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Cedrus Libani Under the Microscope; the Anatomy of Modern and Ancient Cedar of Lebanon Wood

Introduction

Other papers in this journal have described the habitat, botany, conservation and importance of the Cedar of Lebanon (*Cedrus libani)* in antiquity, particularly as an item of trade. This paper describes the way in which the wood of Cedar of Lebanon can be identified accurately using scientific methods. The recognition and description of the detailed anatomical structure of modern Cedar of Lebanon wood gives the framework of reference for identifying ancient samples from archaeological sites. As the ancient wood has often been altered over time, with deterioration of the wood cells, the process of identification is not always straightforward. This paper provides an example of how some of these difficulties have been overcome to enable the identification of desiccated Cedar of Lebanon furniture wood from the Middle Bronze Age tombs excavated by Kenyon (1960) at Jericho.

Methodology and identification

Any scientific subject with its particular methods of describing or analysing material will have its own set of terminology and protocols. Wood science is no exception. Some of the names used here may be unfamiliar to the general reader, but the value of using them rests in the fact that they are universal terms with very precise meanings and applications. Adopting standard terms (such as in Wheeler, Baas & Gasson 1989) and recognised procedures for identifying wood, whether ancient or modern, is the key to being able to compare an assemblage of wood (or charcoal) from one archaeological site with another. From such comparisons, the archaeobotanist can build up a picture of the use of woody resources and the environment of the site itself, and proceed to reconstruct a more regional interpretation. (For a very detailed description of this process, methodology and case study the reader is referred to Cartwright & Parkington 1997). There are some terms in current use, however, which are not as scientifically precise as one might wish. Such examples are the terms 'softwood' and 'hardwood', which are a

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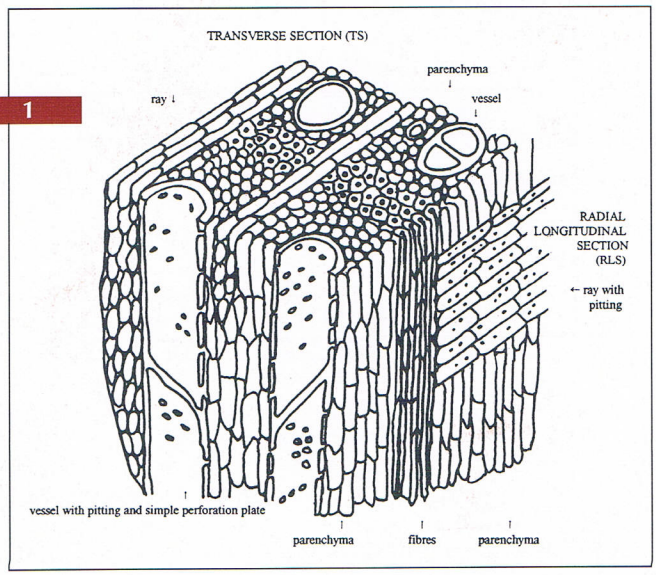

Figure 1: Simplified diagram of a typical hardwood structure in transverse, radial longitudinal and tangential longitudinal planes showing the main types of cells (after Couvert 1970).
Couvert, M. 1970. *Etude des charbons préhistoriques: préparation des coupes minces et analyse des structures.* Paris: Arts et métiers graphiques (Travaux du Centre de recherches anthropologiques, préhistoriques et ethnographiques).

remnant of forestry industry terminology. They are unsatisfactory terms because not all hardwoods are hard and not all softwoods are soft. The descriptions "hard" and "soft" need to have precise definitions also. Although the words 'hardwoods' and 'softwoods' remain in current use, it may be preferable to use the term 'dicotyledons' instead of 'hardwoods' when discussing trees such as oak, maple, elm, acacia etc. For trees such as pine, fir, larch, cedar etc, it is preferable to use the terms 'gymnosperms' or 'conifers' instead of 'softwoods'.

The scientific identification of any wood by optical microscopy needs a view of the cellular structure in three different orientations: transverse section (TS), radial longitudinal section (RLS) and tangential longitudinal section (TLS). These three planes, each at right angles to the other two, show different aspects of a complex cellular wood structure (Figures 1 and 2). Hardwoods, such as oak, walnut or fig, have an interconnecting axial and radial arrangement of cells of different types which perform different functions (Figure 1). For example, vessel cells conduct water and minerals throughout the tree. Regulation of the flow is partly controlled by perforation plates (which can be simple or complex) in the vessels. Pits (which are small openings in the cell wall) of various sizes, shapes and orientation allow interconnection between one type of cell and another. Ray and axial parenchyma cells store food. Fibre cells provide mechanical strength to the tree. When undertaking the identification of a hardwood, it is necessary to search amongst at least 86 separate distinguishing features within the cellular structure.

Softwoods, such as pine, fir, larch and Cedar of Lebanon have a more uniform appearance to their wood structure and there are fewer highly diagnostic features to recognise (maximum 38). Softwoods have no vessel or fibre cells. The functions of conducting water and supporting the tree are provided by cells called longitudinal tracheids. Longitudinal tracheids comprise 90% of softwood cells. Pitting connects the longitudinal tracheids with other cells. Most of the remaining 10% is made up of ray parenchyma cells, although some softwoods may have small numbers of other cell types such as ray tracheids, resin canals with epithelial cells and some axial parenchyma.

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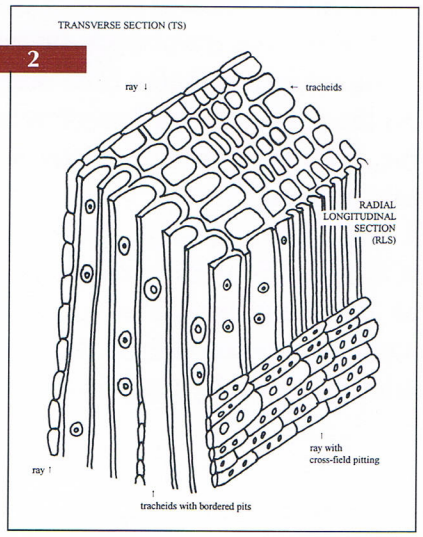

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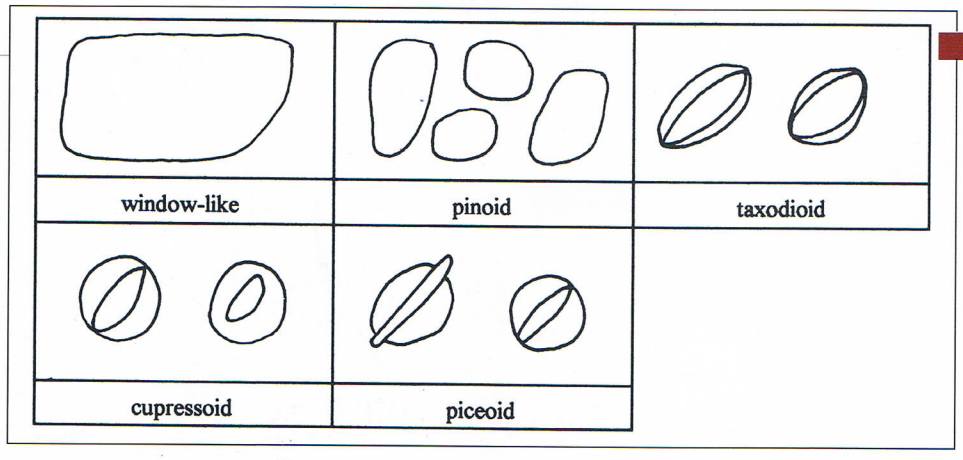

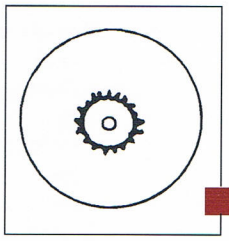

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Figure 2: Simplified diagram of a typical softwood structure in transverse, radial longitudinal and tangential longitudinal planes showing the main types of cells.

Figure 3: Types of softwood cross-field pits: windowlike, pinoid, taxodioid, cupressoid and piceoid.

Figure 4: Simplified diagram of the scalloped torus margin of a longitudinal tracheid pit in Cedar of Lebanon wood.

Unlike hardwoods, for which there are many diagnostic features to consider, often of equal significance, predominant amongst the most useful microscopic features for softwood identification are the pits which connect the ray parenchyma cells to the longitudinal tracheids. These cross-field pits vary in shape from one softwood to another, and so provide very useful diagnostic features for identification. These have been grouped into five different types: windowlike, pinoid, taxodioid, cupressoid and piceoid (Figure 3).

In order to examine these key features, whether for hardwoods or softwoods, it is standard scientific procedure to use a compound optical microscope with a range of magnifications from x 50 to over x 1000. Thin sections of the modern or ancient wood are cut on a sliding microtome in the required three planes (TS, RLS & TLS). They may be stained (e.g. with Safranin, a crimson-coloured dye) to reveal the cellular structure more distinctly. The thin sections, mounted on glass microscope slides, are then viewed under the microscope in transmitted light. The anatomical features observed are compared with a reference collection of wood thin sections, with computer databases (such as Wheeler *et al* 1986) and with wood anatomy atlases (such as Schweingruber 1990; Fahn, Werker & Baas 1986; Gale & Cutler 2000). For some ancient wood, if no thin sections can be cut or if the samples are in particularly poor condition and need magnifications greater than can be offered by the optical microscope, it may be necessary to view tiny samples in transverse, radial longitudinal and tangential longitudinal planes, using the scanning electron microscope.

The wood anatomy of Cedar of Lebanon

Plate 1 shows the cellular structure of Cedar of Lebanon in transverse section (TS). Most of the cells which can be seen making up the structure are longitudinal tracheids. There are also some sparse axial parenchyma cells, but they are very difficult to distinguish clearly from the tracheids in the TS. The boundary demarcations, running across the field of view, denote the growth ring boundary between one season's growth and the next. The earlywood tracheids are larger and more thin-walled than the latewood ones. As one examines the full extent of the season's growth, a gradual change in the tracheids is visible. They become smaller and more thick-walled at the end of the season's growth. This variation in the ratio of ear-

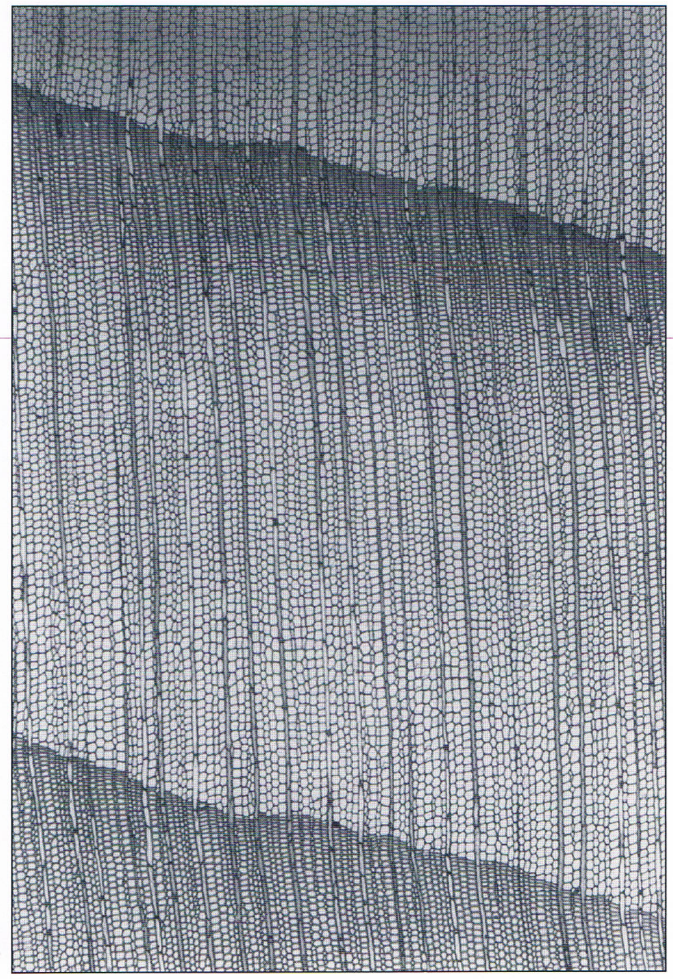

Plate 1: Transverse thin section (TS) of modern Cedar of Lebanon wood.

Plate 1

lywood to latewood and whether there is a gradual or abrupt transition from one to the other has a direct bearing on the wood's properties. The more latewood present, the denser the wood will be. The appearance of the wood, its surface roughness and its suitability for easy carving is affected by the kind of earlywood to latewood transition present. If very abrupt, it may produce adverse effects when the wood is worked. The other features to note in this transverse view are the uniseriate (one cell wide) rays running at right angles to the growth ring boundaries. Occasionally there might be biseriate rays. The rays are visible here as long 'lines' of cells, running vertically in Plate 1. Although not present in this specimen, it should be noted that Cedar of Lebanon wood can sometimes have a row of tangentially orientated traumatic resin canals, which show up best in TS.

The combination of features can result in rather more general terms being used for wood properties. For example, woods can be described as 'close-grained' or 'straight-grained' if the wood cells are generally uniform in size and shape or the trunk / branch is free from knots.

Plate 2 shows the cellular structure of Cedar of Lebanon in radial longitudinal section (RLS). This is one of the most important views and there are many key features present. The 'brick-like' groups of cells show the vital cross-field area where the diagnostic pit types are present in the ray parenchyma cells (interconnecting with the longitudinal tracheids). The pit types present in these rays are piceoid, cupressoid and taxodioid (see Figure 3). It is important to examine the wood carefully under a microscope to try to distinguish the many fine details in the ray parenchyma cell walls which are also very diagnostic. These include pitting in the horizontal walls and nodular end walls with indentures (Plate 2). Prismatic crystals may be present, but these are not diagnostic of the species. The rays are often bordered by a single row of ray tracheids which have thin-walled and irregularly-shaped cells. The RLS also shows the most diagnostic feature of all, which is to be found in some of the bordered pits present in the longitudinal tracheids. This feature is illustrated in Plate 4 and drawn in simplified form in Figure 4. It consists of a fringed margin to the bordered pit, technically known as a scalloped torus.

Plate 3 shows the cellular structure of Cedar of Lebanon in tangential longitudinal section (TLS). The predominant features visible are the longitudinal tracheids and the uniseriate (or rarely biseriate) rays. These rays can range from being just 2 cells high, but are more commonly up to 15 cells high. The maximum height is 40 cells.

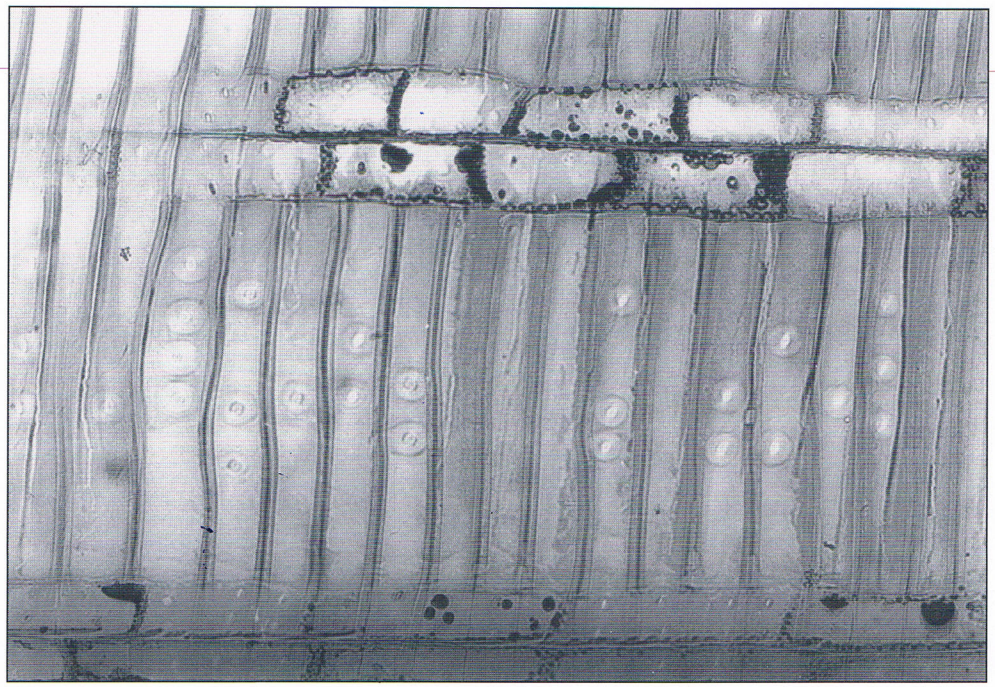

Plate 2: Radial longitudinal thin section (RLS) of modern Cedar of Lebanon wood.

Plate 2

These are some of the main features which we would search for when identifying modern Cedar of Lebanon wood. As we will see from the next part of the paper, how many of these key characteristics are visible in ancient wood is directly dependent on how well the cellular structure of the wood has been preserved in the burial environment.

The Cedar of Lebanon Middle Bronze Age furniture wood from Jericho

Elsewhere in this journal authors have described, how, in Egypt, imported woods such as Cedar of Lebanon were sometimes used for the coffins of high-ranking individuals and other prestigious objects and buildings. The conditions of burial in the desiccated ancient Egyptian tombs were ideal for the good preservation of a diverse collection of wood and other botanical material. Such exceptional conditions of preservation were rarely found in the ancient world outside Egypt. It is particularly fortunate that one of those rare examples, the desiccated Middle Bronze Age tomb furniture excavated from Jericho (Kenyon & Holland 1983), has survived. Over 3100 fragments of the Jericho tomb wood have been identified by the author; the full report is currently being submitted for publication. Many local woods were used in the construction of the various furniture types such as tables and stools and for grave goods such as boxes, platters and cups. It is significant that the craftsmen of Jericho imported Cedar of Lebanon wood for some of the Jericho funerary assemblage, notably for the very decorative inlays on tables, stools, boxes and cups. It is not surprising that they should make the effort to procure Cedar of Lebanon wood as it is close-grained and therefore easy to carve, it is highly aromatic and resists insect and fungal attack well. Being straight-grained it is particularly suitable for splitting into thin sheets to be used as decorative veneers and panelling. Furthermore, it presumably had the reputation in the Mediterranean, Egyptian and Levantine ancient world as a prestigious and sought-after trade timber. So in cultural terms, its presence within a funerary or domestic context, would have specific importance for the people concerned.

It is important to set out clearly here some of the difficulties of microscopically identifying Cedar of Lebanon wood from the Jericho assemblage. When the samples of Jericho wood were first being examined under the optical microscope and it became clear that there was a softwood present, it was very important to examine samples which were sufficiently well preserved to reveal the key diagnostic features needed to make an identification to genus or to species level. This process of observation is now described step by step, so that it is easier to compare with the details noted above for the modern Cedar of Lebanon wood anatomy.

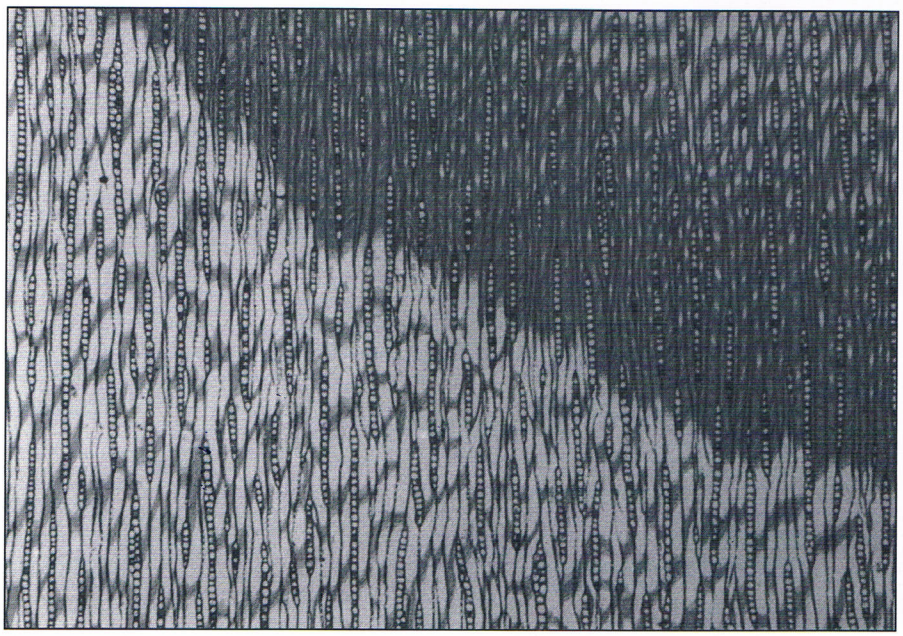

Plate 3: Tangential longitudinal thin section (TLS) of modern Cedar of Lebanon wood.

Plate 3

In transverse views, growth rings were distinct and there was a gradual change from earlywood to latewood longitudinal tracheids. One sample in particular appeared to be in relatively good condition and the wood was thin sectioned. Large splayed cracks were present, however, following the line of the rays (Plate 5). Despite these cracks, the TS showed the relative sizes and shapes of the somewhat distorted longitudinal tracheids and the rays. Radial longitudinal views showed the most significant features, including some longitudinal tracheids with scalloped tori on bordered pits. This highly diagnostic characteristic was crucial to the identification of Cedar of Lebanon wood fragments and was exhaustively checked on each sample under high magnifications. On some samples the scalloped torus margin was severely obscured, degraded or absent. Care was taken not to misinterpret possible longitudinal tracheid pitting breakdown which can mimic scalloped tori (Gale & Cutler 2000). In radial longitudinal section, after considerable microscopical examination at high magnifications, the ray to longitudinal tracheid pitting could be identified as cupressoid, piceoid and taxodioid. Distortion and degradation of the wood considerably hindered easy recognition of this cross-field pitting. Ray tracheids were almost invisible. Uniseriate rays were present and there was very sparse axial parenchyma and traumatic resin canals. The condition of the wood prevented any assessment of whether or not the end walls of the axial or ray parenchyma cells were nodular. Pitting on the horizontal walls and indentures in the end walls of the ray parenchyma cells were extremely difficult to see.

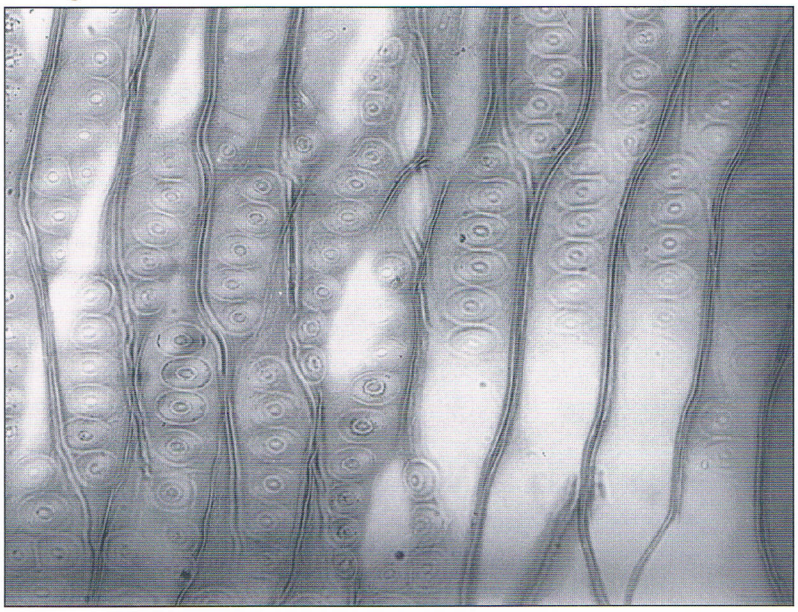

Plate 4

So, how can we be sure that this softwood at Jericho is, in fact, Cedar of Lebanon? Despite the

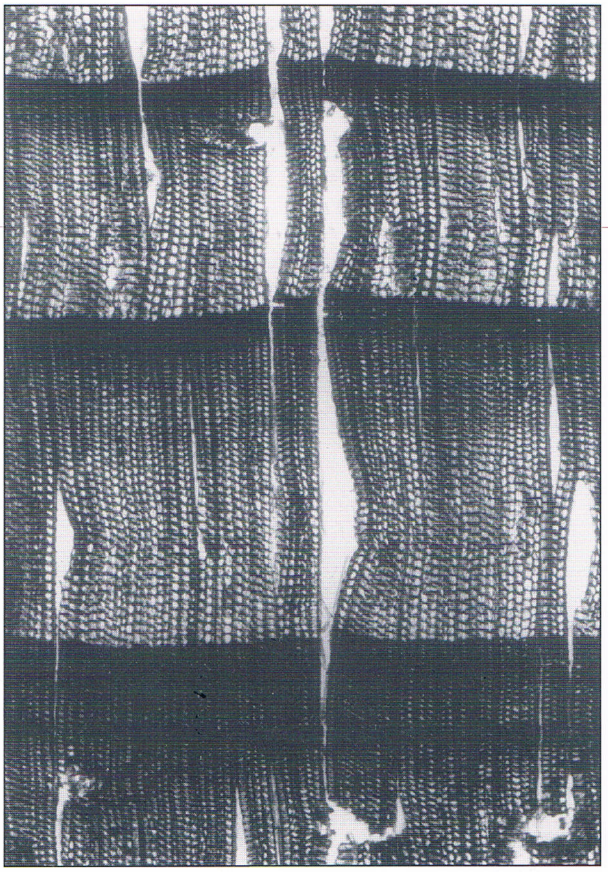

Plate 5

Plate 4: Longitudinal tracheid bordered pits, some with their diagnostic scalloped torus margin (modern Cedar of Lebanon wood).

Plate 5: TS of Cedar of Lebanon wood from Middle Bronze Age tomb furniture at Jericho, showing splitting and some cellular degradation due to burial conditions and desiccation of the wood.

variable conditions of preservation of the wood, certain highly diagnostic features were visible (and not just in one specimen). Their collective presence confirmed the identification. The features which could be observed with certainty were: bordered pits with scalloped tori in the longitudinal tracheids, cupressoid, piceoid and taxodioid cross-field pitting in the rays, gradual change from earlywood to latewood longitudinal tracheids, mainly uniseriate rays, sparse axial parenchyma and occasional traumatic resin canals.

Conclusions

There is no doubt of the value of scientifically-identified ancient wood and charcoal from archaeological sites. These identifications add considerably to our knowledge of the selection and use of woody resources for the essential components of everyday life such as fuel, raw material for artefacts and building timber. Furthermore, these identifications help to build up a picture of the local vegetation of the time available to the site's inhabitants. Local and regional changes in climate, ecology and vegetation through time can be documented using such identifications. Where non-local species are present, the identifications can assist in an interpretation and reconstruction of trade and marketing patterns across regions. It is always important to note, however, that although present-day vegetation can be used as a model for recreating that of the past, the assumption can never be made that the types present today will be the same or that their distribution will be similar. For recreating the broad picture, the solution lies in the examining, comparing and interpreting all the different categories of environmental evidence present on archaeological sites. More specifically, to reconstruct the local vegetation, we are heavily reliant on the value of identifying different kinds of plants, shrubs and trees from the archaeological site. On their own as single identifications, each type may not tell us very much, but in combination, one with another, these will give us a direct window on to particular vegetation communities. If we can identify these communities, we can then turn to our present-day models in which these communities thrive and compare the ancient evidence with the modern. Whether there are similarities in distribution and type or whether there are marked differences, either way the evidence will have a significance for our interpretation.

Using one type of coniferous tree as an example, this paper has focused on the details of how we achieve these accurate identifications and why it is so important to follow the standard scientific procedures for doing so. The archaeological site often provides us with the evidence in the form of wood and charcoal to enable us to take the next steps to unravel the significance of the material. By taking care to excavate and protect the integrity of the samples according to accepted procedures, we can ensure that the wood anatomist has the best possible chance of observing the key features of the wood cells which kick-starts the whole process of discovery.

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