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EFFECT OF STEAMING ON THE FINE STRUCTURE OF *NOTHOFAGUS FUSCA*

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ABSTRACT

Heartwood of **Nothofagus fusca** (Hook. f.) Oerst was examined in transmission and scanning electron microscopes to determine the effect of steaming on the fine structure of green wood; the implications of this in drying were considered. The most obvious changes were seen in materials lining cell lumina and pit areas; in natural condition, these occluding materials formed relatively uniform layers whereas, after steaming, they were more irregular because of flowing, blistering, or formation of rounded bodies. These changes could account for the increase found in drying rate after steaming.

INTRODUCTION

Differences in the fine structure of *Nothofagus fusca* heartwood caused by steaming for 2-4 hr at 100°C are described. Such treatment markedly increases the drying rate of green or partly dried wood in air drying or kiln drying, although partial drying before steaming is recommended in commercial practice (Kininmonth, 1965). It offers the possibility of greater utilisation of this slow-drying species.

Campbell (1961) found that a 2-hr pre-steaming period reduced the initial moisture content and increased the subsequent drying rate of *Eucalyptus obliqua* and he concluded

that this treatment is of considerable value for difficult ash-type eucalypts; similar results were obtained with *Sequoia sempervirens* (Ellwood and Erickson, 1962). Savings in drying time were 20%-40% in both studies. Other workers have reported increased permeability after steaming and obviously any treatment that increased either of the components of moisture movement—free water flow or moisture diffusion—would hasten drying.

Explanation of the mechanism whereby steaming hastens drying is somewhat speculative. Nicholas and Thomas (1968) concluded that components in the pit membrane of *Pinus taeda* are hydrolysed and that in the aspirated condition reduction in the strength of the bond between the border and torus improves permeability. Mackay (1971) said either acid hydrolysis or relocation of extractives could account for his observed increase in rate of diffusion of hardwoods after pre-steaming. Other workers found relocation of extractives after exposure to temperatures of 190°-240°C, seen as flowing of the warty layer and surface distortion of vessel pits in *Fagus sylvatica* (Kollmann and Sachs, 1967).

Green sapwood of *N. fusca* was permeable in the radial and tangential directions when subjected to flow of water at a pressure differential of 53 kN/m^2 (0.53 atm) but heartwood was not (Kininmonth, 1970). The difference in permeability was explained by differences in fine structure: pit membranes in sapwood often exhibited an unencrusted primary wall surface whilst pit membranes in heartwood were almost invariably occluded with polyphenolic extractives and the lumen surface was also covered with similar deposits. Steaming increased the drying rate; this was accounted for by an increase in moisture diffusion, not permeability, and the reason for this improvement has now been investigated.

EXPERIMENTAL METHODS

As a separate study, samples of green heartwood were obtained from two trees in State Forest 90 in the central North Island and stored in water. End matched pieces approximately 3 cm square and 10 cm long were either steamed for 3 hr at 100°C in a reconditioning chamber, or served as controls. Specimens were prepared for both transmission and scanning electron microscopy.

Steamed and control pieces containing the same growth layers were cut to provide 100 μm microtomed sections of tangential and radial surfaces. The sections were freeze dried and direct carbon replicas prepared using the method Côté *et al.* (1964) modified to include floating of the replicas on 5% aqueous sodium hypochlorite after dissolving the cellulose in 72% sulphuric acid. The extra step appeared to improve removal of extraneous material particularly in the wood rays.

Platinum/palladium shadowing was applied at an angle of 45°-50°. The replicas were examined in a Philips EM 300 microscope and all photographic negatives were reversed before printing.

Specimens for the Cambridge Stereoscan microscope were prepared as small blocks 8 mm square and *ca.* 6 mm high, or as split sections of similar height. The top surfaces of some specimens were trimmed with a razor blade. The green blocks were freeze dried, then coated with *ca.* 20 nm each of carbon and gold/palladium while the specimen was rotated.

RESULTS AND DISCUSSION

The material lining the vessel lumen of unsteamed heartwood contrasted with the appearance of underlying wall layers exposed where this material was torn in preparation (Fig. 1). Remnants of similar material are seen adhering to vessel/ray pits in Fig. 2 and in Fig. 3 an area of scalariform (vessel/ray) pits is completely overlain by

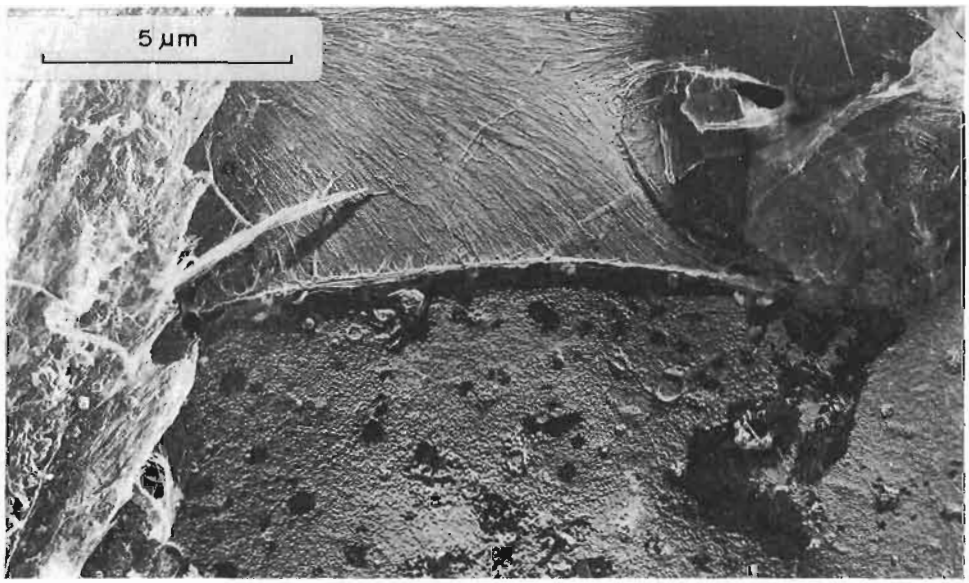

FIG. 1—Replica of a vessel wall with the wall layers exposed where the encrusting material, possibly in a tylosis, has been torn in preparation.

FIG. 2—Heavy deposit lining a vessel lumen, covering a vessel/ray-pit aperture (1) and adhering to a pit membrane (2).

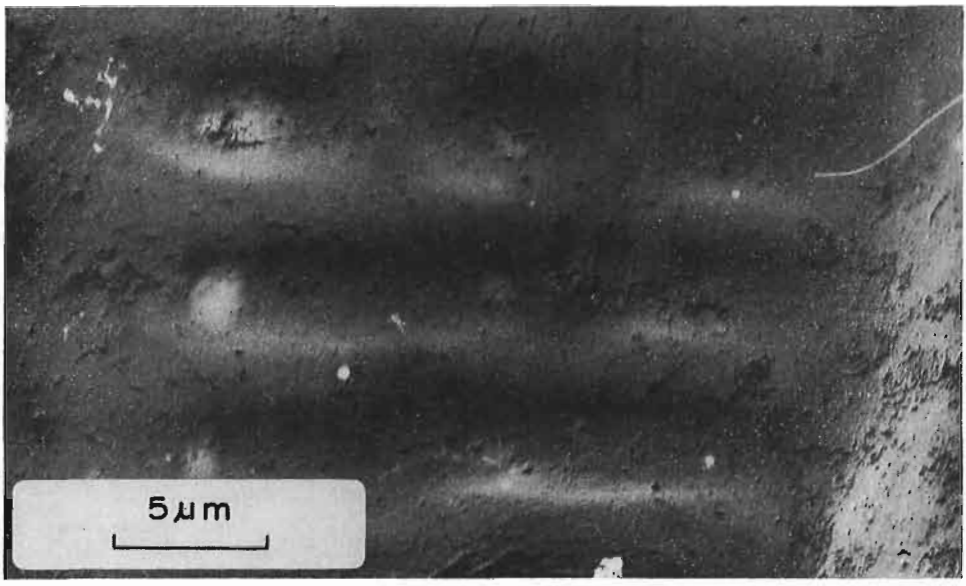

FIG. 3—Area of vessel/ray (scalariform) pits completely occluded in unsteamed control.

material occluding pit apertures and lumen surface. From its appearance, the encrusting material in Fig. 1 may be part of a tylosis, such structures being present in *N. fusca* but not sufficiently frequently to be considered a diagnostic feature (Anon., 1952). In other cases the lining material is a smooth coating and may be of different origin.

Steaming caused a change in the appearance of the vessel coating. Micrographs

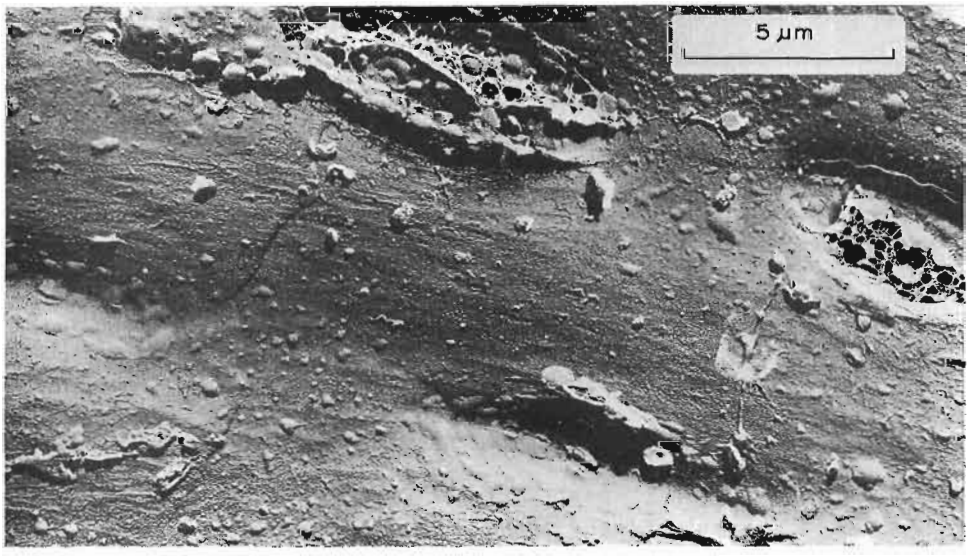

FIG. 4—Appearance of a vessel lumen in steamed heartwood. Coating material has broken down over some pit aperatures and elsewhere it has blistered or formed rounded bodies.

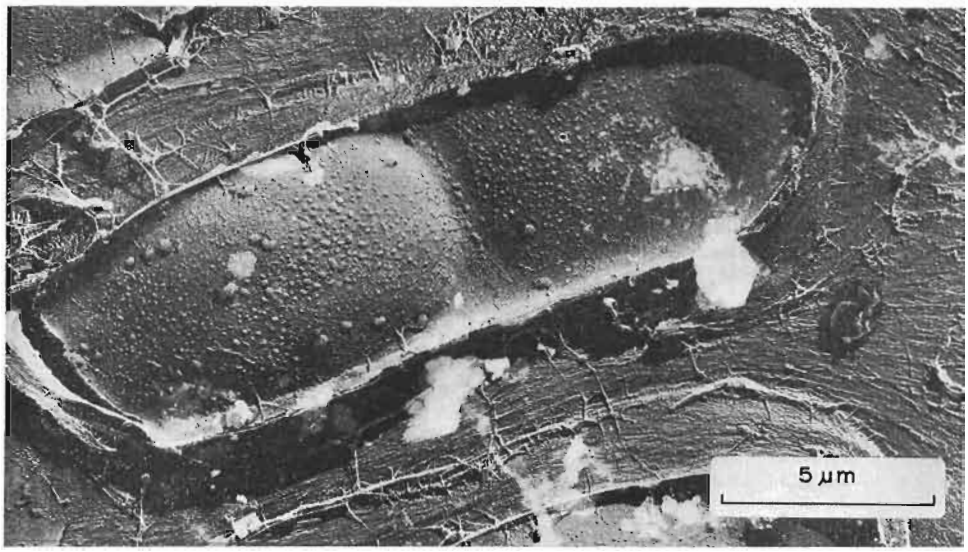

FIG. 5—Vessel/ray-pit membrane in steamed heartwood showing blistering of occluding deposits.

show how encrusting material formed into rounded bodies and broke down over some pit apertures (Fig. 4), formed a blister-like appearance over pit membranes (Fig. 5) or flowed to some extent (Fig. 6).

Occluding materials had a slightly different appearance in vessel/vessel-pit areas seen in tangential sections. A thin layer overlying the pit membrane appears to have

FIG. 6—General area of pits in steamed heartwood in which the coating materials have tended to flow.

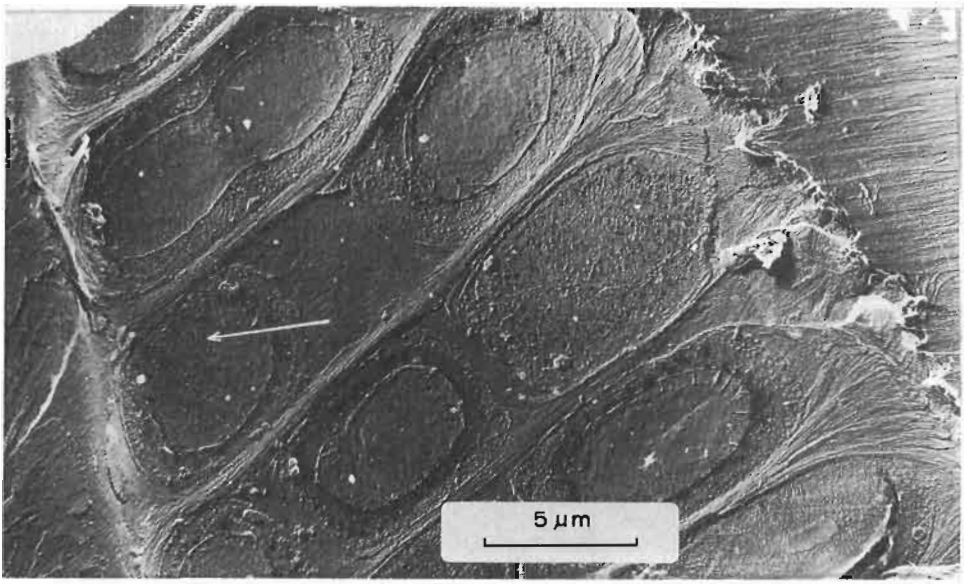

FIG. 7—Area of vessel/vessel pit membranes in unsteamed material. Pit membranes appear to be slightly occluded and overlain by an extra layer which has folded back (see arrow) during preparation.

been torn or folded back during preparation, as seen in Fig. 7. This suggests that the material was continuous over the membrane and pit chamber and possibly extended over the lumen surface as in the vessel/ray systems on the radial walls. The pit membrane beneath the occluding layer was only slightly encrusted. Similar areas after

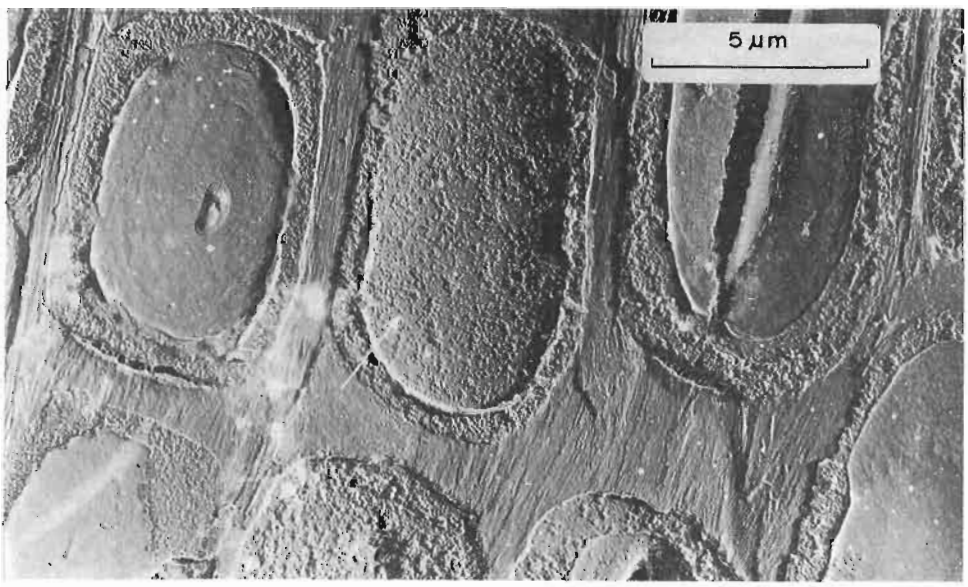

FIG. 8—An area similar to Fig. 7, after steaming. The extra layer over the pit membrane is modified in one case (arrowed) but not in others and the material forming the primary occlusion of the pit membrane has broken up into rounded areas.

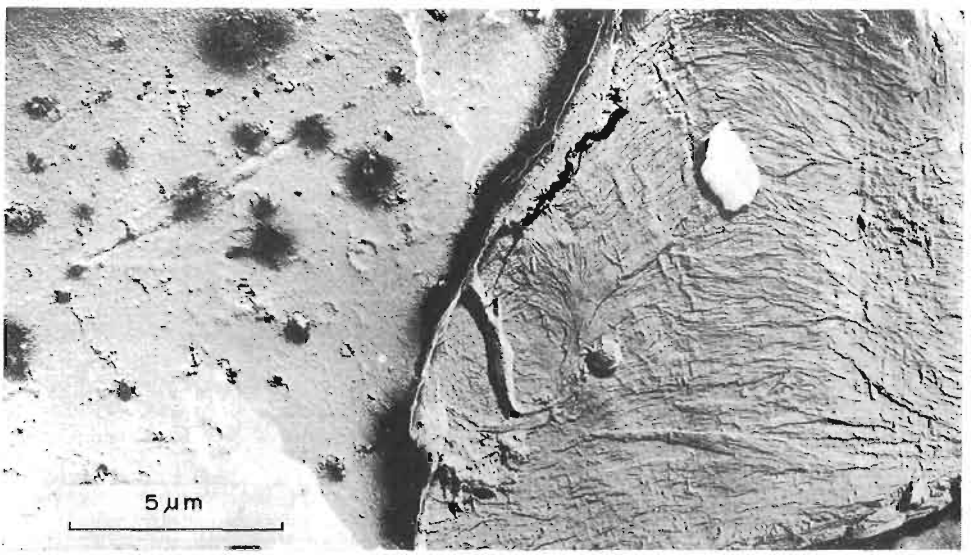

FIG. 9—Ray parenchyma lumen showing the lining of these surfaces in unsteamed material.

steaming (Fig. 8) indicate that the thin layer is not always changed but the other material in the pit membrane is modified. The material encrusting the pit membrane and the overlying layer may therefore be of different composition.

Ray parenchyma lumina also differed in steamed and unsteamed material: the uniform lining of the cell cavity in the natural condition (Fig. 9) was modified by steaming, forming discontinuous rounded bodies. Fig. 10 is an extreme example where the outermost wall layer of the ray cell is exposed. The effects of steaming are similar

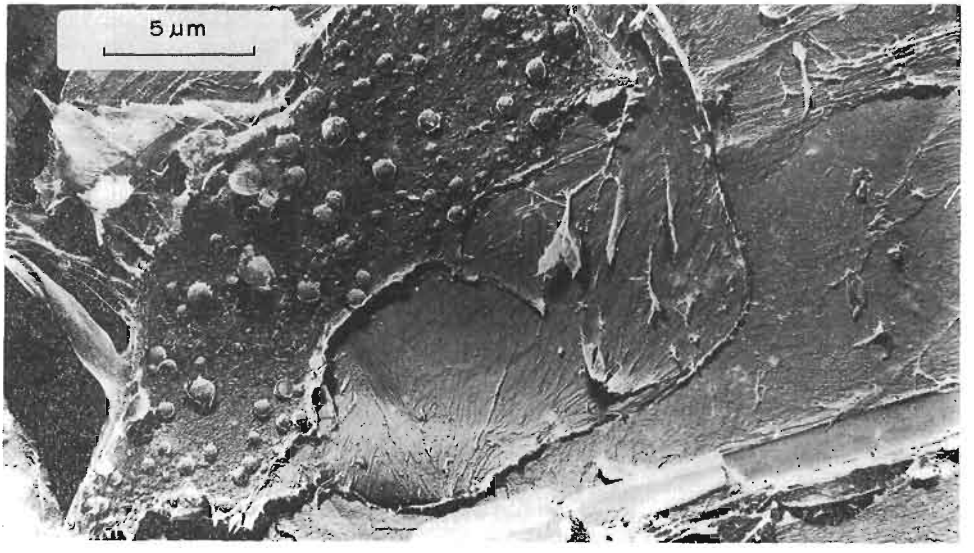

FIG. 10—Lumen surface of a steamed ray cell in which the occluding material has become discontinuous, forming rounded bodies.

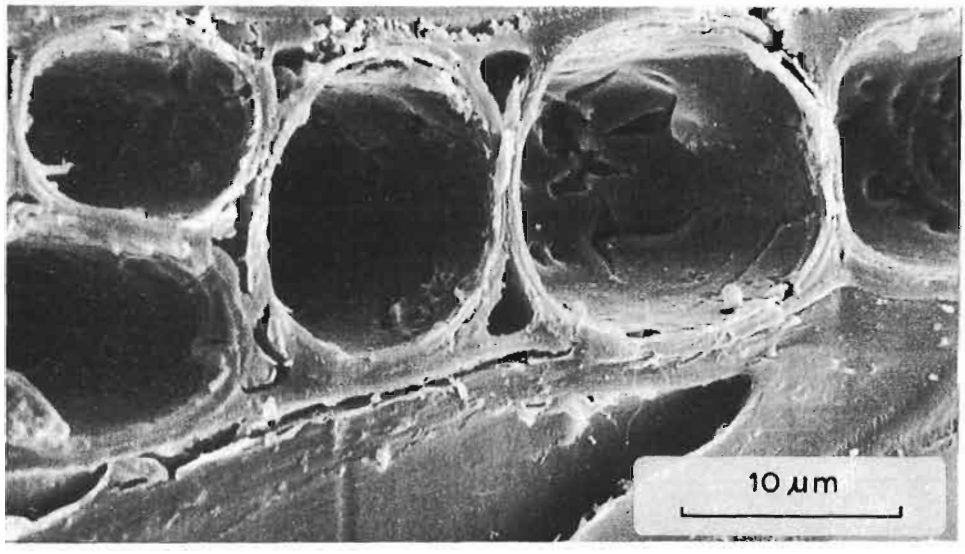

FIG. 11—Appearance of a control wood ray in a scanning electron microscope.

to those found by Kollmann and Sachs (1967) who were dealing with higher temperatures.

The scanning electron microscope proved excellent for examing changes in gross surface detail within the limitations of its resolution. The cut ends of ray parenchyma cells showed consistent differences between the uniform lining of lumen surfaces in control material (Fig. 11) and the change with steaming into rounded areas (Fig. 12).

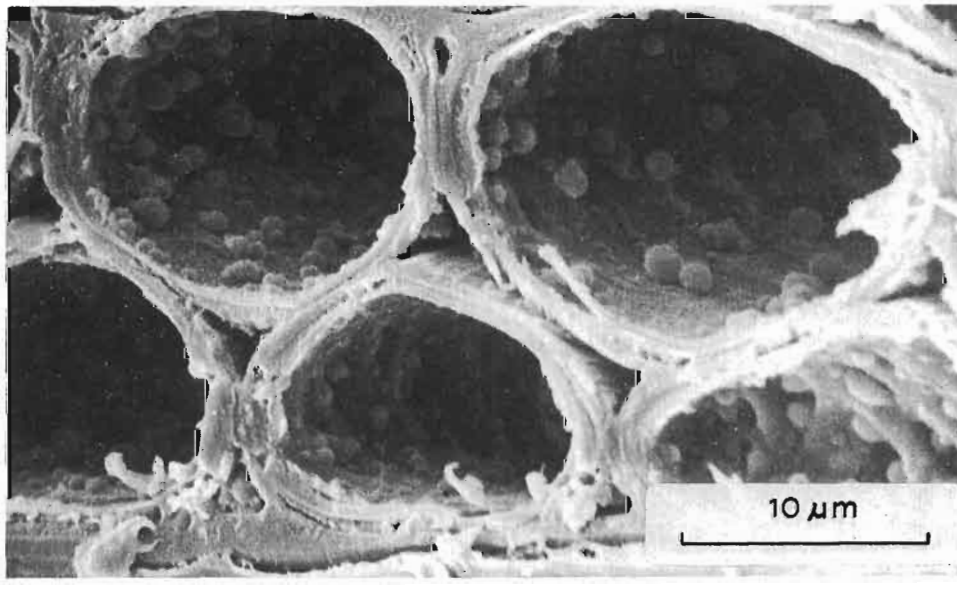

FIG. 12—View of a tangential section similar to Fig. 11, after steaming, showing the characteristic change in appearance of material occluding the lumen surface.

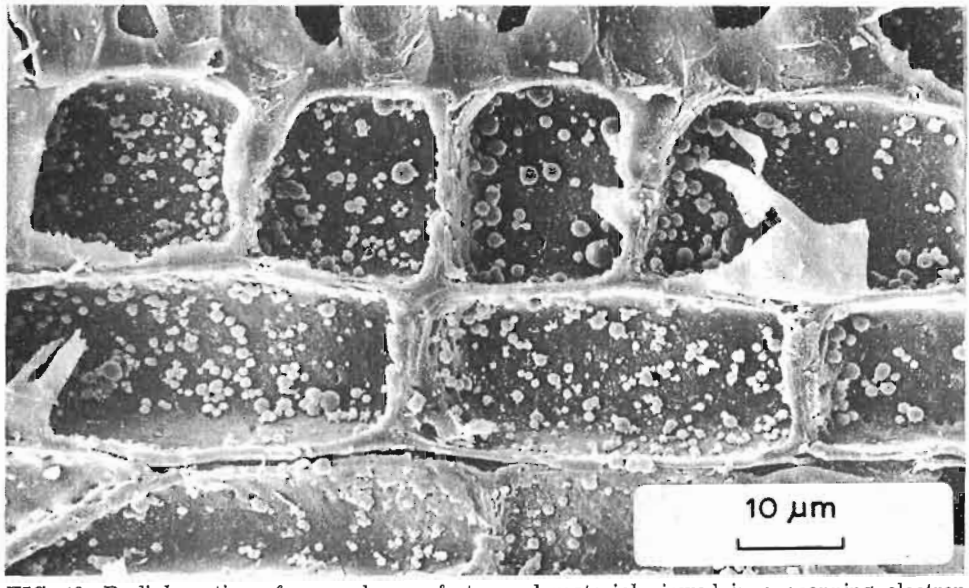

FIG. 13—Radial section of a wood ray of steamed material viewed in a scanning electron microscope. Material steamed at 115°C in a pressure vessel.

There is, therefore, a less continuous covering of the lumen surface after steaming. The cracking apparent in Fig. 11 developed despite the fact that the material was freeze dried. Such cracking was confined to the encrusting material and no cracks were observed in cell walls although I had earlier observed macroscopic checking in steamed *N. fusca.* Radial sections of steamed (Fig. 13) and control (Fig. 14) material also emphasised the effect of steaming.

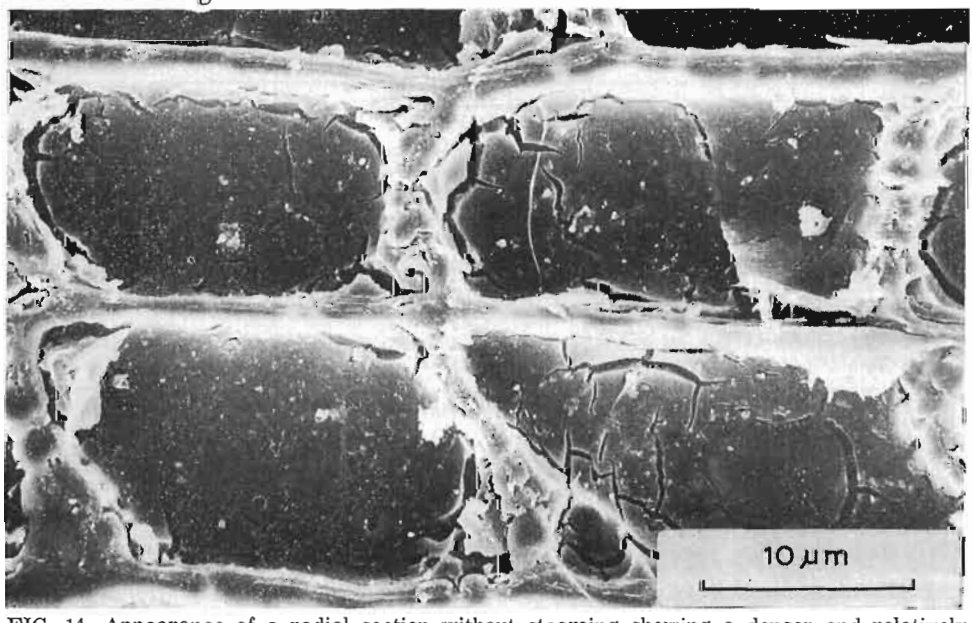

FIG. 14—Appearance of a radial section without steaming showing a denser and relatively uniform lining of the lumen surface. Cracking was probably caused by drying.

Occasional vessel lumina showed the rounded deposits characteristic of the rays but, in general, these and other cells did not show any marked changes attributable to steaming. Other changes may be masked by the *ca.* 40 nm coating of carbon and metal applied to prevent charging of the specimen surface, and by the limitation of the resolving power of the instrument.

It remains to decide whether the changes induced by steaming are sufficient to account for the observed improvement in drying. Moisture movement during drying takes place by diffusion with a varying component of capillary flow depending, in the main, upon permeability (Hart, 1965). According to Stamm (1963), capillary flow is predominantly through pores in pit membranes and diffusion predominantly through the bulk of the cell wall. These conclusions were based on a model for coniferous woods; in hardwoods most types of pit pair do not have obvious pores, being made up of two apparently unmodified primary walls and the middle lamella between (Cronshaw, 1960). Sapwood of species such as *N. fusca* and *Eucalyptus regnans* is permeable to transverse flow of water but much less so than are conifers such as *Pinus radiata* (Kininmonth, 1970). Heartwood is impermeable at low pressures and moisture diffusion is also slower than in sapwood, these changes being attributed to occlusion of pit membranes and cell lumina by polyphenolic extractives. Steaming improves the rate of diffusion but does not affect permeability. It apparently improves access of moisture to areas of cell wall including the pits without rendering the pit membranes permeable, i.e., it fails to reopen void spaces in the pit membranes which were present in sapwood but occluded during heartwood formation. This explanation is supported by the relatively minor changes apparent in pit areas.

Separate studies are being made of chemical changes in the polyphenolic extractives that could contribute to the overall effect of steaming on drying.

ACKNOWLEDGMENTS

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