PROCESSING AND PRODUCTS CONSIDERATIONS CRITICAL IN UTILIZING SECOND-GROWTH PONDEROSA PINE

Robert R. Maeglin

ABSTRACT

Juvenile wood, compression wood, and longitudinal growth stresses in second-growth ponderosa pine can cause warp in lumber and veneer through excessive longitudinal shrinkage. In all cases, it is the disparity between "normal" and "abnormal" wood that causes problems. Certain processing techniques can circumvent or eliminate warp caused by juvenile wood, compression wood, and growth stress. The primary method for overcoming warp in lumber is balanced cutting. The Saw-Drip-Rip (SDR) process provides a simple way to balance forces by live-sawing logs, using parallel cuts. The Edge-Glue-and-Rip (EGAR) process and the manufacture of standardized panels used balanced live-sawing to produce wide products and higher valued products from small trees. A special sawing technique is recommended for eccentric logs with concentrated compression wood.

Juvenile wood, compression wood, and longitudinal growth stresses also affect the processing of veneer from second-growth trees. The peeling operation can be accomplished without severe problems, but drying causes buckling and warp if the veneer is not restrained. The Modular Veneer Press dryer, a continuous veneer press dryer recently developed at the Forest Products Laboratory, flattens the veneer and dries it quickly and uniformly. The dryer has improved veneer yield.

Finally, this paper presents cultural options for growing larger and higher quality ponderosa pines.

Keywords: Ponderosa pine, juvenile wood, compression wood, growth stress, Saw-Dry-Rip, Edge-Glue-and-Rip.

INTRODUCTION

Ponderosa pine has been a major timber species of the western United States for many decades. Most of the harvest has been used for shop and board lumber, and the manufacture of solid wood products has been based on the recovery of quality lumber with a high proportion of higher grade boards. However, the steady decline of mature ponderosa pine has resulted in the harvest of younger and smaller trees. The juvenile wood, compression wood, and longitudinal growth stresses associated with young trees cause excessive longitudinal shrinking and swelling of the wood, which results in warp of lumber and veneer products.

This paper discusses the effects of juvenile wood, compression wood, and longitudinal growth stresses on the processing of second-growth ponderosa pine, and presents ways to circumvent or eliminate warp in processing.

TROUBLESOME CHARACTERISTICS OF SECOND-GROWTH PONDEROSA PINE

The anatomical, chemical, and physical features of juvenile wood and compression wood causes longitudinal shrinking in lumber and consequent warp in processing. Longitudinal growth stresses also cause processing difficulties.

Juvenile Wood

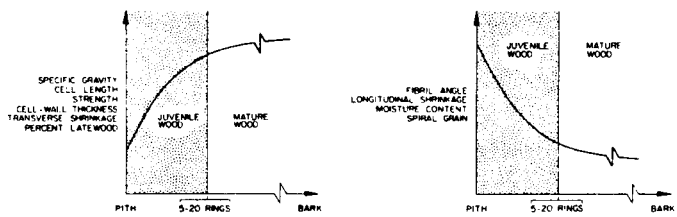
Juvenile wood is that wood formed, in a zone, from the pith outward for a variable number of growth rings. Although juvenile wood is everchanging until it becomes "mature" wood, it nevertheless has definite characteristics, and in some species, fairly well-defined numbers of rings in the core. For ponderosa pine, the number of rings has not been defined.

Certain anatomical and chemical characteristics separate juvenile wood from mature wood; anatomical characteristics give rise to physical features that further distinguish juvenile wood (Bendtsen, 1978):

Anatomical and Chemical Features	Physical Features
Shorter fiber length	Lower transverse shrinkage
Smaller cell diameter	Lower density
Thinner cell walls	Lower strength
Larger microfibril angles	Greater longitudinal shrinkage
Lower percentage of latewood	
Higher moisture content	
Higher lignin content	
Lower cellulose content	

Some researchers have indicated that the juvenile zone (core) also includes wider rings than those of mature wood. Wider rings, combined with a lower percentage of latewood and cellulose and higher percentage of lignin, may account for what some have called the dull and lifeless appearance of the juvenile zone (Bendtsen, 1978; Zobel *et al.*, 1972). Hallock (1968) evaluated the form and extent of the juvenile zone in loblolly pine on the basis of dull appearance and concluded that the juvenile zone averaged about six rings in butt logs and four or five rings in upper logs. Voorhies (1982) noted that ponderosa pine on fairly open sites may grow at a rate of five to six rings per inch during the juvenile years, but growth diminishes to 20 or more rings per inch as the wood matures.

Although the faster growth rate and dull appearance may help define the juvenile zone, these criteria are quite subjective and are not as definitive as the anatomical characteristics of juvenile wood, namely cell morphology (size and shape), fibril angle, and percentage of latewood (Figure l). However, even these characteristics are not entirely definitive. Fiber length may indicate the juvenile-mature transition at one stage of growth, whereas fibril angle may indicate this transition at another stage. The determination of the point at which the change from juvenile to mature occurs is somewhat subjective for each of the anatomical features (Figure l). In addition, as indicated in the work of Hallock (1968), different positions in the heights of the tree, based on dull appearance, may have a different juvenile zone size. Furthermore, morphology may vary at different heights. This may partially explain why lumber from butt logs has greater warp than that from upper logs (Blake and Voorhies, 1980; Hallock, 1965, 1969; Hallock and Malcolm, 1972; Maeglin and Boone, 1983).



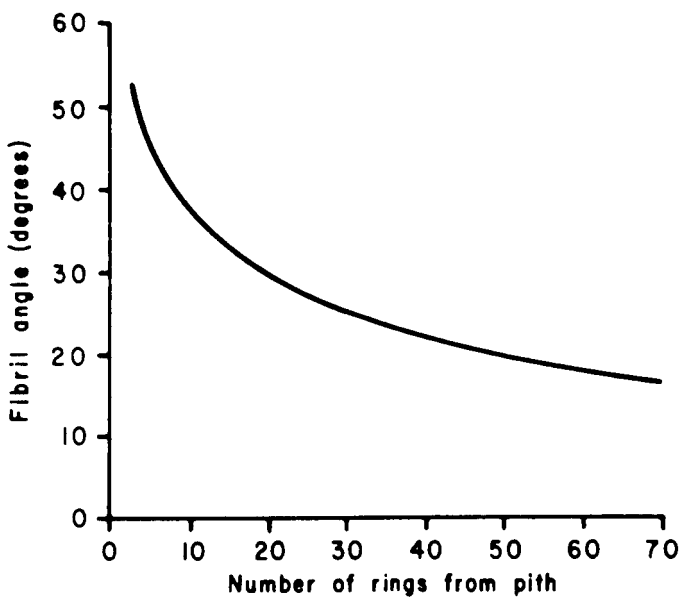


Figure 1.—Schematic representation of the gradual change in properties from juvenile wood to mature wood in conifers. After Bendtsen (1978). (M 146 399; M 146 400)

Figure 2.—Relationship between fibril angle and number of annual rings (Voorhies and Groman, 1982). (ML 88 5311)

Voorhies and Groman (1982) showed a direct relationship between juvenile fibril angles and greater longitudinal shrinkage (Figures 2 and 3). Other anatomical features of juvenile wood, such as shorter, thinner, and weaker fibers, augment this shrinkage. When lumber has both juvenile and mature wood, differential longitudinal shrinkage causes warp.

Juvenile wood may contain a greater amount of compression wood than mature wood. Compression wood affects the quality of lumber in much the same way as juvenile wood, and it may be difficult to separate the effects of juvenile wood and compression wood.

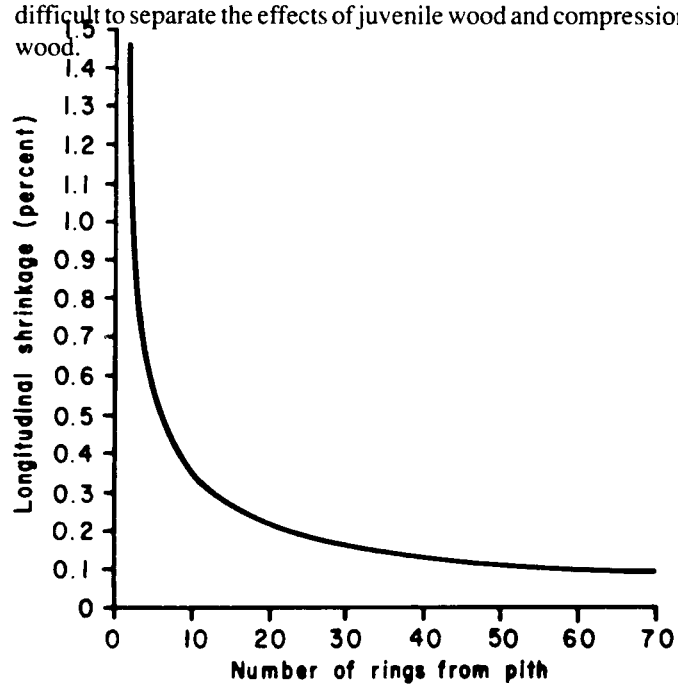


Figure 3.—Re1ationship between longitudinal shrinkage and number of annual ringe (Voorhies and Groman, 1982). (ML 88 5310)

Compression Wood

Compression wood is a type of reaction wood that is formed in coniferous species in response to a state of nonequilibrium caused by gravity, light or wind. Compression wood is generally found on the lower side of leaning trees or on the bottom of branches. Certain anatomical and chemical characteristics separate compression wood from normal wood; the anatomical characteristics give rise to physical features that further distinguish compression wood.

Anatomical and Chemical Features	Physical Features
Shorter tracheids	Higher density
Thicker cell walls	Greater hardness and brashness
Thicker S_1 layer	Higher longitudinal shrinkage
Deeper fissured S_2 layer	Lower strength
Higher fibril angle in S_2 wall	
Rounded cross-sectional shape	
Intercellular voids	
Reddish-brown color	
Higher lignin content	
Lower cellulose content	

In leaning trees, compression wood is formed to move the tree into a vertical position. In trees affected by prevailing winds, compression wood is formed on the lee side of the tree to counter the force of the wind, and if any lean occurs because of the wind, to right the tree. Trees also lean in response to light. When light is restricted to one side of the crown (e.g., a tree on the edge of a forest), or when two trees are growing in close contact (Figure 4), the tree may respond by forming a one-sided crown. The weight of the crown causes the tree to lean, and compression wood is then formed to reestablish vertical equilibrium.

Figure 4.—In a crowded group of trees adjacent to an opening, the border trees usually lean toward the opening. A thinning when the trees were young would have provided sufficient space to permit the crop trees to remain upright. (M 80273 F)

Young trees in the seedling to sapling stage are very flexible and subject to many external forces, such as light, wind, and snow. Because the young tree is small and easily moved, compression wood forms quickly to correct any deflection from the vertical position. In these instances, compression wood may appear to occur randomly within the wood, because fewer cells are needed to effect the change. As the tree grows larger, more persistent development of compression wood may form (Figure 5). Such concentrated bands will cause warp in lumber from commercial-sized trees, even the smaller second-growth trees.

The presence of both compression wood and normal wood in a board or veneer sheet causes warp. With second-growth trees, the combined effects of juvenile wood and compression wood make the processing of lumber and veneer difficult.

Longitudinal Growth Stresses

Compression wood contributes to the formation of longitudinal growth stresses in conifers. Growth stresses are the forces

Figure 5.—Cross section of ponderosa pine showing increase in compression wood with characteristically high longitudinal shrinkage (upper right-hand portion). (M 75 399 F)

developed in a tree that provide it the engineering properties to keep the tree upright. A tree may be thought of as a prestressed vertical cantilever. A perfectly vertical ponderosa pine with a balanced crown has minimal growth stresses. However, if the tree is affected by wind, gravity, or unbalanced light, compression wood and the attendant stresses will form to balance the situation. A normal tree with no compression wood has low levels of tension stress at the periphery of the tree and low levels of compression stress at the center. A tree with banded compression wood has higher levels of compression at the periphery and higher levels of tension at the center (Timell, 1986). The younger and smaller the tree, the more apt it is to form compression wood and levels of longitudinal growth stress that caused processing difficulties. Because longitudinal growth stressed in conifers are so closely tied to the formation of compression wood, growth stresses and compression wood will be discussed simultaneously when presenting options for processing and manufacturing products from second-growth ponderosa pine.

SOLID WOOD PRODUCTS FROM SECOND-GROWTH PONDEROSA PINE

Mature ponderosa pine will probably continue to be a source for solid wood products such as shop lumber, structural products, and plywood. Second-growth trees are less desirable for higher grade shop lumber (such as door and window parts, and mouldings), but can be used for structural products. For example, second-growth trees are now being used for the manufacture of studs and random length lumber. It may also be possible to use small-dimension ponderosa pine to manufacture wide, joist-type lumber by edge gluing, or to make flanges for wooden I-beams.

However, the manufacture of these products requires processing methods that overcome or reduce the warp caused by juvenile wood, compression wood, and longitudinal growth stress.

At present, the manufacture of structural products from ponderosa pine is generally a last resort. The most valuable product is shop lumber for remanufacture. In addition to the problems that accompany juvenile wood, compression wood, and longitudinal growth stress, second-growth trees have more knots. It is difficult to obtain the clear lumber necessary for moulding and millwork applications from these trees. To gain quality in board products from them, it will be necessary to develop genetically improved stock and to improve the silvicultural practices used to grow the species (for example, planting patterns, thinning, fertilization, and pruning).

PROCESSING CONSIDERATIONS

The production of lumber, veneer, and plywood from young ponderosa pine is complicated by the presence of juvenile wood, compression wood, longitudinal growth stresses, and knots. The key to using second-growth wood is improved processing techniques.

Saw-Dry-Rip

The Saw-Dry-Rip (SDR) process minimizes the effects of juvenile wood, compression wood, and longitudinal growth stresses in the manufacture of structural products from second-growth wood. Whereas conventional sawing and drying often yield low amounts of quality studs and random length lumber, SDR has been shown to improve the grade yield of STUD lumber while producing the same volume of lumber as conventional practices (Maeglin and Boone, 1983, 1986). Using conventional processing, Arganbright *et al.*, (1978) recovered a maximum of 67% of STUD grade ponderosa pine lumber; Blake and Voorhies (1980) recovered a maximum of 45% of STUD grade lumber. Using SDR, nearly 78% of STUD grade lumber was recovered after 30 days or more storage for ponderosa pine (Maeglin and Boone, 1983) and as high as 91% for loblolly pine (Maeglin and Boone, 1986). The key to the SDR process as opposed to conventional processing is the balancing of stresses in the cutting process. In conventional sawing, the imbalance of juvenile wood, compression wood, and growth stresses in individual pieces of lumber causes warp. By live-sawing logs (all cuts parallel) and drying the live-sawn flitches, stresses from juvenile wood, compression wood, and growth stresses are balanced in sawing and minimized as the wood is dried (Figure 6). The SDR process is currently being practiced by several small ponderosa pine mills in Montana.

Edge-Glue-and-Rip

A related process for the manufacture of wide structural or board lumber from small logs is the Edge-Glue-and-Rip (EGAR) process (Harpole *et al.*, 1977) (Figure 7). Like SDR, EGAR uses live-sawing to balance the forces in the lumber. It is possible to selectively rip clear-edged board products from an EGAR panel to upgrade structural quality and value. It may also be possible to select clear portions of panels for moulding and millwork.

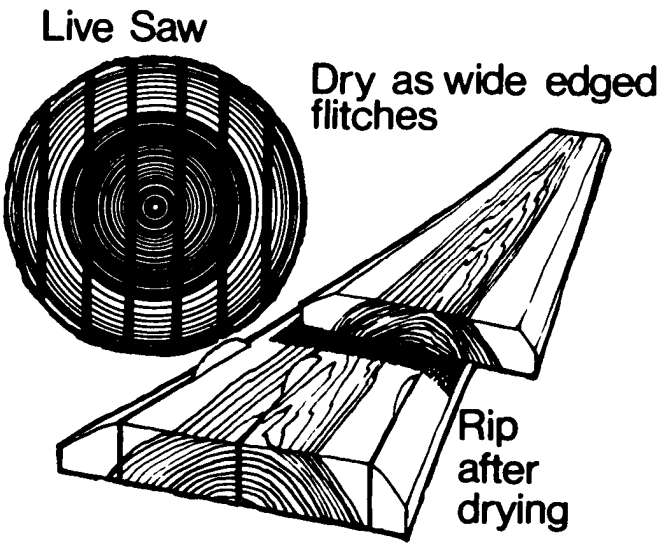


Figure 6.—The SDR process: small logs are live sawn into 7/4 flitches; flitches are lightly edged for a compact kiln load, dried, and ripped to desired final width. (M146 219)

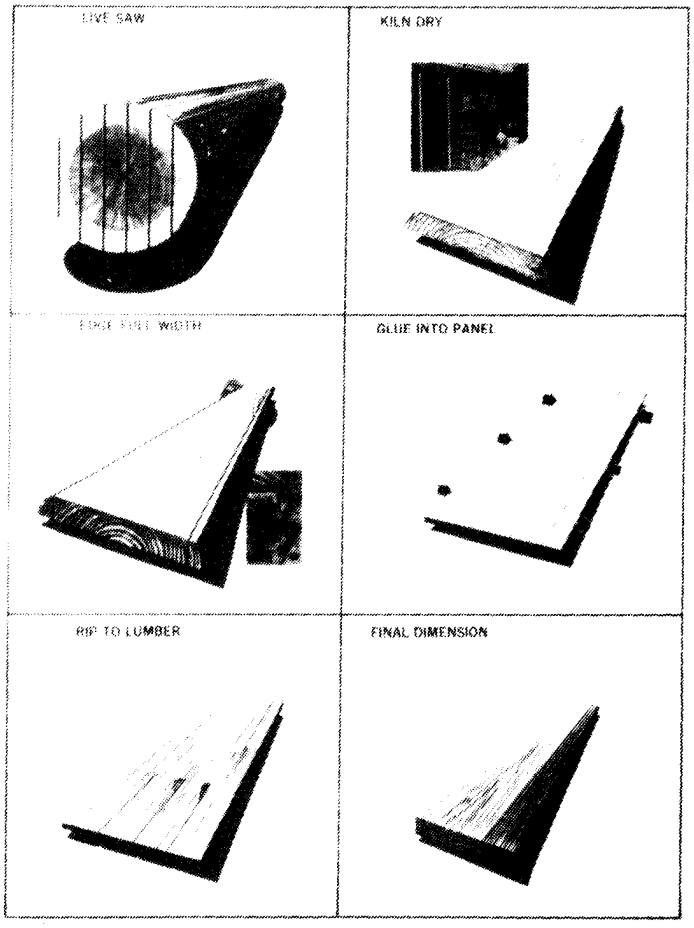


Figure 7.—Steps in the EGAR lumber-producing process. (M 145 756)

Manufacture of Standardized Panels

Another processing technique for small logs, which is in some respects similar to EGAR, is the manufacture of standardized panels (Araman and Hansen, 1983). This process uses edge

gluing and can use fingerjointing to produce clear uniformly sized panels for remanufacture. Dry flitches manufactured using the SDR process are gang ripped, freed of knots and other defects, fingerjointed, and edge glued into standard-sized panels. These standardized panels are excellent for furniture or cabinet manufacturers and specialty markets.

Veneer Drying

Current methods for peeling or slicing veneer are adequate. Problems arise when the veneer is dried and the presence of juvenile wood and compression wood causes buckling and warping of the veneer sheets. This occurs especially in the conventional roller and jet veneer dryers, which are commonly used. It is possible to use platen dryers to produce high quality, flat veneer, but these dryers are very slow and inefficient. A Modular Veneer Press dryer developed at the Forest Products Laboratory overcomes the deficiencies of the roller, jet, and platen dryers. It consists of large-diameter oil-heated drums and flexible web belts that travel over the drums. The system is a continuous dryer that flattens the veneer while drying it uniformly and quickly. The Modular Veneer Press dryer reduces shrinkage in width that occurs with roller and jet dryers (Loehnertz, 1986).

Sawing Logs With Compression Wood

When compression wood causes the formation of eccentric logs. it is important to saw or slice the logs so that compression wood and normal wood are not combined in the product. Sawing may be controlled by positioning the log or veneer flitch for cutting. Figure 8 shows the orientation of the log or flitch for separating compression wood from normal wood. Although the compression wood will still have excessive longitudinal shrinkage, it will not cause warp because it will not be combined with normal wood. Wood that is totally composed of compression wood should not be used in applications where high levels of stability are needed.

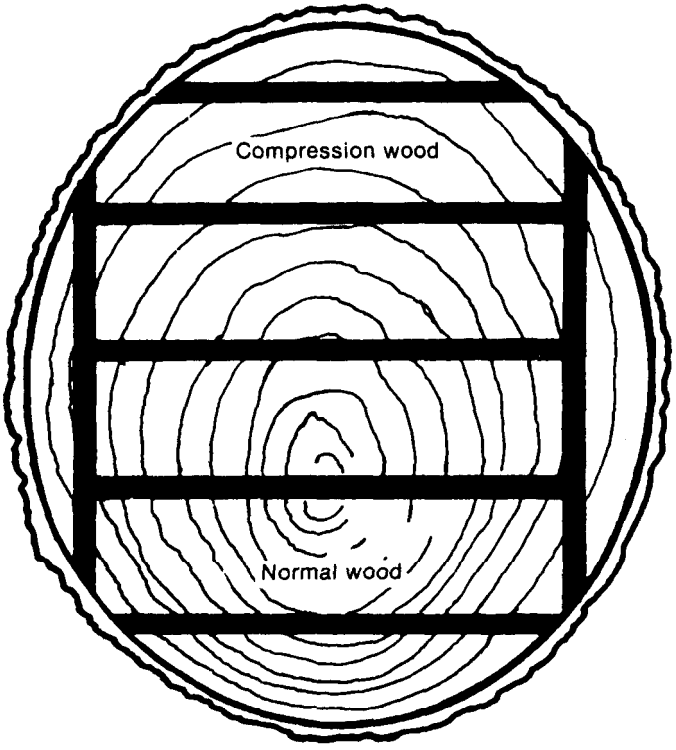


Figure 8.—Cutting pattern for eccentric logs to isolate compression wood. (ML 87 5422)

Use of Yield Studies

Although the use of yield studies is not a method for processing small dimension lumber, a moulding, millwork, or furniture plant that uses ponderosa pine may find it useful to know the maximum yields that can be obtained from standard shop lumber grades. A series of publications and computer programs for determining yields is available from the Forest Products Laboratory (Giese and McDonald, 1982; McDonald *et al.*, 1981; McDonald *et al.*, 1983a,b). These reports describe the maximum yield that is possible from the various shop grades as well as ways to achieve the best yields.

CULTURAL OPTIONS

While the processing techniques noted in this paper can enable the manufacture of products from second-growth wood, I believe that ponderosa pine growers should consider longer rotations for at least a part of their forests. As the average size of the harvested tree diminishes, larger trees will become more valuable, increasing the value of solid wood. Today, the worth of solid products from ponderosa pine makes it the most valuable western tree species. Because the larger, higher quality trees give the species its reputation and value, some portion of the forest should continue to provide this type of resource.

I also encourage the genetic improvement of ponderosa pine. Longer internodes will make possible improved recovery of clear wood and the possibility for markets in the moulding, millwork, and furniture industries. Of course, the use of silvicultural techniques to speed the growth of ponderosa pine will provide larger trees in a shorter time. However, it is important to remember that tree spacing and the effects of wind can have a major impact on the quality of the trees. Any thinning should take into consideration the exposure of individual trees to balanced light to minimize compression wood. Also, trees should be protected from prevailing winds as much as possible to minimize the formation of compression wood and growth stresses.

SUMMARY

Many solid wood products can be made from second-growth ponderosa pine if it is processed properly to overcome the problems caused by juvenile wood, compression wood, and longitudinal growth stresses. In the future, solid wood products will include all of the currently manufactured items, although structural products may take precedence over lumber. For example, more structural products will probably be made from the small-dimension logs using techniques like the SDR process. Processes like EGAR and standardized panels will permit the use of small-dimension trees for wider products. The processing of veneer for plywood may be enhanced by using a continuous press dryer like the Modular Veneer Press dryer to flatten the veneer

sheets and avoid the warp caused by juvenile wood, compression wood, and growth stresses.

I recommend that a portion of the ponderosa pine resource be managed to achieve larger and higher quality trees. Means to this end include genetic improvement for longer internodes, cultural practices for accelerating growth, and extended rotations.

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Author

Robert R. Maeglin, Supervisory Research Forest Products Technologist
U.S. Department of Agriculture, Forest Service
Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53705-2398

The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.
Personal communication with Ken Kilborn, USDA Forest Service, Missoula, MT.

In: Baumgartner, David M.; Lotan, James E., eds. Ponderosa pine—The species and its management: Proceedings of symposium; 1987 September 29-October 1; Spokane, WA. Pullman, WA: Washington State University; 1988: 19-24.