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Reconsidering the Process for Bow-Stave Removal from Juniper Trees in the Great Basin

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In 1988, Wilke described juniper trees in the Great Basin from which bow staves had been removed, and suggested the method that had likely been employed to do so. Based upon our own knowledge of tree growth and responses to wounding, we question certain of his assumptions, and offer modifications to Wilke's proposal as to how prospective staves might have been removed. Further research and experimentation is encouraged.

In a classic paper on Great Basin archeology, Wilke (1988) integrated information from ethnography, knowledge of indigenous practices of tool fabrication and use, and extensive field observations of trees that had been anthropogenically wounded to propose a process by which prospective bow staves were removed from trees. Based on our knowledge of tree growth and wound response, and our own field observations of scarred trees (CIM: December 2016, Long Valley, California and Little Whisky Flat, Nevada), we question several premises that underlie Wilke's (1988) proposed mechanism. Our concerns focus on two of his assumptions: first, that the bowyer's cuts, made one to several years in advance of extraction, resulted in cessation (arrest) of wood production along the length of the prospective stave, thus allowing the wood to season before extraction; and second, that in the years following stave extraction, the margins of the longitudinal scar would regrow in such a manner as to produce straight-gained wood used for subsequent stave extraction. In this report, we review Wilke's key observations and stages in his bow-stave removal proposal; provide background information on tree growth and wound response; describe how we expect trees to respond to cuts made by bowyers; and offer modifications to Wilke's proposal as to how prospective staves might have been removed. In so doing, we do not question that the scarred trees were used for bow-stave extraction, nor do we question other aspects developed by Wilke (1988) about stave harvesting methods.

SUMMARY OF WILKE'S (1988) KEY OBSERVATIONS AND PROCESSES FOR BOW-STAVE REMOVAL

Based on extensive observation of intentionally scarred trees in the western Great Basin, Wilke (1988) described the desired characteristics of wood from available trees of the western Great Basin, primarily Utah juniper (*Juniperus osteosperma*). These included straight grain and an absence of knots, cracks, and drying checks. Detailed observations of wounding patterns led Wilke to conclude that wood staves had been split away along the stem axis of live juniper trees. Some trees contained evidence of multiple extractions, arranged around the stem circumference or in two tiers along the stem axis, or on branches. He determined that the wood removed was likely used as stock for bow staves, with alternative uses being unlikely.

Wilke (1988) described two types of notch wounds involved with stave extraction. The *growth-arrestment cut* was a transverse, symmetrical V-shaped notch (~6–8 cm. wide and 3 cm. deep) made to the upper, lower, or both

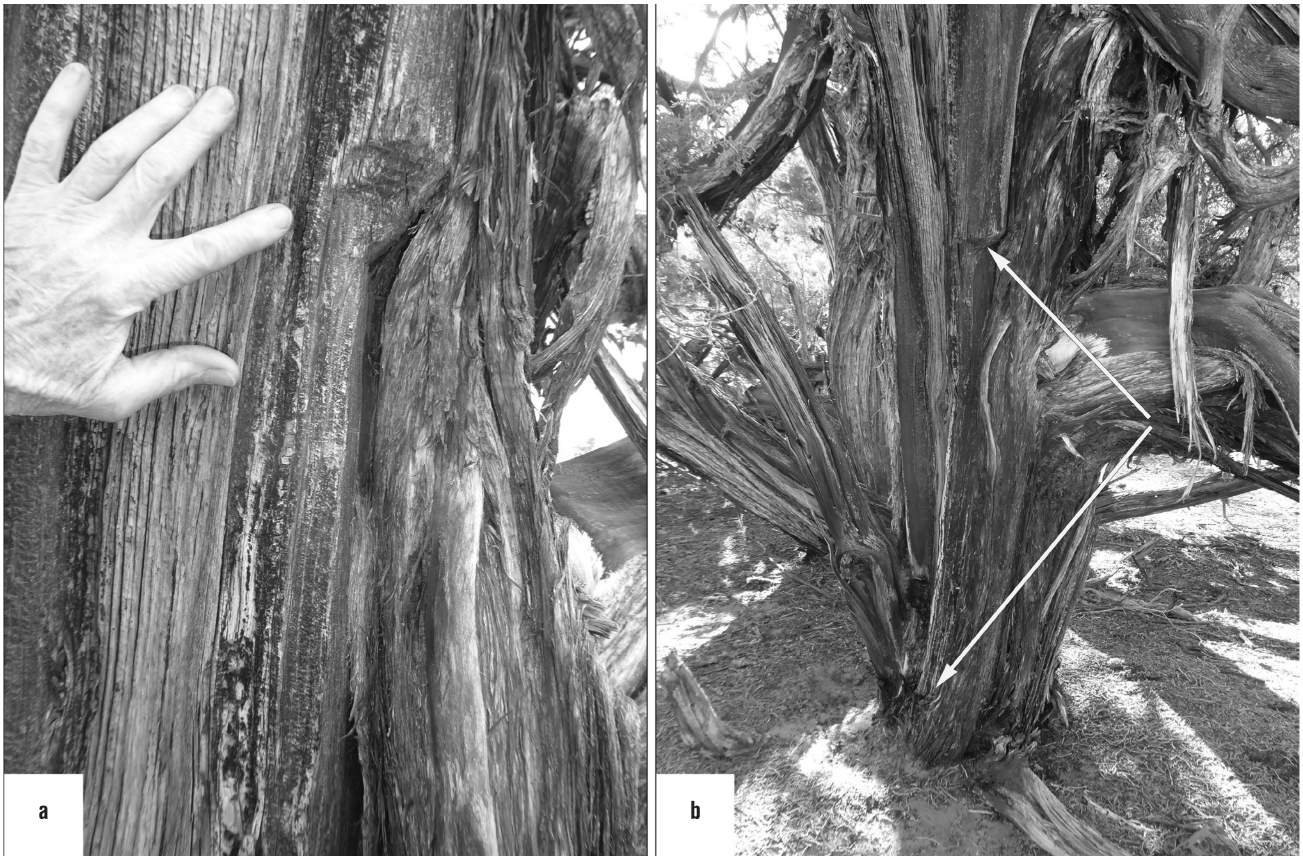

Figure 1. Live *Juniperus osteosperma* trees showing bow stave notches and cuts, Little Whisky Flat site, Nevada, December 2016: (a) close view of notch at the top of a stave removal cut; (b) entire cut zone from a tree that had both upper and lower notches. Arrows indicate stave removal strip.

ends of the prospective stave (Fig. 1a). Wilke proposed that the growth arrestment cut(s) caused wood production to cease along the length of the prospective stave. This would allow the wood to season on the tree, making stave removal in subsequent years easier for the bowyer.

The second type of notch wound was the *stave-removal cut*. This was also V-shaped and of a similar size, but strongly asymmetrical. On the far side of the notch (with respect to the prospective stave) the cut was transverse and at a right angle to the stem. On the near side, the cut was at a much more oblique angle. The asymmetry would facilitate insertion of a chisel-tipped lever inward along the near side of the notch at the edge of the prospective stave. The right angle of the far side of the notch could act as a fulcrum for the lever to pry out the stave. The harvest scars indicated that the staves had an average length of 113 cm. (Fig 1b).

After extraction, wood regrew along the longitudinal margins of the extraction wound and into the space formerly occupied by the removed stave. Wilke proposed that the stave removal scars provided a template for subsequent regrowth of straight-grained wood and later harvests of additional staves.

Key statements from Wilke's (1988) proposal for the bow-stave removal process that pertain to concerns addressed here are given in Table 1.

TREE GROWTH BIOLOGY AND RESPONSE TO WOUNDING

Our objections to the proposed mechanism for stave removal rest on our understanding of the biology of tree growth and response to wounding. Here we provide a brief overview of these processes (see also Shigo 1984, 1985; Shortle and Dudzik 2012; Smith 2015 for more detail). The tree wound response involves two separate, interrelated processes: *compartmentalization* and *wound closure*. Much of the research on compartmentalization

Table 1

STATEMENTS FROM WILKE'S BOW-STAVE REMOVAL PROPOSAL THAT PERTAIN TO CONCERNS ADDRESSED IN THE PRESENT REPORT[a]

Statement
1. "Stave scars removed from Utah juniper are characterized as being "a rough, trough-shaped groove split out and following the grain of the wood, somewhat over a meter long [$\bar{x}=113$ cm., range 87–187 cm.], about 6 cm. wide, and 2.5–3 cm. deep. The ends of the scar are marked by transverse V-shaped cuts made by the bowyer to isolate the stave, arrest its growth, and split it from the tree" (Wilke 1988:7; Fig. 1a).
2. "Growth arrestment was accomplished by cutting into the wood at the upper or lower end of the stave or at both of these points" (Wilke 1988:15).
3. "Isolating the potential stave by a cut into the tree at one or both ends severed the connective tissue and caused the wood between the cuts to cease growth and season naturally on the tree, presumably with a minimum of splitting and twisting" (Wilke 1988:17). "Seasoning the wood might have taken several years…"(Wilke 1988:17). "It is apparent from the junipers studied that stave removal frequently was accomplished only after the wood had been growth-arrested and seasoned for some time on the tree" (Wilke 1988:17).
4. "Most of the trees show healthy regrowth…indicated by gradual laying-in of wood from the edges of the stave-removal scar" (Wilke 1988:22). "Healing of the scar resulted in the inlaying of new straight-grained, knot-free wood from either side of the scar. The straight scar served as a template for subsequent regrowth of straight-grained wood (Wilke 1988:23). "…continued removal of wood from a favored tree actually guaranteed the continued availability of wood with the proper grain characteristics" (Wilke 1988:23).

[a]Page numbers refer to Wilke (1988); figure numbers refer to the present report.

and closure has focused on stem injury from fire, storms, timber management, and other direct human activities.

Compartmentalization is the integrated boundary-setting process that resists the loss of function and spread of infection after injury. The compartmentalization concept includes features of constitutive growth and induced defense of trees (Shigo 1984; Smith 2015) that protect hydraulic integrity and the vascular cambium (VC). The VC is the "new cell generator" beneath the bark that undergoes cell division to produce secondary tissues including phloem ("inner bark") and xylem that mature into wood.

In the junipers of the Great Basin (as well as for many other tree species), a band of light-colored sapwood surrounds a core of older, dark-colored heartwood. Healthy, functioning sapwood contains both living and non-living cells. Water is conducted primarily through relatively thick-walled open cells (tracheids) that function as a series of pipes. Sapwood also contains small, thin-walled cells (parenchyma) with living contents that to some degree control translocation of water and dynamically respond to injury. Water flow is maintained through the cohesion of water under tension, pulled by evaporative demand through the tracheids. On an individual tree basis, the system can move a large volume of water against the force of gravity to the top of the tree crown, even in quite dry environments. However, the system is vulnerable to cavitation, the introduction of air bubbles that break the continuous flow of water. Once the water column within a series of tracheids breaks, it is difficult for the tree to restore continuity of flow. The immediate response of the constitutive architecture and induced physiological defense to sapwood injury is to form boundaries to minimize wood aeration and the spread of air bubbles when the system is breached.

Compartmentalization protects the VC through resisting the spread of microbial infection as well as cavitation. Chemicals such as terpenes and phenolics are formed through shifts in metabolism of parenchyma in existing sapwood. After injury, wood produced by the VC has altered characteristics that resist the spread of infection into the wood formed after injury.

In regard to bow-stave extraction, our understanding of wound response and cell growth implies that the notches cut by bowyers in juniper trees and interpreted as growth arrestment cuts (Wilke 1988) would not kill the VC nor cause the VC to cease wood production along the length of the prospective stave. We also expect that these cuts would not cause the wood of the prospective stave to dry in place along the stem (which is our interpretation of "season"). We expect instead that the compartmentalization response would maintain healthy wood function, including normal cell growth, except for the tissue immediately adjacent to the notches. In red spruce (*Picea rubens*), for instance, the death of the VC caused by removal of a 1-m.-long "window" or rectangle of bark for one-quarter of the stem circumference (Smith and Shortle 1993) resulted in the dieback of the VC from the edge of the applied wound of less than 10 cm. In a separate study with red spruce, a notch sawn into the stem caused the VC to die back for about 10 cm. along the stem axis (personal observation of KTS). However, wound closure processes began soon thereafter and were about two-thirds complete after 5 years. In research on compartmentalization of fire scars in Montana, including western larch (*Larix occidentalis*), ponderosa pine (*Pinus*

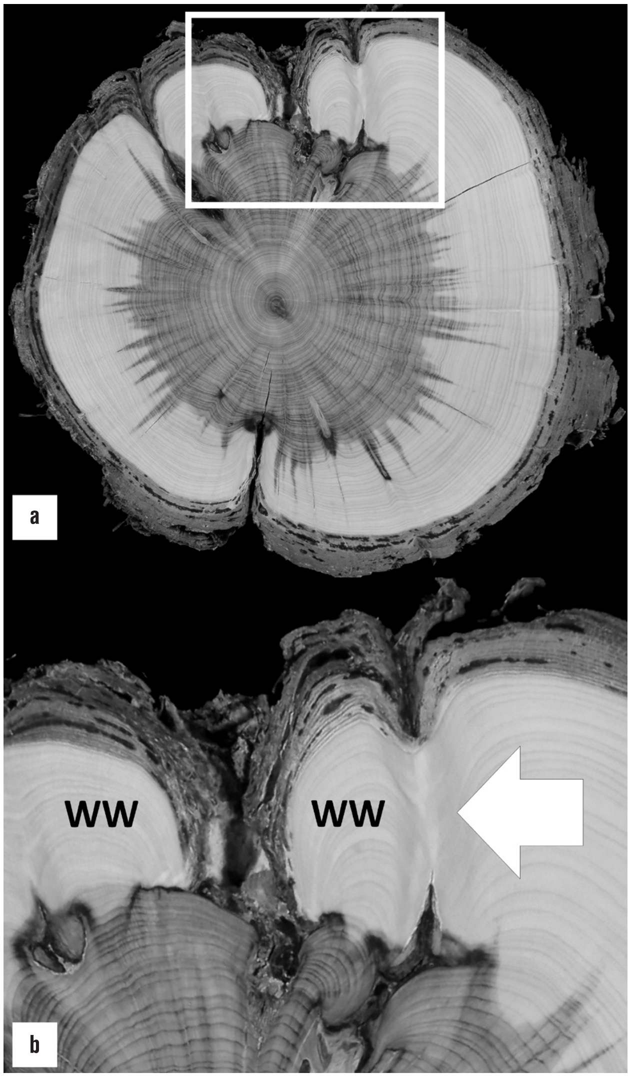

Figure 2. Stem disk of *Juniperus californica*: (a) complete disk showing multiple injuries from mistletoe infection and other sources; (b) detail from a with changes in ring orientation within woundwood (WW) and interlocked grain (arrow).

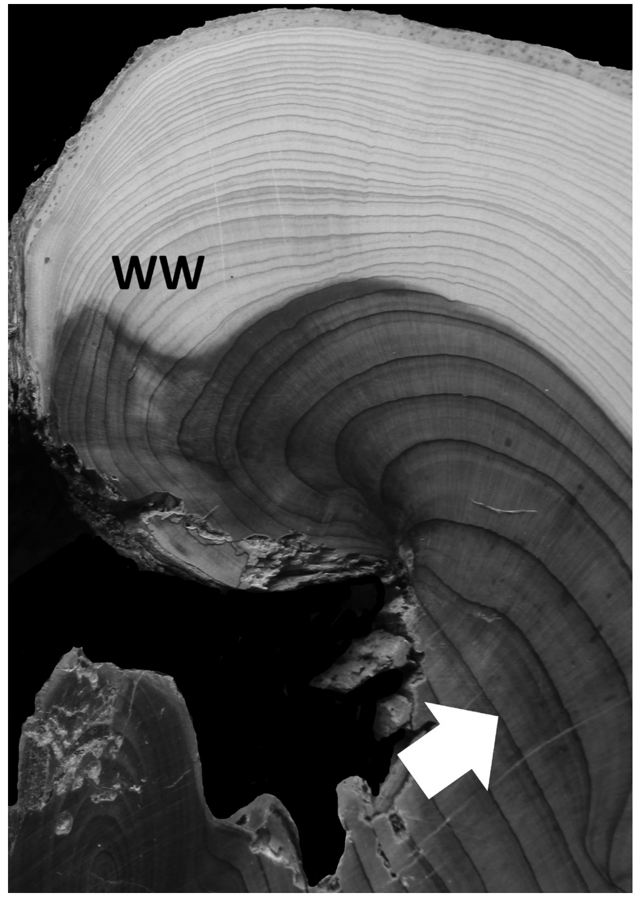

Figure 3. Partial stem disk of *Juniperus virginianum* showing the tree ring that was outermost at the time of stem injury (arrow). Subsequent rings included a rib or curl of woundwood (WW) growing into a void in the stem.

ponderosa), and Douglas-fir (*Pseudotsuga menziesii*), there was little dieback of the VC beyond the initial fire injury (Smith et al. 2016).

Wound closure involves the stimulated growth of woundwood at the margin of an injury and occasionally on the wound face itself. Successful closure restores the circuit continuity of the VC and reduces availability of oxygen in the stem, reducing the rate of the aerobic wood decay process. Wound closure in *Juniperus* involves wide rings of woundwood arranged in a pronounced arc, frequently with interlocked grain (Fig. 2). The departure from normal curvature and ring thickness is greater when the woundwood rib extends into a stem cavity (Fig. 3). The curvature, irregular ring thickness, and interlocked grain of woundwood forming on bow-stave-cut juniper trees (Fig. 4) are unlikely to provide straight-grained characteristics desired by bowyers for bow staves. Therefore, we expect that bowyers did not extract additional staves from margins of the original wound.

In summary, we expect that the one or two "growth-arrestment" notches that defined the prospective stave would trigger active compartmentalization and wound closure processes rather than arrest growth resulting in wood seasoning or formation of subsequent straight-grained growth.

One may rightly question that the examples of compartmentalization and closure we have offered are based on the manipulation and dissection of other

Figure 4. Curved woundwound forming along the margin of a bow-stave scar below notches in western juniper, Little Whisky Flat, Nevada.

tree species grown under more mesic conditions. Our proposals could be readily evaluated through a closer look at the tree-ring record contained within existing culturally-modified Utah junipers. Standard dendrochronological techniques could resolve the question of whether growth was arrested along the length of the prospective stave and verify whether the initial notches were placed one or more years before extraction of the stave. Such an investigation could also resolve whether there is significance to the initial notch(es) being above, below, or above-and-below the prospective stave. Under extreme girdling, growth of the VC is often stimulated above the girdle due to the constricted phloem and accumulation of sugar.

Understandably, no stave trees may be available for such sampling and analysis. The same questions, however, could be answered by making similar-sized notches in juniper trees growing under the same range of environmental conditions. The wounded trees could be left to grow and respond for several years and then harvested and dissected. As the goal would be to better understand the tree wound response rather than bow-making as such, the cuts and stave extraction could be made with modern tools.

AN ALTERNATIVE EXPLANATION FOR NOTCH CUTS AND STAVE REMOVAL

If growth-arrestment and seasoning did not occur on the bow-stave harvested trees, what other explanation could explain why notches were cut? Based on our understanding of tree growth and wound response, we propose that notch cutting, rather than arresting growth along the stem of juniper trees and additionally providing

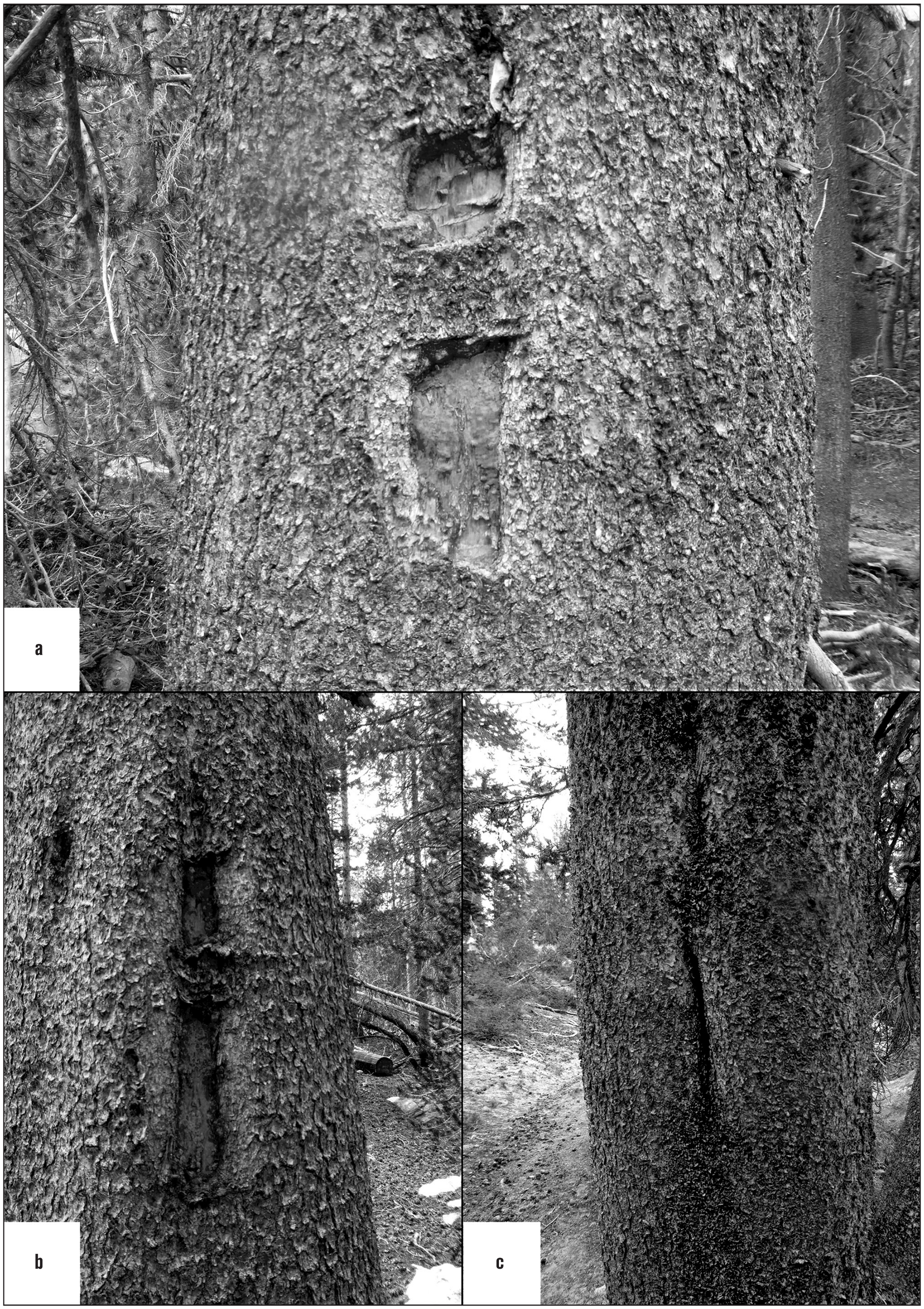

Figure 5. Trail blazes cut by modern woodsmen in lodgepole pine (*Pinus contorta*), Sierra Nevada, California. The "i style" blaze, with a long and short cut, was done to distinguish an intentional blaze from a natural wound on the tree. (a) Recent blaze, showing clean edges of blaze from axe cuts. (b) Older blaze, where woundwood is forming as an arc around the edges of the original cuts. (c) Oldest blaze, with woundwood nearly completely closing the original blaze cuts.

a means to insert a lever, might have been made to assist in the removal of a clean stave. Notch cuts would serve to bound the end(s) of the live stave when it was removed from the tree. Further, if stave removal happened months or years after the notches were cut, localized cell death might create a small crack where a tool could better gain purchase for efficient stave removal, and the top and bottom of the stave would more likely have a clean rather than ragged break from the stem. In the same way, early Euro-American woodsmen made bounding cuts with an axe before slicing wood from tree stems to create trail blazes (Fig. 5; personal communication to CIM by Jim Blanchard, University of Oregon, from U.S. Forest Service oral histories, 2016).

Importantly, as noted by Wilke (1988), a stave removed from dead trees would be unsuitable for bow manufacture, and thus wood was cut from live trees. By corollary, we assume that a strip of seasoned (dead) wood on an otherwise live tree would not make a good stave, even if seasoning could be induced. By cutting notches in a live stem, the stave to be removed would remain alive, and the notches assisted in removing a clean-edged stave.

In summary, Wilke's (1988) process for bow-stave removal can be readily modified to accommodate current understanding of tree growth and wound response. Even without analyzing or experimenting on bow-stave trees, continued basic and applied research on conifer wound response should provide further insight into the processes we discuss. Prior observations and interpretations of bow-stave trees by Wilke (1988) and others remain a remarkable addition to our understanding of the life ways of indigenous Great Basin people.

ACKNOWLEDGEMENTS

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