* Rays, storied parenchyma. TLS. Scale: 74, 75, 80 = 200 μm; 81 = 100 μm; 76, 77, 78, 79 = 50 μm.