Oldest Known Conifers in the Southwestern United States: Temporal and Spatial Patterns of Maximum Age[1]

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Tree-ring collections obtained from Arizona and New Mexico old-growth forests were used to assess age structure and maximum ages of conifer stands and trees. Mean ages of the oldest Douglas-fir, ponderosa pine, and piñon trees in stands selected for maximum age varied from about 270 to 290 years. Mean ages of the oldest Douglas-fir trees in northern New Mexico old-growth stands not specifically selected for maximum age were about 200 years. Trees older than about 400 years (establishing before 1590) were less common in Southwestern forests, and trees older than about 500 years (establishing before 1490) were rare. A decrease in numbers of sampled trees in age classes establishing before about 1590 and an increase in numbers of trees in early 1600s age classes may be related to a severe drought in the late 1500s, and a subsequent wet period in the early 1600s. Many of the oldest stands ("super old-growth") in the Southwest are characterized by stunted trees growing in sites with steep, dry, rocky slopes. Some of the super old-growth stands, however, have more stereotypical old-growth characteristics of closed, multi-layered canopies, large and small diameter trees, and presence of abundant snags and logs. Scientific values, particularly tree-ring resources, of old-growth are high and important to studies of past global change.

INTRODUCTION

A fundamental attribute of old-growth forests is the presence of old trees. Despite the obviousness of this statement, it is not clear how old is "old", nor is it clear that tree age can or should be used as a primary criteria for identifying old-growth. Interim definitions of old-growth list minimum tree ages, but most of the emphasis in classification has been on structural, compositional, and ecological attributes that are age-related, but not necessarily age-specific (Franklin et al. 1981, Franklin and Spies 1986, Spies and Franklin 1988, Franklin and Spies 1989, Southwestern Region Old-Growth Core Team 1992). For example, Pacific Northwest old-growth stands must contain trees at least 200 years old, and the stands should have broad diameter distributions with some trees greater than 30 inches dbh. Proposed minimum tree age in Arizona and New Mexico old-growth is 150-200 years, and trees should have diameters of 9 to 20 inches dbh (depending upon forest cover type). Deep, multi-layered canopies and a minimum number of snags and logs per unit area are also specified. Actual tree age distributions within regions or within old-growth stands have not been considered in the context of old-growth definitions. However, the implicit importance of tree or

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stand age is evident in assessments of stand structure indices as a measure of "old-growthness", since actual stand ages are the standard against which the indices are tested (Franklin and Spies 1989).

Franklin and his colleagues argue that old-growthness in the Pacific Northwest is a continuum rather than a discrete state; one cannot identify a single set of attributes and quantities that will classify all stands as either old or young growth. Local disturbances and site-related differences have led to a wide variety of tree ages, stand structures, and species compositions across the landscape. Given this ecological variability, and the many resource values contained in old-growth (e.g., wildlife habitat, forest industry jobs, esthetics, etc.), it is quite reasonable that definitions should include a broad assessment of attributes. While we agree that multiple age-related attributes must be considered, we submit that scientific understanding of old-growth ecosystems, and decisions on old-growth preservation, can benefit from a more specific examination of actual tree ages within regions and within old-growth stands. Assessments of tree age distributions (how old is "old"?) are needed as a baseline to determine the rarity and uniqueness of particular trees and stands.

The main subjects of this paper are the age structure and character of the oldest known Southwestern old-growth stands. We will describe temporal and spatial distributions of maximum ages of the four most widespread and economically important conifer species - ponderosa pine (Pinus ponderosa), Douglas-fir (Pseudotsuga menziesii), piñon pine (Pinus edulis), and white fir Abies concolor. We will also emphasize the distinctive characteristics of the "oldest" old-growth stands ("super" old-growth) in the Southwest, since qualitative and quantitative features of these stands are not well known among land managers or natural resource scientists. Ancient trees and stands in the southwest also have high scientific values, and we will discuss some of these values.

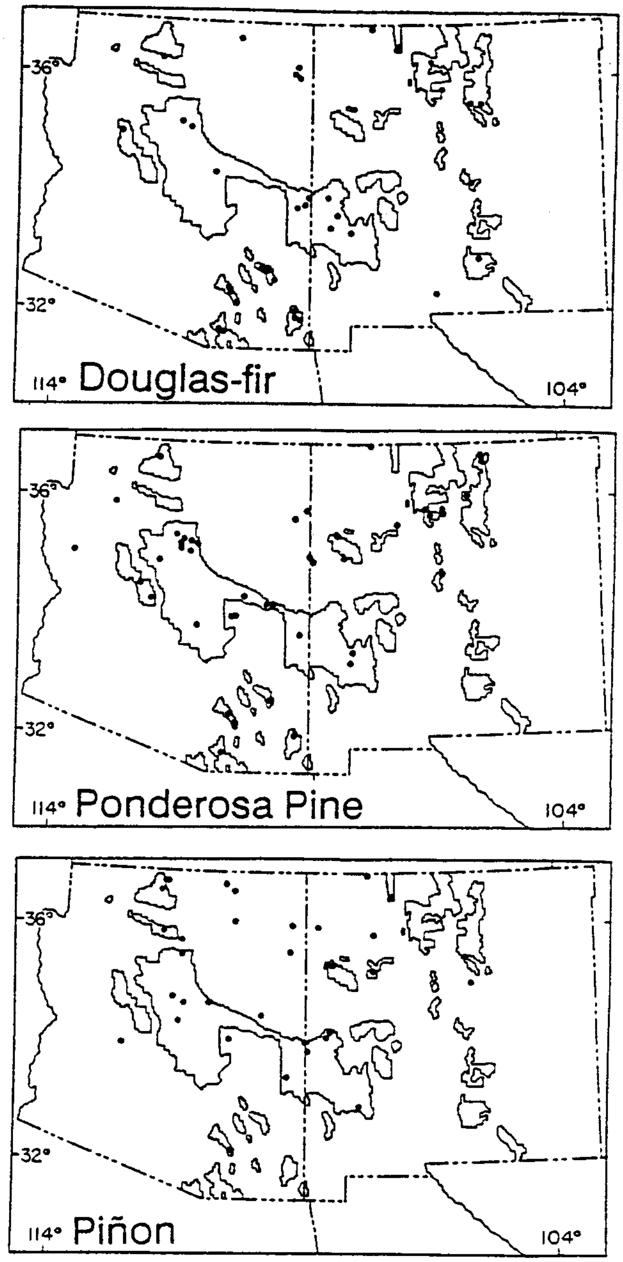

Figure 1. Location of tree-ring collections (dots) in Arizona and New Mexico, sorted by species. National Forest boundaries are shown (approximately). Because of close proximity, two or more sites are sometimes shown as a single dot.

METHODS

The Data Set

We used a unique data set to develop an estimate of maximum tree ages in the Southwest. A set of ring-width measurements of more than 2,800 trees in 164 sites dispersed throughout Arizona and New Mexico was analyzed (Fig. 1). These data were collected mainly by dendrochronologists working at the Laboratory of Tree-Ring Research (LTRR), University of Arizona. Since 1904, when A. E. Douglass began his tree-ring research in the Southwest, thousands of trees have been sampled, dated and measured using the techniques he pioneered (Webb 1983). Early in the history of LTRR these collections were extended throughout the western U. S. and North America, and data bases now contain collections from most temperate and boreal forest regions of the world. Most of these collections have been obtained for the purpose of investigating past climate variations, and for the dating of past events, such as construction dates of ancient dwellings. Although collections are globally dispersed, the Southwest still has the highest concentration of sampled sites of any region (Hughes et al. 1982, Hughes 1989).

Southwestern tree-ring collections have been obtained and used for a variety of purposes, but a common sampling strategy has been to maximize the length of the tree-ring record by selecting the oldest stands and trees. An additional strategy in most sites, but not all, has been to maximize climatic sensitivity. In the Southwest these two strategies are often complementary because the oldest trees in arid and semi-arid regions are commonly found in stressful sites (Schulman 1943, 1954, 1956) where year-to-year ring-width variations tend to be high (sensitivity), positively correlated among trees, and closely coupled with climate variations (e.g., rainfall or temperature) (Fritts 1976, 1991). Although most of the sites in our data base were at least partly selected for climatic sensitivity, the data includes samples from a broad range of habitats from low to moderate productivity sites, in piñon-juniper woodlands at elevations of about 1,350 m up to mixed-conifer forests at elevations of 3,200 m.

In general, the collection of tree-ring samples from the Southwest is a highly stratified data set. They are the result of more than 80 years of efforts by dendrochronologists to find the oldest trees and stands. The selective nature of these collections has advantages and disadvantages in assessing age structure. On the one hand, clearly, they cannot be used to characterize the overall age structure of Southwestern conifer forests. On the other hand, they are a very useful data set for assessing maximum tree and stand ages in this region.

We began data compilation by reviewing individual site collections contained in a ring-width database used at LTRR. Because of time limitations only sites from Arizona and New Mexico (referred to here as the "Southwest") were included in our sorting of the data (Fig. 1). Future investigations could extend the analyses to portions of the Colorado Plateau in southern Utah and Colorado, and in the Southern Rockies in Colorado, where the densities of sampled tree-ring sites are as high, or nearly so, as in Arizona and New Mexico.

In addition to 143 sites from throughout Arizona and New Mexico we also compiled and analyzed a systematically sampled set of 21 stands from the Carson and Santa Fe National Forests in northern New Mexico. These stands were selected for a study of western spruce budworm history in this region (Swetnam and Lynch 1989, Lynch and Swetnam, this volume). These stands were old-growth mixed-conifer with Douglas-fir and white fir as primary components, and they have had minimal or no human disturbance. Douglas-fir and white fir trees were sampled at evenly spaced points along transects. Three or four evenly-spaced transects were approximately centered in the stands and the nearest Douglas-fir and white fir to each point were cored. Tree sizes down to about 20.3 cm dbh (8 inches) were cored. A total of about 15 trees of each species were sampled in this manner. We also selectively sampled an additional five of the oldest appearing Douglas-fir and white fir in each stand to obtain the longest (oldest) tree-ring record possible for each stand. Hence, this data set contained a broader range of size and age classes than the larger regional data set, but oldest trees within the stands were still disproportionally represented.

Analyses

Each of the site data files typically contained two radial measurement series from each of at least 10 trees. In some cases, many more trees were sampled per site (e.g., 30 or more). The year of the first measured ring was extracted from each radial series from each site. The shortest of the two series from the same tree (later innermost ring date) was deleted. The resulting data was a list of inner-most measured ring years (dates), identified by site, tree, and species.

The inner-most ring years were not germination or establishment dates. The samples were increment cores taken from the lower trunk from at a height of about 1.5 m to about 25 cm from ground level. The pith was infrequently included in the samples (we estimate less than 10% of the time), although most cores probably extend near to the pith, so that in the majority of cases inner-most measured rings were within a few years to a decade of the pith. Thus, we estimate actual germination dates of the trees usually varied between about 5 and 20 years earlier than the inner-most ring dates. Because of these uncertainties, we grouped the inner-most ring dates into 20-year age classes for assessment of temporal patterns. Frequency distributions were compiled for each species and plotted on the first year of the 20-year age classes.

RESULTS

Regional Maximum Age Distribution

All three of the major conifer species had a maximum age distribution that is more or less bell-shaped, with means and modes centered around the late 1600s and early 1700s (Fig. 2). The mean ages (years) of all trees in the data sets, and modes of the twenty-year age class (innermost ring dates) were, respectively: Douglas-fir 289 years, 1700; ponderosa pine 279 years, 1680; and piñon 278 years, 1680. The age distributions also had a long "tail" of fewer older trees that established before about 1580 (Fig. 2). The lower percentages of trees in more recent age classes (i.e., post-1800) are mainly a reflection of the sampling strategy which typically targeted only

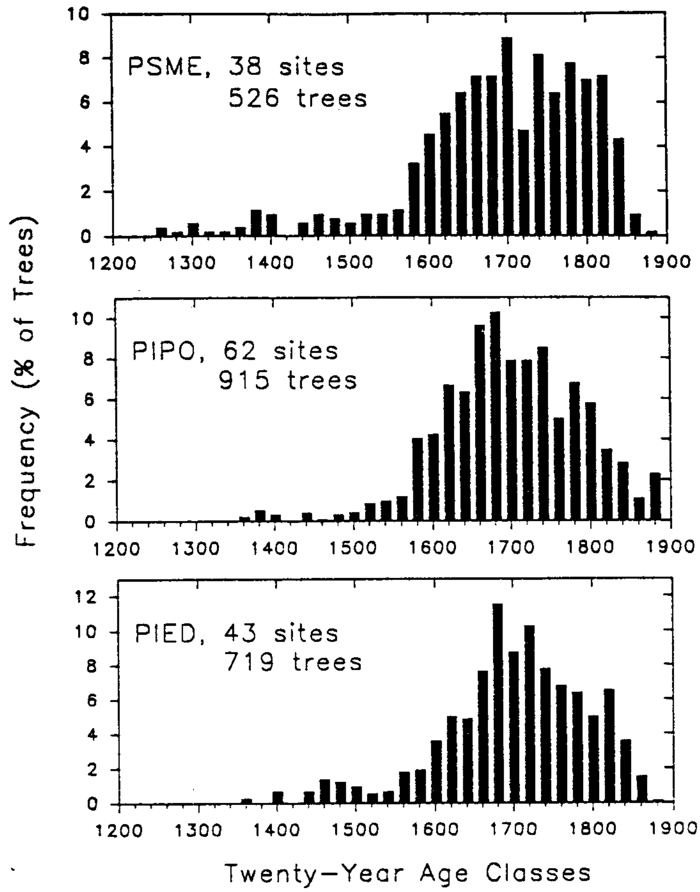

Figure 2. Distribution of all trees sampled within sites in Arizona and New Mexico, sorted by species. The percentages of inner-most ring dates of trees falling in each age class are plotted on the first year of the twenty-year age classes. For example the age class shown at the 1600 tick mark includes trees with inner-most ring dates falling between 1601 and 1620. Species abreviations are: PSME = Douglas-fir, PIPO = ponderosa pine, PIED = piñon.

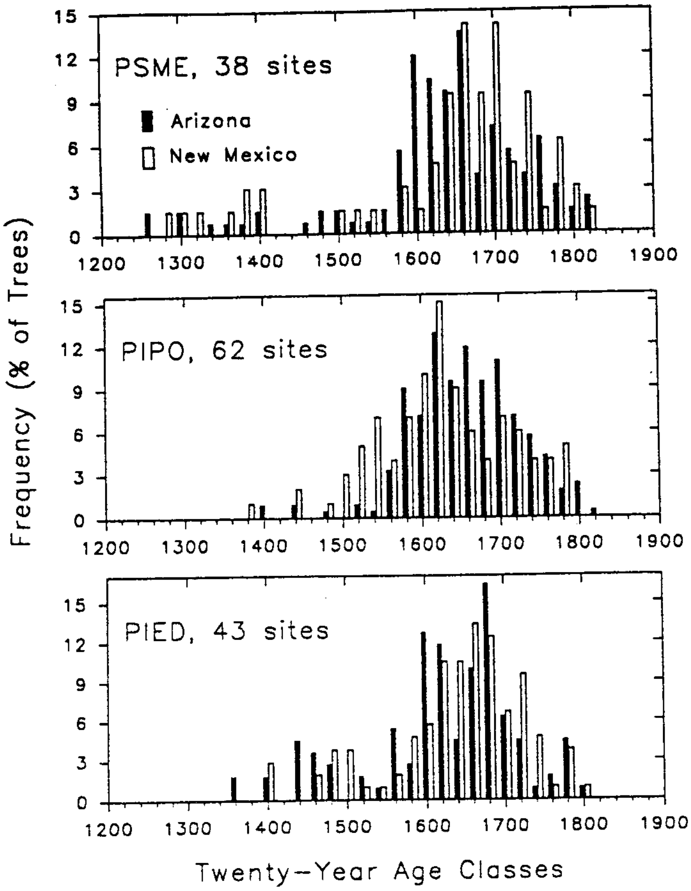

Figure 3. Distribution of five oldest trees from 143 sites in Arizona and New Mexico, sorted by species and state. As in Fig. 2, percentages falling in each age class are plotted on the first year of the twenty-year period.

the oldest stands, and oldest trees within stands. A sorting that included only the five oldest trees within each site had a similar pattern, although modes of the Douglas-fir and ponderosa pine were shifted to older twenty-year age classes (1660 and 1620, respectively) (Fig. 3).

Age distributions of Douglas-fir and white fir sampled systematically in the 21 stands from northern New Mexico (Fig. 4) reflect the dominance of younger age classes that would generally be expected in uneven-aged stands with a pattern of more-or-less continuous recruitment and mortality. The lower number of individuals in age classes after 1920 was probably due a lack of sampling of trees smaller than 20.3 cm

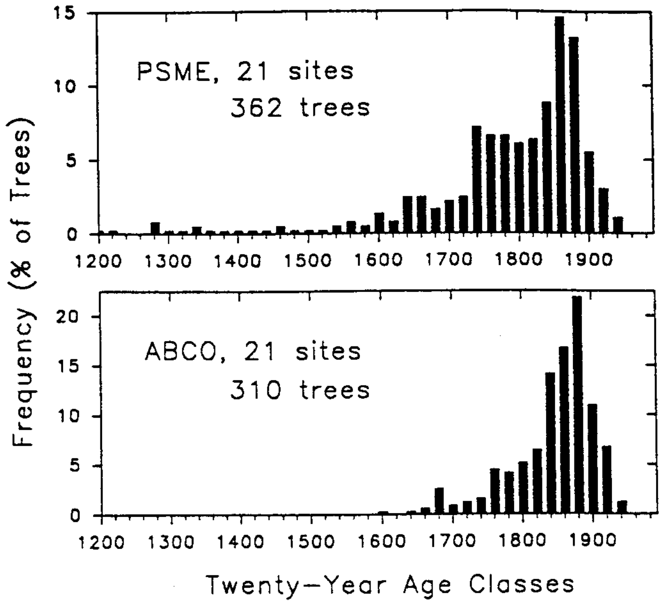

Figure 4. Distribution of all trees systematically sampled in 21 mixed-conifer stands in northern New Mexico. ABCO = white fir.

dbh. White fir were generally younger than the Douglas-fir (Fig 4.), although we suspect that the lack of older inner-most ring dates is partly due to the fact that many of the oldest trees of this species had heartrot and hollow interiors.

The oldest Douglas-fir trees in these stands were considerably younger than the oldest trees in the larger regional set (Figs. 2 and 3). For example, the median age of the larger regional set was about 275 years (establishing before 1716), whereas less than 23% of the Douglas-fir sampled in the 21 northern New Mexico stands were older than this. An even smaller percentage of such older trees (relative to all trees) are present in the northern New Mexico stands, because we also sampled at least five of the oldest appearing trees. This suggests that the oldest trees within the regional data set of old-growth stands (as described by distributions in Figs. 2 and 3) may comprise a relatively small proportion of the total stocking of more typical old-growth stands of northern New Mexico (i.e., those not specifically selected for maximum age).

Dendrochronologists working in the Southwest have known for a long time that trees up to about 350-400 years of age (establishing in the period from about 1600 to 1640) could usually be found in most mountain areas, but trees older than this were more difficult to locate. This phenomenon is reflected in the decline in inner-most ring dates before 1600 (Fig. 2 and 3), especially in Douglas-fir. This pattern shows up most clearly in Fig. 3, especially as fewer trees in the mid to late 1500s age classes, and larger numbers of trees in the early 1600s age classes. Ponderosa pine in New Mexico appear to be an exception to this pattern. The classification by twenty-year periods, necessitated by uncertainty in the relation between our inner-most ring dates and actual germination or establishment dates, tends to obscure the actual date of decline in number of trees sorted by age class. However, the age distribution within many individual sites show the oldest trees (including pith dates) establishing in the early decades of the 1600s, with only a few, or no trees establishing earlier. The lower number of inner-most ring dates before the late 1500s could be a reflection of higher mortality rates, lower regeneration rates, or both, before this time. This pattern could also simply be measure of some physiological age limit for these species, although the fact that we can find some trees and stands that are much older seems to counter this argument.

These observations led us to hypothesize that an event or events in the late 1500s and early 1600s affected the mortality and regeneration patterns of conifers throughout the Southwest. An obvious possible cause for such a pattern is climate change. Tree-ring width chronologies are the best available source of information on climate variations on these time scales, but the decline in sites with trees old enough to reflect changes during the late 16th and early 17th century somewhat limits our ability to examine climate change during this period. Fortunately, a tree-ring chronology network derived from living trees and archaeological specimens (beams and timbers from ancient dwellings) has recently been used by dendrochronologists to reconstruct the past 1,000 years of winter-spring precipitation (D'Arrigo and Jacoby 1991) and spatio-temporal variations in tree-

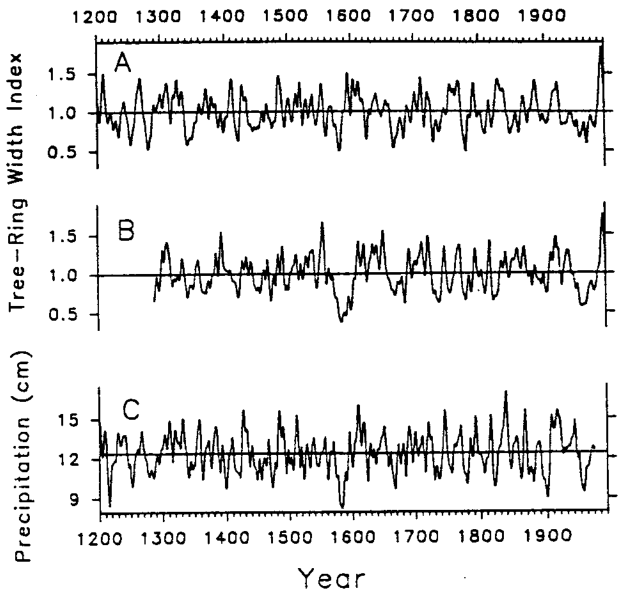

Figure 5. Precipitation variations in New Mexico can be inferred from the tree-ring-width index chronologies from ancient limber pines at the Elephant Rock site (A) and Douglas-fir at El Malpais site (B). These time series were smoothed with a 13-weight symmetrical filter (Fritts 1976). See text for descriptions of the sites. Dendroclimatic study (Grissino-Mayer et al., in preparation) shows that the limber pine have a strong spring-summer precipitation response. The El Malpais Douglas-fir reflect primarily winter-spring precipitation. Tree-ring reconstructed winter precipitation from living tree and archaeological samples from northwestern New Mexico is shown in the bottom plot (C) (modified from D'Arrigo and Jacoby 1991). All three time series show the severe late 1500s drought, especially the El Malpais indices (B) and the winter precipitation reconstruction (C). The reconstruction ends in 1970.

Table 1. Oldest known living trees (at time of sampling) of various tree species in Arizona and New Mexico.

Species	Date of* Inner Ring	Date Sampled	Number of Years	Site Name	Location
ponderosa pine (*Pinus ponderosa*)	1243	1984	742	Mount Bangs	Mt. Bangs S.E. of Littlefield, AZ
Douglas-fir (*Pseudotsuga menziesii*)	1062	1991	930	Bandera	El Malpais National Mon. south of Grants, NM
piñon (*Pinus edulis*)	1295	1960	666	Mariano Lake	N.W. of Gallup, NM
bristlecone pine (*Pinus aristata*)	547	1984	1,438	San Francisco Peaks	San Fran. Peaks N. of Flagstaff, AZ
limber pine (*Pinus flexilis*)	±320	1989	1,670	Elephant Rock	Sangre de Cristo Mtns. E. of Questa, NM
Southwestern white pine (*Pinus strobiformis*)	±1454	1991	538	Camp Point	Pinaleño Mtns. S.W. of Safford, AZ
white fir (*Abies concolor*)	1655	1987	333	Alamitos	Sangre de Cristo Mtns. S. of Angostura, NM
Engelmann spruce (*Picea engelmannii*)	1696	1990	295	Emerald Peak	Pinaleño Mtns. S.W. of Safford, AZ
gambel oak (*Quercus gambelli*)	±1587	1987	401	Beaver Creek	Beaver Creek S. of Flagstaff, AZ

* ± indicates inner-most ring date is estimated from a ring count only, while other dates are dendrochronologically crossdated.

ring growth (Graybill, pers. comm.) in northwestern New Mexico and northeastern Arizona. We also have recently discovered ancient tree sites in north central and west central New Mexico that provide an estimate of climate variations through the relevant time period (Grissino-Mayer et al., in preparation).

The tree-ring width data indicate that a severe drought occurred in the late 1500s, followed by very moist conditions during the early 1600s (Fig. 5). Spatial analysis of tree-growth variations in the archaeological tree-ring set indicate that this response, particularly the drought, was more pronounced in northwestern New Mexico than in northeastern Arizona (Graybill, pers. comm). The sorting of oldest trees within sites by state (Fig. 3) generally shows fewer trees establishing or surviving before the late 1500s in New Mexico (no Douglas-fir are included in the 1560 age-class) although ponderosa pine does not show an obvious sharp decline in numbers of trees before 1600. A pronounced increase in numbers of innermost ring dates in the early 1600s age classes is observed in Arizona sites, especially Douglas-fir and piñon (Fig. 3).

Figure 6. Strip-bark limber pine at the Elephant Rock site, west of Red River, New Mexico. Scattered trees and steep slopes visible in the background are typical of this site and other super old-growth stands.

"Super" Old Growth

Many other tree-ring collections from the most ancient stands and trees in the Southwest are not included in the data set compiled for the age distributions discussed in the previous section. This is because they are from other species not considered, or ring-width measurements have not been obtained from them yet. The oldest known trees of various Southwestern species are reported for the first time here (Table 1). Recent discoveries of very ancient Douglas-fir trees in several sites, and the oldest known trees the Southwest - limber pines in the Sangre de Cristo Mountains - deserve special descriptions because they illustrate several characteristics of "super old-growth" in this region.

Elephant Rock Limber Pines

In many ways this site epitomizes the "classic" type of site that dendrochronologists look for to sample maximum age conifers with climate-sensitive ring-width patterns. It is located on a very dry, steep, south facing slope (Fig. 6). The trees are widely spaced, stunted, and many have spike-tops, and "strip-bark" growth form. Numerous living trees at this site are over 800 years old. The oldest tree we have sampled so far is well over 1,600 years old (Table 1).

This site is on the Carson National Forest, a few kilometers west of Red River, New Mexico. Although the site is clearly not suitable for timber harvesting because of the extreme low productivity and steep slope, it could be threatened by future road building, or mining activity (a large molybdenum mine is only a few kilometers away).

Before we discovered this stand, the oldest known trees in the Southwest were the ancient bristlecone pines on the San Francisco Peaks near Flagstaff, Arizona (Table 1). As in many super old-growth stands, remnant snags and logs on the ground surface also contain ancient and valuable tree-ring records (Fig. 7).

Figure 7. Ancient snags and logs, such as this partially buried limber pine log at the Elephant Rock site, are a valuable tree-ring resource because they help extend the tree-ring record back in time. A short increment core was taken from the outer shell of this hollow log. The innermost ring, which was obviously quite far from the original pith, was crossdated at A.D. 767, and the outermost ring dated at A.D. 1231.

<u>El Malpais Douglas-Fir</u>

This site also appears to be an extreme situation for conifer growth. Very stunted Douglas-fir trees are growing in crevices and small pockets of soil accumulated on the Bandera lava flow in El Malpais National Monument, south of Grants, New Mexico (Fig. 8). Although the lava field is broken and undulating, the trees are apparently in stable and more-or-less level micro-sites. We have sampled dozens of trees here with inner-most ring dates in the late 1200s to early 1300s. The oldest living tree sampled so far has a pith date of A.D. 1062. This is the oldest inland Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) that has ever been reported. Maximum ages of the coastal variety of Douglas-fir (*P. menziesii* var. *glauca*) reportedly exceed 1,000 years (Hermann and Lavender 1990).

The harsh conditions of this site have severely stunted the trees, but they are not subject to significant competition or spreading fires. Even though moisture is limited, and the annual rings have high year-to-year variation, good thermal insulating or water retaining properties of the lava may provide the trees with a relatively consistent water supply through the centuries that rarely is

Figure 8. Oldest known inland Douglas-fir growing in a small pocket of soil on the Bandera lava flow in El Malpais National Monument, south of Grants, New Mexico.

Figure 9. Ancient tree site on Mount Graham, near Safford Arizona. The oldest trees found on this site are among the large boulders on the steep slope (center of photograph), but other ancient trees, living and dead, are also found nearby.

so low that trees die from drought stress. The surprising lesson of this stand is that very ancient stands sometimes occur in highly unusual habitats that do not fit the usual expectations of where to find super old-growth, or of what it looks like.

Mount Graham Douglas-fir

In terms of moisture stress this site could be characterized as intermediate. Like the Elephant Rock site, it is on a steep slope, but tree density and overall site productivity are higher. The oldest trees are found on a rocky, south facing slope of Mount Graham just below a relatively level bench where road construction and logging has taken place in the recent past (Fig. 9). Several 600 to 700 year old Douglas-fir trees have been sampled here. The oldest tree has an inner-most ring date A.D. of 1257. The inner-most ring of a snag was dated at A.D. 1102, and fire-scarred logs of southwestern white pine (Pinus strobiformis) have been dated back to A.D. 1380. We are unaware of any immediate threats (such as road building or harvesting) to the ancient trees we know about on this mountain, but the overall environmental sensitivity of this area is well known as a result of the heated controversy over the endangered Mt. Graham red squirrel (Tamiasciurus hundsonicus subspecies grahamensis) and the building of an astronomical observatory, which is only about 3 km from the ancient trees (Pennisi 1989, Waldrop 1990).

Rito Claro and Bonita Douglas-fir

These stands are quite different from the other super old-growth stands just described. Both sites are in Cabresto Canyon on the Carson National Forest east of Questa, New Mexico. The Bonita site (Fig. 10) would probably easily classify as old-growth based on the presence of many relatively large diameter Douglas-fir and white fir, multiple canopy levels, and abundant snags and logs. Although structurally this stand appears similar to many other old-growth forests we have sampled in northern New Mexico (see Lynch and Swetnam, this volume), it is unusually old and contains many trees (especially Douglas-fir) that established in the 14th century. Part of the stand is on a north facing slope, but many of the oldest trees are on a relatively level bench just above the canyon floor.

Figure 10. This old-growth mixed-conifer stand, which we call Bonita, is east of Questa, New Mexico. This stand has more typical characteristics that would probably match interim definitions of old-growth. The maximum ages of trees in this stand, however, are atypical.

At first glance it is not at all obvious that the Rito Claro stand is ancient. In fact, it is one of the oldest Douglas-fir stands ever sampled in the Southwest. The site is on a south facing slope that is not especially steep (about 20%), tree diameters are generally small (most trees < 30 cm dbh), tree density is moderate, and the stand is primarily composed of Douglas-fir. Snags and logs are present, but they are not as abundant as in the Bonita stand. We sampled more than 60 trees in this stand, and among this collection ten trees had inner-most ring dates in the mid to late 1200s, and four other trees had inner-most ring dates before 1230. The oldest living Douglas-fir had a pith date of 1210 (Fig. 11).

Figure 11. Oldest Douglas-fir tree in the Rito Claro stand.

DISCUSSION AND SUMMARY

The Southwestern tree-ring data we have analyzed represents only a small proportion of stands that potentially qualify as old-growth. However, this data set is useful as a documentation of the maximum ages of conifer trees that can be found in this region. Because these data are the product of many years of effort to identify the oldest stands, and the oldest trees within stands throughout the region, we argue that the compiled age distributions (Figs. 2, and 3) offer an estimate of what is "rare" in terms of age. The maximum age distributions of three major conifer species - Douglas-fir, ponderosa pine, and piñon - all confirm what dendrochronologists have generally known for many years: Super old-growth stands with trees over 400 years old (establishing before ca. 1590) are somewhat rare, and stands with trees over about 500 years old (trees establishing before about ca. 1490) are very rare.

The available tree-ring chronologies that extend back through the 1500s and earlier show that a very pronounced drought occurred in the late 1500s (Fig. 5). This offers a possible climatic explanation for the temporal pattern of decreased numbers of inner-most ring dates before about 1600. Our sorting of inner-most ring dates by state (Fig. 3) was arbitrarily defined by the state-line, and the resulting distribution by species and state do not show entirely consistent patterns. For example, ponderosa pine in New Mexico does not show an obvious decline in numbers of inner-most ring dates in the late 1500s, but both Douglas-fir and piñon in both Arizona and New Mexico do exhibit such a decline. The Arizona Douglas-fir and piñon sites have a more pronounced increase in numbers of inner-most ring dates in the early 1600s than the New Mexico sites.

Overall, the specific importance, if any, of the late-1500s drought or the subsequent wet period, to the dynamics and age structure of these species is not clear. We do not know if the important effect is on mortality or regeneration rates, or both. The co-occurrence of these climate changes and the age distribution changes could be coincidental, or the relations could be indirect through other climate-related factors, such as disturbance (e.g., fires and insect outbreaks). Better time resolution in the age distributions (annual to decadal) may be needed to verify that a real change in age structure has occurred during this particular time period, especially since it occurs near the tail of the more-or-less bell shaped curves of the overall distribution (Fig. 2).

The super old-growth stands that are highly valued by dendrochronologists for scientific reasons (see discussion below), are distinctly different from the conception of old-growth that many land managers, and the public may have. The controversial endangered species issues of the Pacific Northwest (i.e., the spotted owl) have imprinted the image of old-growth as stately monarch trees with shafts of sunlight streaming down through tall, dense canopies. The Southwest does contain old-growth stands that fit this stereotype, but many of the oldest conifer stands in the Southwest do not. Structurally they are more "woodland" than "forest". The stands are often very open with sparse understory, and trees may be stunted in diameter and height. Sites are typically on steep slopes, with shallow rocky soils, and consequently, productivity (especially tree growth rates) is very low. Most of these sites are unlikely to be targeted for timber harvest. However, they are occasionally threatened by other human disturbances, such as fuelwood cutting, road building, or other development. Currently, the definitions for old-growth do not clearly include this special kind of old-growth.

It is also true that not all Southwestern super old-growth stands fit the descriptions given above. The Bonita stand, and to a lesser degree the Mount Graham stand, are examples of closed-canopy forests that more closely approximate the interim definitions of old-growth, and could be (and have been in the case of the Bonita stand) included in timber sales. While economically harvestable stands containing structural

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