MICROSCOPY OF WOOD FINISHES

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INTRODUCTION

The surface finish of wood is obviously important to an instrument maker. Cut, scraped and sanded finishes each have their own look and feel, and they may also respond differently to glue, or to the many and various treatments inflicted in the name of varnishing. Makers often have individual and deeply-held views about the suitability of different surface finishes for particular purposes: for example some might hold that sandpaper is acceptable (though dogfish skin would be better) for finishing a back, while a front must only be scraped.

The maker's opinion of these surface finishes is of course formed by their effect on finger and eye, as well as by empirical knowledge about how varnishes or glue "take" on different surfaces. However, these things all have their origin in what happens on a microscopic scale to the cells on the surface of the wood, in the course of the various finishing operations. Some interesting insights may be gained by looking at these surfaces on a cellular level. The purpose of this article is to present a picture gallery, obtained with a scanning electron microscope, of some important examples from the instrument maker's repertoire.

ORGANISATION OF THE PICTURES

To keep the number of pictures within bounds, we show five different finishes for each of two woods. The two woods used are those most likely to occur to a violin maker, Norway Spruce *Picea abies,* and European Maple *Acer platanoides.* The samples were prepared from offcuts of violin fronts and backs of reasonable quality. The surface finishes can be briefly described as cut, scraped, sanded, burnished, and dogfish-skinned, and will be described in more detail shortly. Each combination of wood and finish is then shown at two different magnifications (the same two in every case). A scale bar appears in the lower right-hand corner of each picture, showing 300μm (0.3mm) for the low-magnification pictures and 30μm for the higher-magnification ones.

The individual surface finishes were obtained as follows. The cut surfaces were made with a brand-new scalpel blade. If end-grain views are wanted, it turns out that these may be obtained without excessive damage to the cells by cutting somewhat obliquely to the grain, then taking advantage of the scanning microscope's depth of field to view end-on. The scraped surfaces were made with a conventional cabinet scraper, freshly sharpened and cutting well. The starting point was a planed surface, and the final surface was of a quality suitable for varnishing.

The sanded surfaces were made with some care, again starting from a planed surface. A succession of ever finer grit sizes was used, ending with fine grade (320 grit) "Lubrisil", a silicon carbide paper impregnated with a dry lubricant. Then the wood was wiped thoroughly with a damp cloth to remove debris. This inevitably caused the grain to swell up, so after the wood had dried it was sanded again with the same paper. This was repeated until the grain ceased to swell, so that the final surface could be cleaned of debris and remain smooth to the touch.

The burnished surfaces were obtained by rubbing a scraped surface with a shaped boxwood burnisher — tradition may favour agate burnishers, but it is hard to believe that this would make much difference to the surface finish. Finally, a traditional violin-maker's method was used, rubbing over a scraped surface with dried dogfish skin, which is a natural abrasive.

THE RESULTS FOR SPRUCE

Figures 1-3 all show spruce with a clean-cut surface. In order to illustrate the structure of the wood clearly, cuts in all three principal orientations are shown here. Figure 1 shows an end-grain view. This view shows many *tracheids,* the main cells of a softwood like spruce. These are aligned vertically in the tree, and are here seen in cross-section. The lower magnification in Fig. 1(a) shows two annual rings. The direction of growth of the tree is from bottom right to top left. The spring-growth cells have thin walls and a lot of empty space, but as the season progresses cells are produced with much thicker walls and less space inside them, until growth stops for that season, before resuming abruptly the following spring.

A small proportion of cells, constituting the *rays,* run radially in the tree. A typical ray is just one cell thick, and perhaps 15 cells high. A ray has been caught in long section running across the centre of the higher-magnification Fig. 1(b), but the structure of rays is more readily appreciated in Fig. 2, where the cut has been made approximately in a circumferential plane, so that rays appear in cross-section. Figure 2(a) shows many such rays as lines of small holes, and a few of these can be seen in more detail in Fig. 2(b) at higher magnification.

Figure 3 shows the final orientation of cut, approximately in a radial-axial plane. This corresponds to the surface of an approximately quarter-cut plate, and is the orientation of all the other pictures in this article. Here we see successive layers of tracheids cut at a glancing angle, and also a ray running at right-angles to the tracheids roughly in the centre of both pictures. The annual ring structure is again visible in these pictures since we have cut across rings, whereas in Fig. 2 no trace of the rings was seen since the cut surface was parallel to the rings.

As a point of botanical detail, two types of pores connecting the different cells together are clearly visible in these pictures. Those most prominent in Fig. 2(b) are called *bordered pits.* These connect tracheids together. The smaller holes evident at the lower left of Fig. 3(b) are called *piceoid pits,* and link tracheids to rays. Both types can be seen in Fig. 1(b). For more details of wood structure, see for example Bucur [1] or Bodig and Jayne [2].

Figure 4 shows a scraped finish on spruce. It is interesting to notice the extent to which the cell-wall material has been "smeared" by the scraper. The cellular structure is largely concealed over parts of Fig. 4(a), since material has been pulled in to fill the spaces in a relatively uniform way. The higher-magnification Fig. 4(b) shows that most of the surface is covered with rather smooth platelets of material whose dimensions are large compared with the wavelength of light (of the order of 1μm). These will reflect light in a specular way, and thus presumably account for the characteristic glistening appearance of a scraped surface.

Figure 5 shows the sanded surface. Here we show two different parts of the picture at higher magnification, Figs. 5(b) and 5(c), since there are two distinctively different types of terrain. The abrasive paper has on the whole cut the material much more cleanly than did the scraper, and no "smearing" is evident here. Also, notice that the choice of final grit size seems to have been quite adequately fine, since there is no sign of grit scratches in the pictures. (The transverse lines in Fig. 5(a) at upper centre are the remains of a ray.) The contrast with Fig. 4 shows rather the reverse of a conventional folklore, in which it is often asserted that a scraper is used because it cuts more cleanly than sandpaper.

These pictures reveal the explanation of a phenomenon which will be quite familiar to all wood-workers who have produced a carefully sanded finish like this. Readers in that position will know that a pattern of sinuous lines somewhat reminiscent of shot silk appears on the wood surface. This pattern results from the alternation of the two types of terrain illustrated here. When passing through a region where cells are being cut at mid-height, the abrasive paper has cut through the walls without touching the bottoms of the cells, as in Fig. 5(b). When passing through a layer of cell walls, on the other hand, the material has been substantially chewed up into a fibrous mat, as in Fig. 5(c). This latter type of surface will scatter light and thus appear relatively white, while the other terrain of Fig. 5(b) will appear darker. The sinuous lines visible to the naked eye [and also visible in Fig. 5(a)] are the lines of intersection of the cell-wall layers with the cut surface, and the shot-silk pattern arises from the slight variations of growth from place to place in the wood.

Figure 6 shows the burnished finish. Not surprisingly, the process of smearing cell-wall material into gaps has been enhanced by the burnisher. Indeed, some regions are almost featureless, the individual cells having been effaced and the cell-wall matter spread evenly over the surface.

The last of the spruce pictures, Fig. 7, show the dogfish-skin finish. Although dogfish skin feels to the fingers like an abrasive, the surface revealed here does not resemble the sanded surface of Fig. 5; indeed, it looks hardly different from the scraped finish of Fig. 4. Presumably, the rough surface of the dogfish skin is made of a material like keratin, with a hardness comparable perhaps with that of fingernails. In contrast with the hard particles of the abrasive paper, this is not very much harder than the cell-wall substance of the wood. Thus the action on the wood has been more akin to burnishing than to sanding. Some of the loose material left by the scraper may perhaps have been removed in the process.

THE RESULTS FOR MAPLE

The series of pictures for maple specimens follows similar lines to the spruce series. Figure 8 shows a clean-cut surface. Some differences of wood structure from spruce are immediately apparent. The cells are on the whole thicker-walled, and tend to have oval rather than rectangular cross-sections. The rays take a significantly different form in a hardwood like maple. They still run radially in the tree (from bottom right towards top left in the pictures), but they are bigger and more conspicuous. A typical ray is 2-10 cells thick and up to 5mm high [1,2]. One appears prominently at the top left of Fig. 8(b). The final structural feature to note is the presence of the large vessels, running vertically in the tree. Maple has these vessels randomly distributed through the volume, while some hardwoods like ash or oak have them concentrated in rings parallel to the annual growth rings.

Figure 9 shows a scraped finish on maple. As with the spruce, a considerable degree of material smearing has occurred. Not only have the cell boundaries been blurred, but even the vessels have been partially filled. However, the regions of rays are still clearly differentiated from the rest of the surface by showing signs of alignment in a direction at right angles to the grain. This difference is no doubt visible to the naked eye, and contributes to the visual appeal of maple. (Note that "flames" in the maple occur over a longer distance than is covered in these pictures, so their effects are not visible here although the specimen was an offcut from an attractively flamed violin back.)

Figure 10 shows a sanded surface. Many of the same remarks apply as in the case of spruce. On the whole, cutting rather than smearing governs the character of the surface, although notice that the vessels are still partially filled since the surface had been scraped before the sanding process began. Because of the thicker-walled cells in this case, the qualitative difference between the scraped and sanded surfaces is perhaps less conspicuous than was the case with spruce. The sanded surface still reveals the rays as patches with a different orientation, and is probably different to the naked eye primarily by being rougher and thus more matte than the scraped surface. This is in accord with violin-making tradition, which might allow sanding of maple when it is often found unacceptable for spruce on visual grounds.

The burnished surface shown in Figure 11 is much as one would anticipate. As with the spruce sample, the cell structure has been largely effaced, although again the rays are visible through a difference in general orientation. Finally, Figure 12 shows the dogfish-skin polished surface. In this case, it is very significantly smoother than the scraped surface. To the naked eye, this surface was strikingly shiny. The lower-magnification picture Fig. 12(a) shows some scratch marks — those who have used dogfish skin in this way will know that it is rather prone to cause slight scratching.

DISCUSSION

We can draw a few tentative conclusions from these pictures. The main area of interest relates to fillers and varnishes. It seems clear that the different surface finishes shown in the pictures here might be quite different in the degree of penetration they allow to a filler. The smearing effect of scraping, even more if followed by burnishing, fills the available empty holes quite thoroughly, so that one would imagine that the penetration of a filler would be minimal. The sanded finish on the other hand leaves holes more open, although somewhat obstructed by shredded remains of cell walls. Penetration in that case might be greater. There are of course different schools of thought on the question of whether any stage of the finishing process should involve deep penetration of the wood, but perhaps these pictures have something to say to proponents of all schools on how best to achieve their aim.

A related question is that of gluing. It seems quite likely that the different surface finishes shown here would differ in their tenacity to glue. That is not an issue which arises for burnished or dogfish-skinned surfaces, but it is relevant to cut, scraped or sanded surfaces. The folklore would seem to hold that cut or scraped surfaces glue well, but sanded surfaces do not. If by a sanded surface we understand the rather carefully-produced finish shown here, it is hard to see why this should be the case. The form of the sanded surface seems to be intermediate between the cleanly open cells of the cut surface and the smeared-over cells of the scraped surface. This suggests that the dislike of sanded surfaces for gluing, which no doubt is founded on practical experience, may have its origin in some aspect of sanded surfaces other than those discussed here. Two possibilities come to mind. First, if the sanding debris is not carefully removed before gluing, it might interfere with the bonding of the wood surfaces. Second, it is a matter of common experience that it is harder to control the precise shape of a surface while sanding than it is when scraping or planing, so that two sanded surfaces may fit less accurately together, leaving bigger gaps to be spanned by glue.

Microscopy at the sort of scale used here can also shed light on other aspects of the behaviour of wood. From the woodworking point of view, for example, it would be interesting to see how far below the surface the effects of the various surface treatments have penetrated. We can go beyond woodworking interest, though. It has been pointed out recently [3] that many aspects of the highly anisotropic elastic behaviour of wood can be explained in terms of the microstructure. If that understanding could be extended and made more quantitative, one might be able to shed some light on the problem of wood selection by putting samples under the microscope as a complementary approach to making extensive and rather difficult vibration measurements.

REFERENCES

[1] Bucur, V., "Anatomical structure and some acoustical properties of resonance wood", Catgut Acoust. Soc. Newsletter 33, 24-29 (1980).

[2] Bodig, J. and Jayne, B.A., *Mechanics of Wood and Wood Composites,* (Van Nostrand Reinhold, New York, 1982).

[3] McIntyre, M.E., and Woodhouse, J., "On measuring wood properties, Part 3", J. Catgut Acoust. Soc. 45, 14-24 (1986).

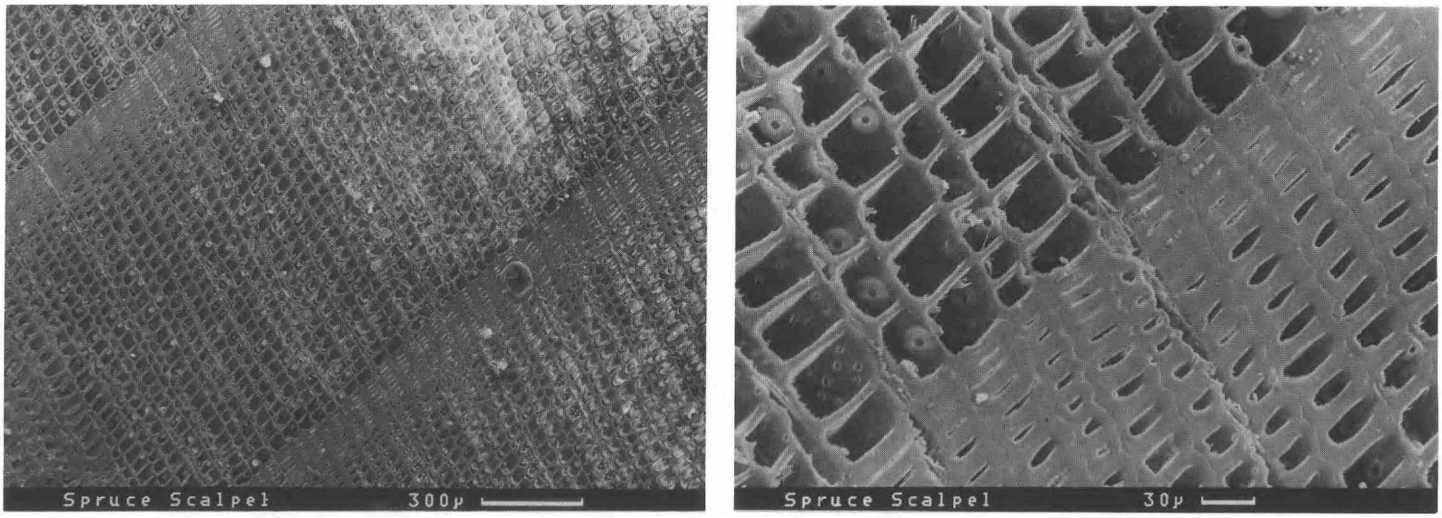


Figure 1. A scalpel-cut surface of spruce, seen in end-grain view. The left- and right-hand pictures will be referred to as (a) and (b) respectively.

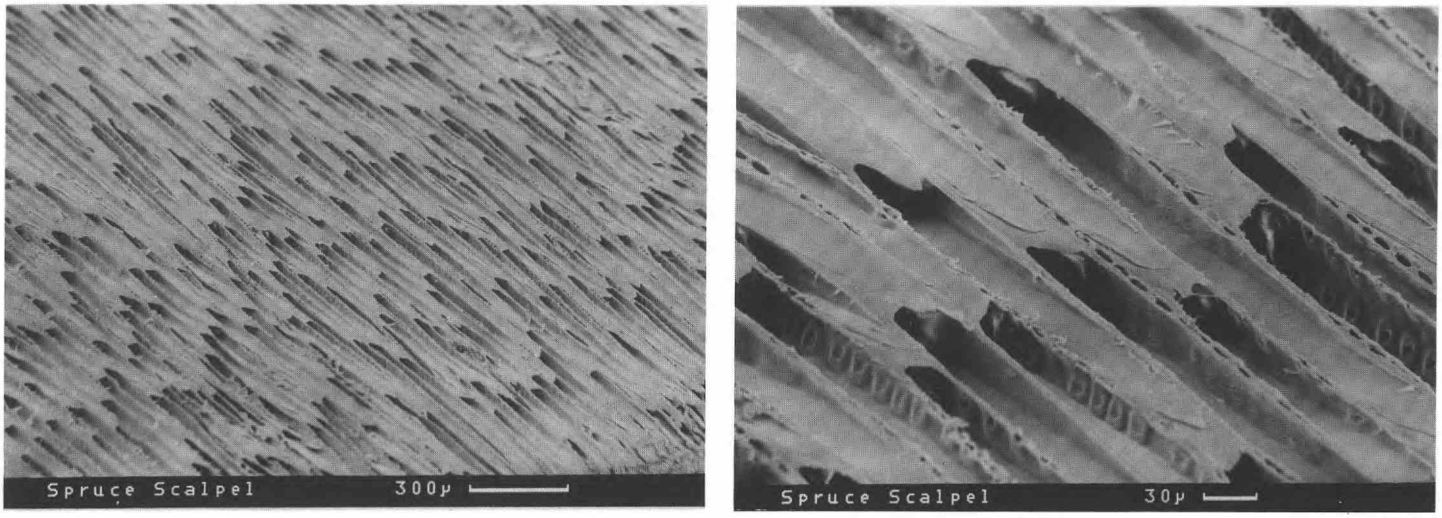


Figure 2. A scalpel-cut surface of spruce, cut roughly parallel to the annual rings.

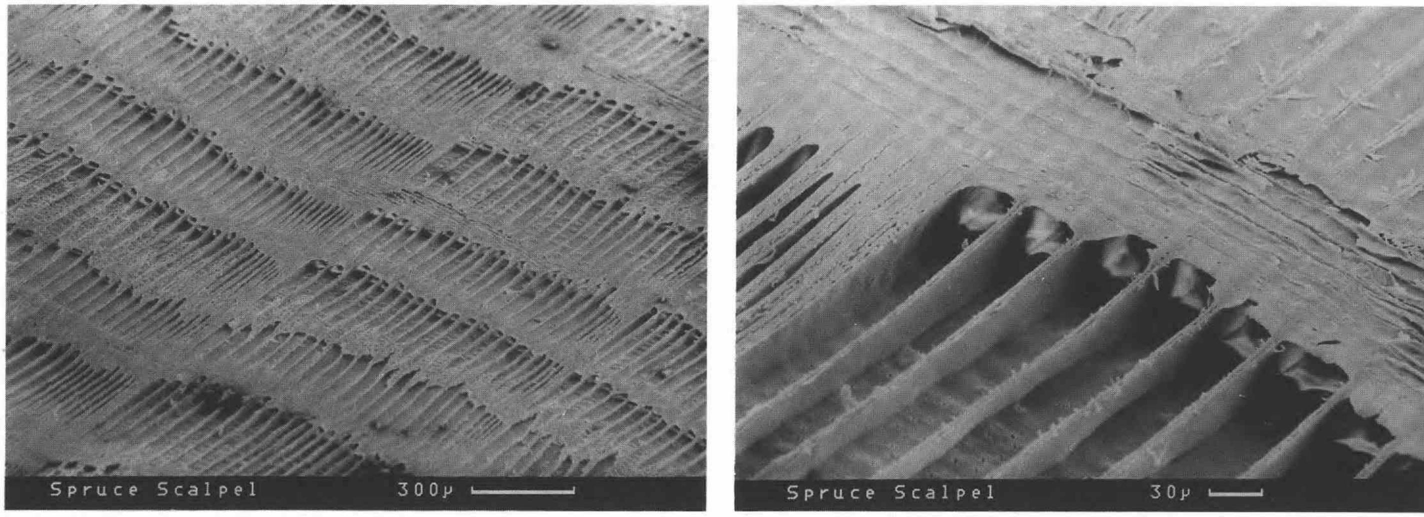


Figure 3. A scalpel-cut surface of spruce, corresponding roughly to the surface of a quarter-cut plate.

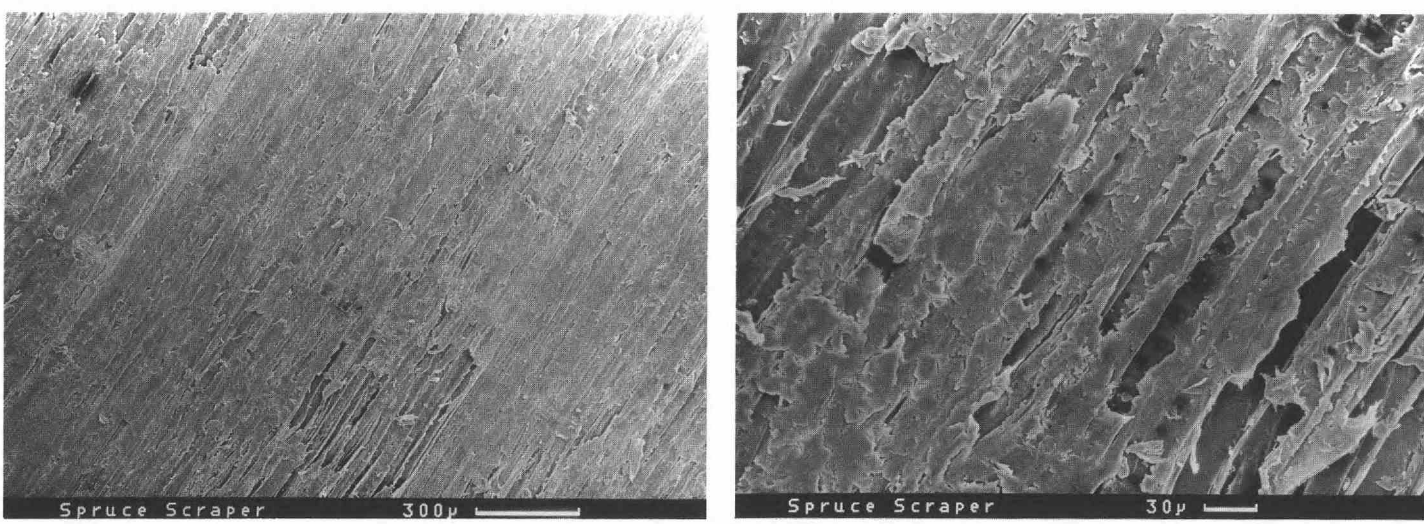
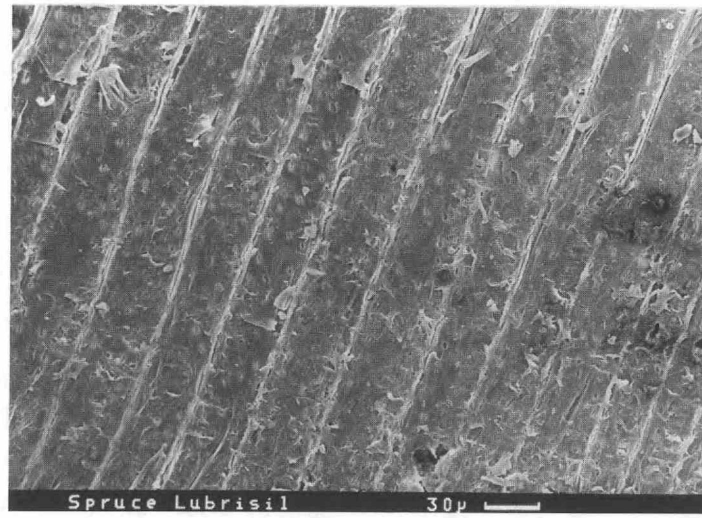


Figure 4. Spruce finished with a scraper to a state ready for varnishing.



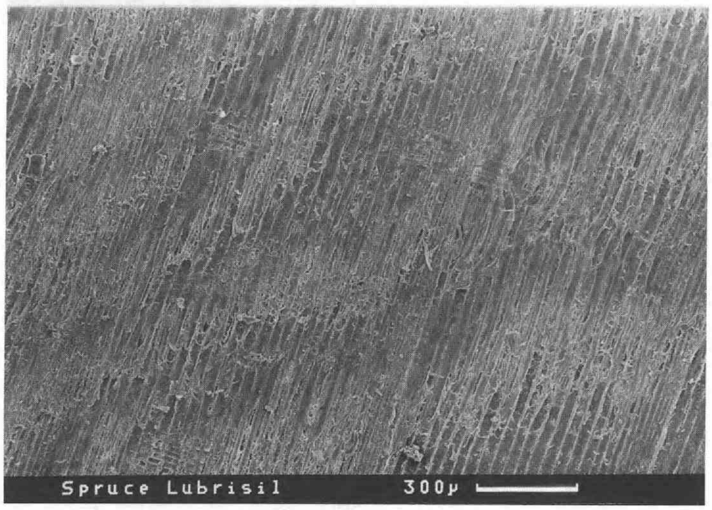
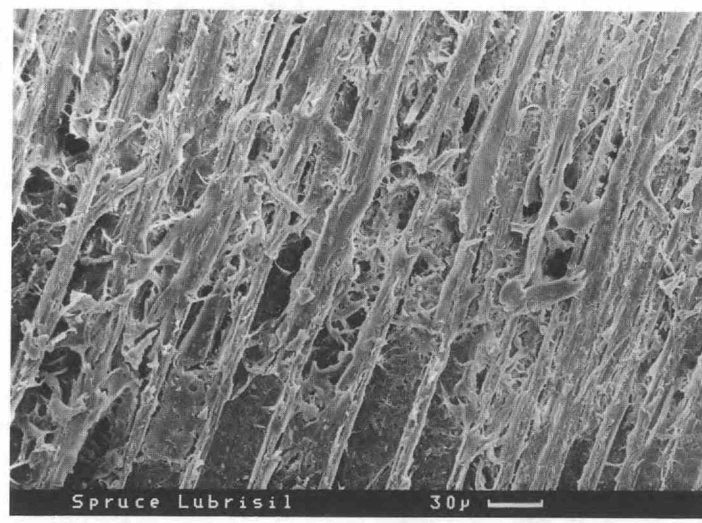


Figure 5. A high-quality sanded finish on spruce. Two high-resolution pictures are shown here, (b) and (c) on the right, as described in the text.



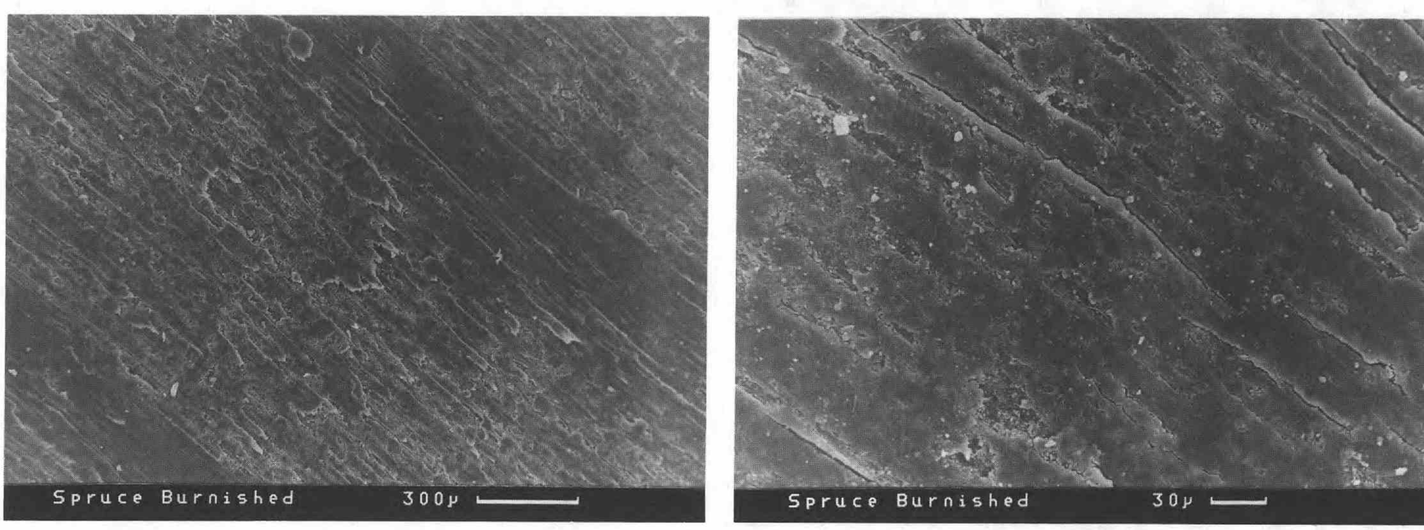


Figure 6. A burnished surface on spruce.

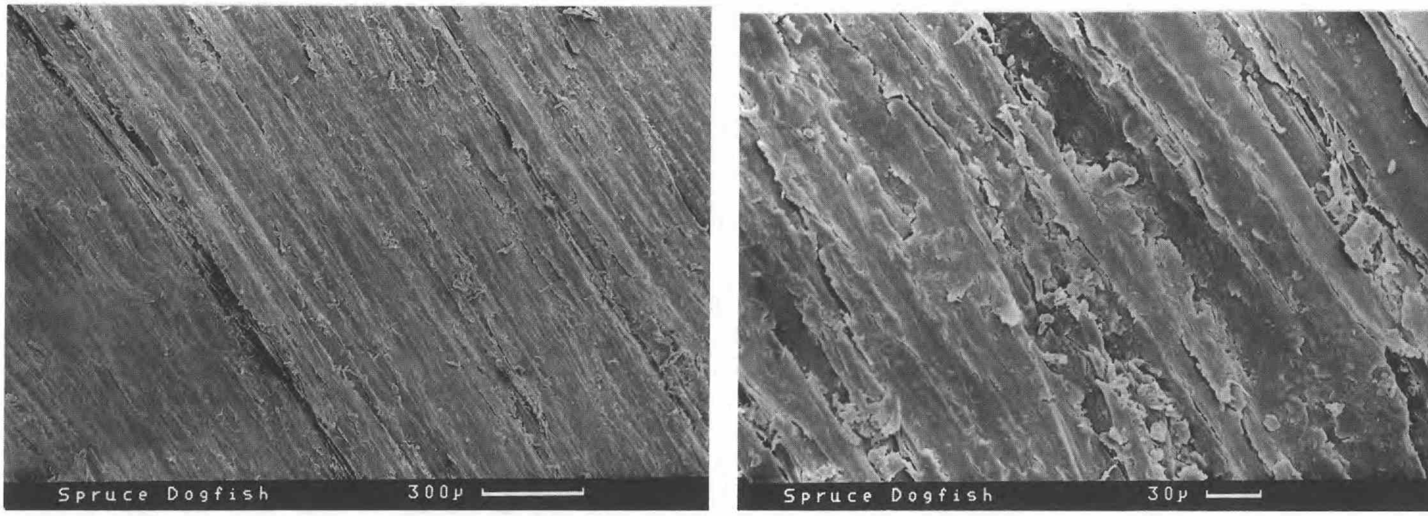


Figure 7. Spruce finished with dogfish skin.

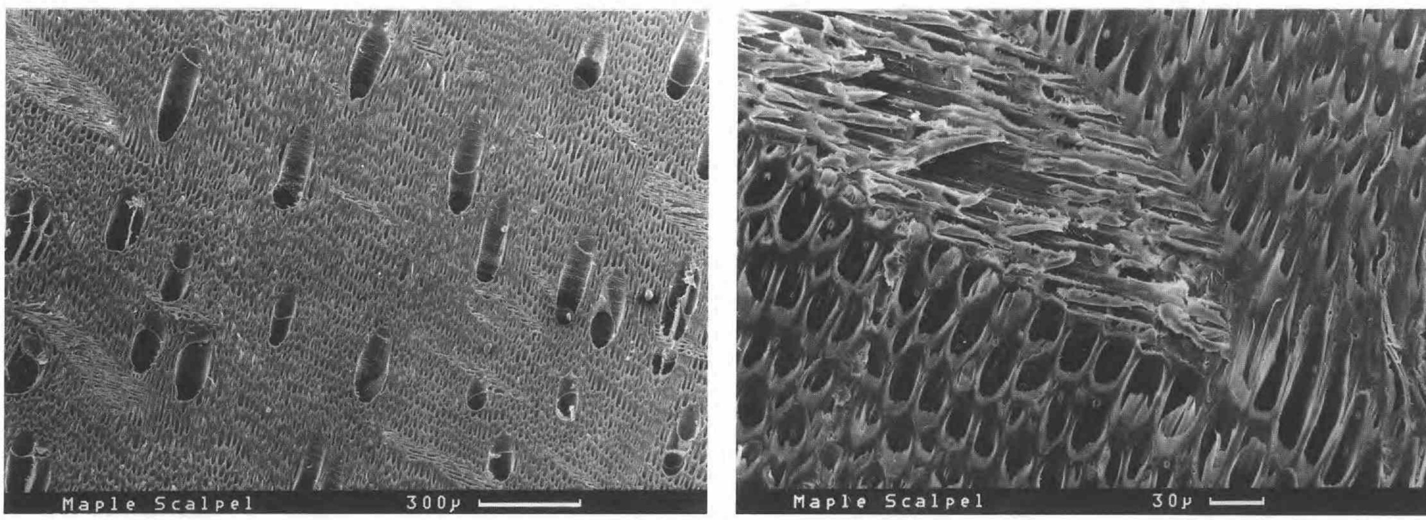


Figure 8. A scalpel-cut surface of maple.

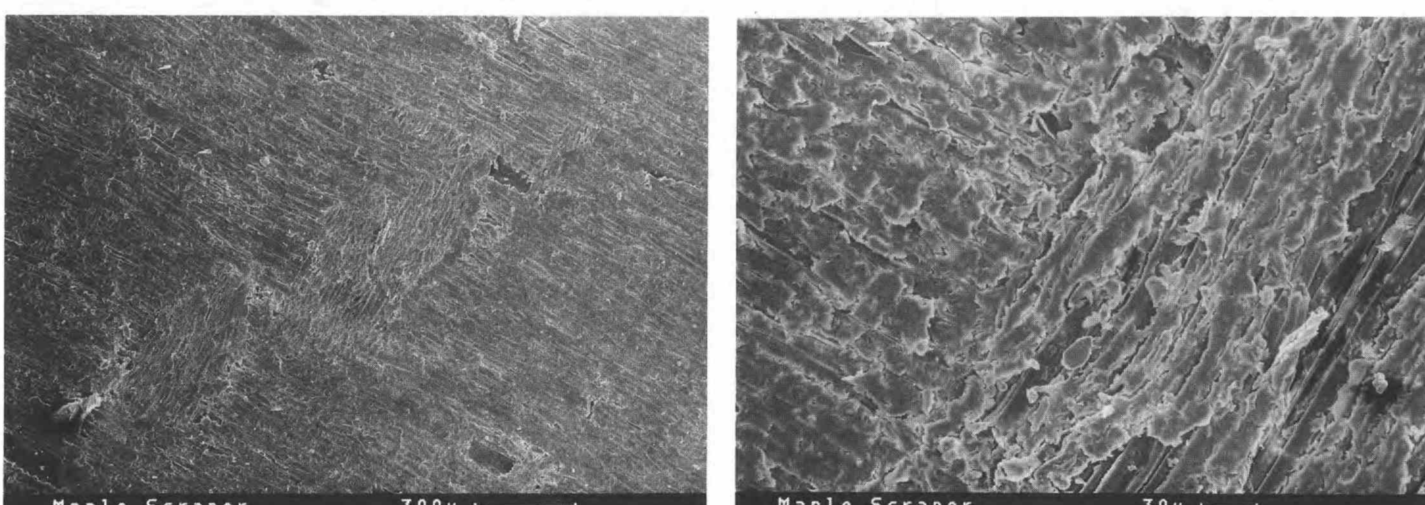


Figure 9. A scraped surface of maple.

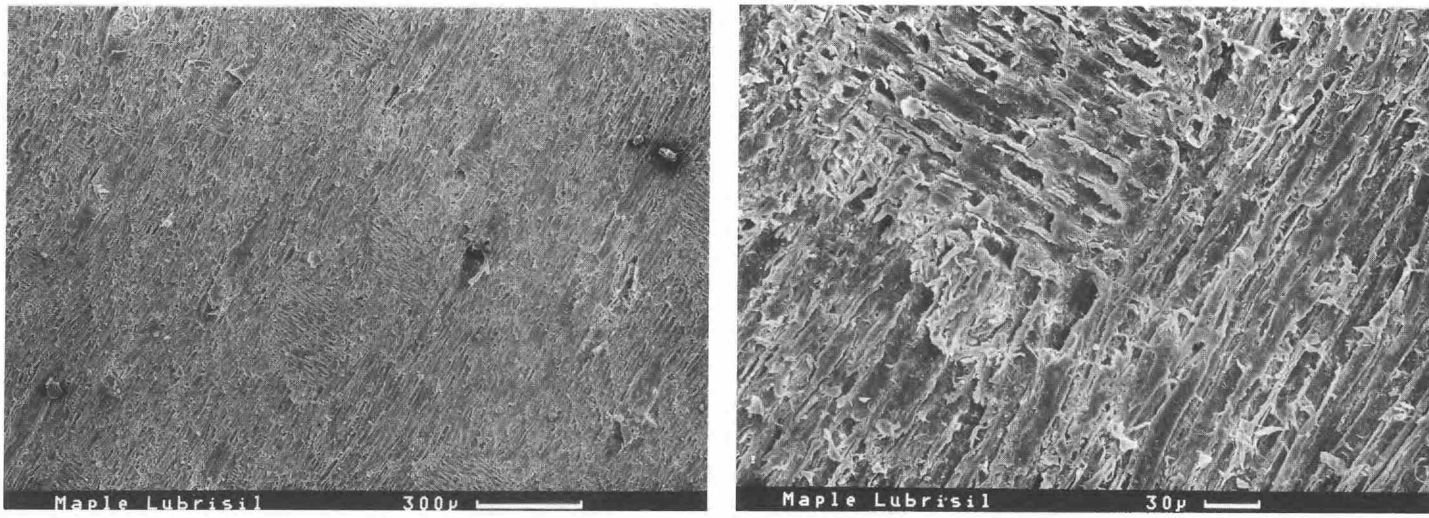


Figure 10. A sanded surface of maple.

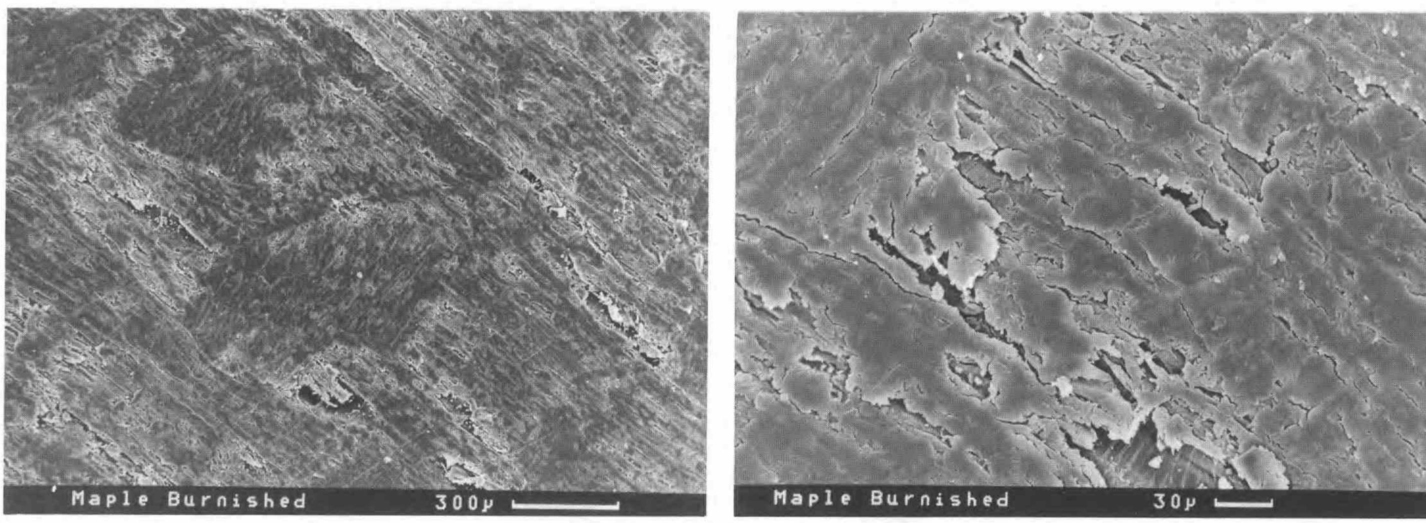


Figure 11. A burnished surface of maple.

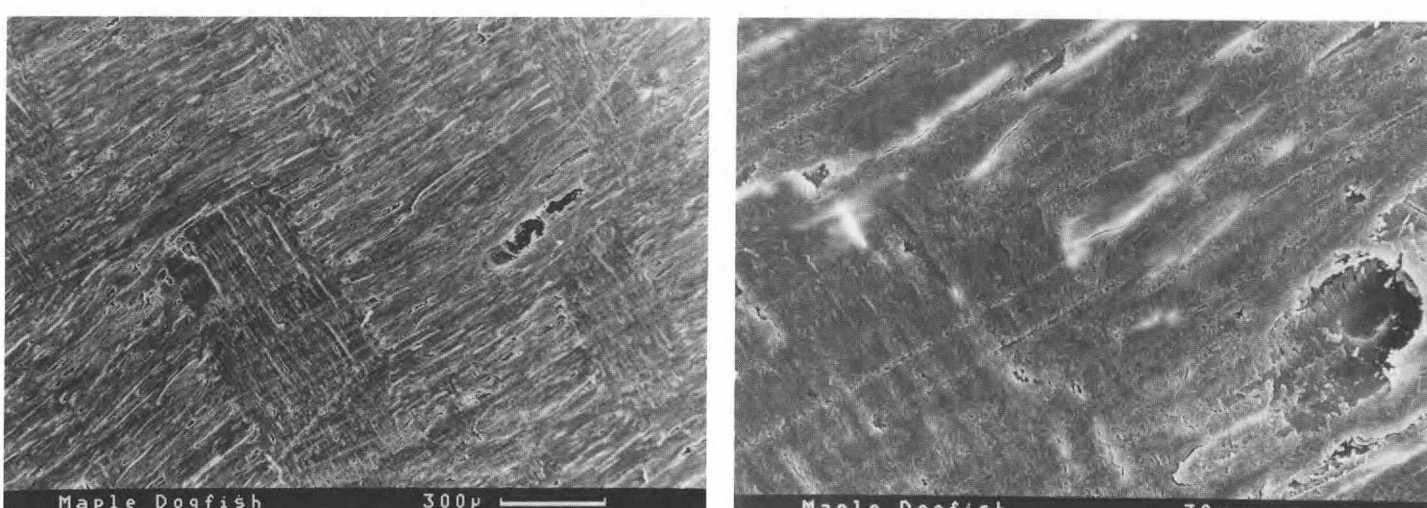


Figure 12. Maple finished with dogfish skin.