Bristlecone Pine: Science and Esthetics

A 7100-year tree-ring chronology aids scientists; old trees draw visitors to California mountains.

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Bristlecone pine as a unique feature of the plant world has been in the public eye for only a little more than a decade. As the great ages of these trees and the beauty of both the trees and their environment became known, visits to bristlecone-pine localities took on the nature of pilgrimages. And scientists were in the vanguard. This article deals with the development and application of a 7100-year tree-ring chronology for bristlecone pine, *Pinus aristata* Engelm., in the White Mountains of east-central California.

Interest was drawn to the bristlecone pine in 1953 when the late Edmund Schulman began tree-ring studies of species of the upper timberline in a search for evidence of climatic change. He and his colleagues at the Laboratory of Tree-Ring Research, University of Arizona, had for many years studied conifers of the lower forest zones. Then they learned that some upper-forest species, especially trees growing under conditions of stress, also showed a record of sensitivity to drought in their growth-ring sequences. Greater emphasis was placed on this aspect of the study after a limber pine, *Pinus flexilis* James, discovered in Trail Canyon, near Sun Valley, Idaho, was found to have a drought-sensitivity record of almost 1700 years (*1*).

In 1954 and 1955, a widespread search through the western United States resulted in the discovery of three bristlecone pines more than 4000 years old and six others more than 3000 years old (*2*). One, a 3100-year-old specimen, was in the Schell Creek Range, east of Ely, Nevada. All the others were in the White Mountains of east-central California, and this fact caused Schulman to focus his attention on that district of the Inyo National Forest.

Collections by Schulman and Ferguson in 1956 and by Schulman and Cooley in 1957 were reported in the *National Geographic* (*3*), in an issue that went to press just before Schulman's death on 8 January 1958. That article brought the trees worldwide attention, and the U.S. Forest Service, in the course of developing the Ancient Bristlecone Pine Forest, designated one area the Edmund Schulman Memorial Grove (Fig. 1) as a tribute to the scientist whose life work culminated in the knowledge that the bristlecone pine is the world's oldest known living tree.

With Schulman's death, however, our study of the bristlecone pine lapsed until 1961, when the Laboratory of Tree-Ring Research secured support (*4*) for further research.

Chronology building and some of its ramifications are described in this article. Harold C. Fritts, also of the Laboratory of Tree-Ring Research, is preparing a detailed report of the highly instrumented growth studies that were carried on in the White Mountains for three summers and, as a corollary, the analysis of replicated tree-ring samples from 20 different sites in the same range.

Bristlecone pines grow in six states of the Southwest (*5*), but we confined our research primarily to the White Mountains because we knew old trees were there, and such factors as accessibility, research facilities, and climate were favorable. As Pacific storms move inland, the moisture from them falls on the Sierra Nevada, leaving the White Mountains and the intervening Owens Valley in a rain shadow (Fig. 2). Thus, even though conifers in the White Mountains grow at elevations of 3000 to 3350 meters (10,000 to 11,000 feet) above sea level, they are in a relatively arid environment having an average annual rainfall of 305 to 330 millimeters (12 to 13 inches) (*6*). This combination of aridity, a predominantly dolomitic soil (Fig. 3), and a huge mountain mass results in old, slow-growing trees which have a tree-ring record that reflects climatic change. Other factors favor the persistence of both the trees and the wood. The sparse ground cover and the scarcity of litter result in relative safety from ground fire. The highly resinous nature of the compact wood provides resistance to moisture and decay. And the retention of needles for 20 to 30 years insures a somewhat stable photosynthetic capacity that can carry a tree over several years of stress. These age-producing features, combined in varying degrees, occur throughout the range of bristlecone pine; a 4900-year-old tree was recently reported in the Snake Range of east-central Nevada (*7*).

Specimen Collection and Preparation

Radial growth-ring sequences in core samples extracted with a Swedish increment borer are the primary source of chronologic data. In older bristlecone pines, the center of the tree often becomes exposed, due to partial cambial dieback, unilateral growth, and erosion or decay of the dead and exposed wood. When this is the case, it is practical to extract a core from the original center of growth (pith area) with a standard 16-inch (40-centimeter) increment borer.

To secure additional specimens and improve the quality of the chronology in the earlier periods, especially beyond the maximum age of living trees, we began, in 1963, to collect material of two types: (i) cores extracted either from the original central portion of standing or fallen snags (Fig. 4) or from large, eroded remnants of trees, and (ii) entire smaller remnants having the appearance of age and without specific known origin in relation to any tree, living or dead.

Cores obtained from near the original center of the stem (pith-area coring) indicate the general characteristics

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Fig. 1. Entrance to the Edmund Schulman Memorial Grove. Pine Alpha, the first tree recognized to be over 4000 years old, is on the ridge in left foreground.

of the ring record for a given tree and provide the earliest possible date for the specimen. Even though such a core, usually less than 40 centimeters long, may contain many hundreds of growth rings useful in chronology building, pith-area coring is considered only a rapid-survey technique. In contrast, more time is required to obtain the multicore sample that is often necessary to reconstruct the entire curvilinear radius characteristic of the unilateral growth of older trees, a technique developed by Schulman and illustrated by Bowers (*3, 8*).

A study (*9*) of the relationship between the ring pattern along a single radius and the ring pattern of the cross section of which the radius is a part clearly shows that a cross section is of greater value than a core. While a single radius may contain only 95 percent of the annual rings (that is, 5 percent are "missing"), at least half of the missing rings may be found in their anticipated position through careful search of as little as 10 centimeters of circuit. Therefore, remnants are highly valuable in that they provide more surface area for detailed study of the very narrow and often locally absent rings that are critical in chronology building. In addition, remnants constitute the principal source of tree-ring specimens for radiocarbon analyses. And finally, the availability of such remnants makes it unnecessary to cut down a living tree for dendrochronological purposes. In the field, each potential specimen is critically examined to make sure it (i) has an average ring width noticeably greater than 0.10 millimeter (this minimum was established both to lessen the probability of missing rings, which present problems in dating, and to provide a greater volume of wood per year for radiocarbon analysis); (ii) is a pith-area specimen; and (iii) is not too large to be conveniently carried—no small factor at elevations of 3000 meters.

As requests increased for samples of dated bristlecone pine for purposes of calibration in radiocarbon analysis, it became necessary to develop standardized techniques of specimen preparation and dating control. Cross sections of bulk specimens are cut to a maximum thickness of 2 centimeters. For examination of the ring structure, both surfaces are prepared by sanding with successively finer-grit papers. A pinhole on the ring that ends each decade marks the growth-ring chronology along one or more radii. To delimit each unit for carbon-14 analysis, its boundary rings are incised with a probe. Then the unit is cut from the cross section with a specially prepared bifacial chisel. A 20-gram sample that encompasses only 10 years of growth is the standard unit for radiocarbon analysis.

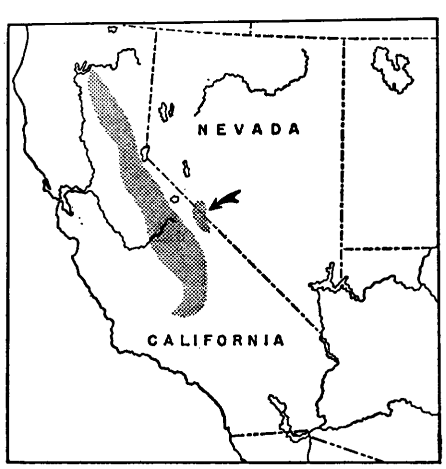

Fig. 2. (Arrow) Location of the Ancient Bristlecone Pine Forest in relation to the Sierra Nevada (larger shaded area).

Chronology Building

Basic to a tree-ring chronology is the fact that each consecutive annual growth ring is assigned to the calendar year in which it was formed. Thus, cores taken through living tissue have the chronology control provided by an outermost ring with a precisely known date. Inward from this so-called "bark" ring, successive annual growth layers are assigned to sequentially earlier years. A pattern of wide and narrow rings which is common to all radii and to different specimens forms the basis for cross-dating among specimens. The master chronology for all specimens involved is unique in its year-by-year pattern; nowhere, throughout time, is precisely the same long-term sequence of wide and narrow rings repeated, because year-to-year variations in climate are never exactly the same.

In certain species of conifers, especially those at lower elevations or in southern latitudes, one season's growth increment may be composed of two or more flushes of growth, each of which may strongly resemble an annual ring (*10*). Such multiple growth rings are extremely rare in bristlecone pine, however, and they are especially infrequent at the elevation and latitude (37°23′N) of the sites being studied. In the growth-ring analyses of approximately 1000 trees in the White Mountains, we have, in fact, found no more than three or four occurrences of even incipient multiple growth layers.

In bristlecone pine, problems of cross-dating are caused by so-called "missing" rings associated with the extremely slow growth rate of this species on arid sites. One specimen in our collection, for example, contains more than 1100 annual rings in 12.7 centimeters of radius. Such slow-growing wood, with an average ring width of only a few hundredths of a millimeter, frequently lacks evidence of growth in a large portion of the circuit during a year of environmental stress. In some instances, 5 percent or more of the annual rings may be missing along a given radius that spans many centuries. The location of such "missing" rings in a specimen is verified by cross-dating its ring pattern with the ring pattern of other trees in which the "missing" ring is present, or by checking against the ring record of the occasional specimen that contains every ring in a span of over 2000 years.

In developing the bristlecone pine chronology for the White Mountains, other chronologies were used for comparison and verification. Schulman's primary cross-dating control was the tree-ring record back to 1250 B.C. for the Sierra Nevada giant sequoia, *Sequoia gigantea* (Lindl.) Decne. (*11*). Since that was the longest chronology then available, he had been increasingly concerned because the bristlecone pine chronology, which he had developed back to 780 B.C., was fast approaching the limits of the sequoia record.

In more recent, computer-based research, Fritts (*12*) demonstrated that the bristlecone pine chronology correlates with chronologies from trees as far away as 1600 kilometers to the east and south and about 480 kilometers to the north. This provides a basis for comparing portions of the White Mountain chronology for recent centuries with the preliminary bristlecone pine chronologies in the Spring Mountains, near Las Vegas, Nevada; in the Panamint Mountains, Death Valley National Monument (*2*); and in the Inyo Mountains, the southern extension of the White Mountain range. Other correlated chronologies include those of limber pine in the White Mountains and of the oldest known limber pine (in central Nevada), with an innermost ring at A.D. 25 (*2*); the integrated modern-archeological chronology for the Southwest, which goes back to 59 B.C. (*2, 13*); and chronologies for both White Mountain and Panamint Mountain specimens of the single-leaf pinyon, *Pinus monophylla* Torr. and Frem., and big sagebrush, *Artemisia tridentata* Nutt., a shrub species that

Fig. 3. A typical bristlecone pine site, showing south-facing dolomite outcrops, sparse ground cover, and trees with a high percentage of dead wood. For contrast, note the more densely covered north-facing slope at right.

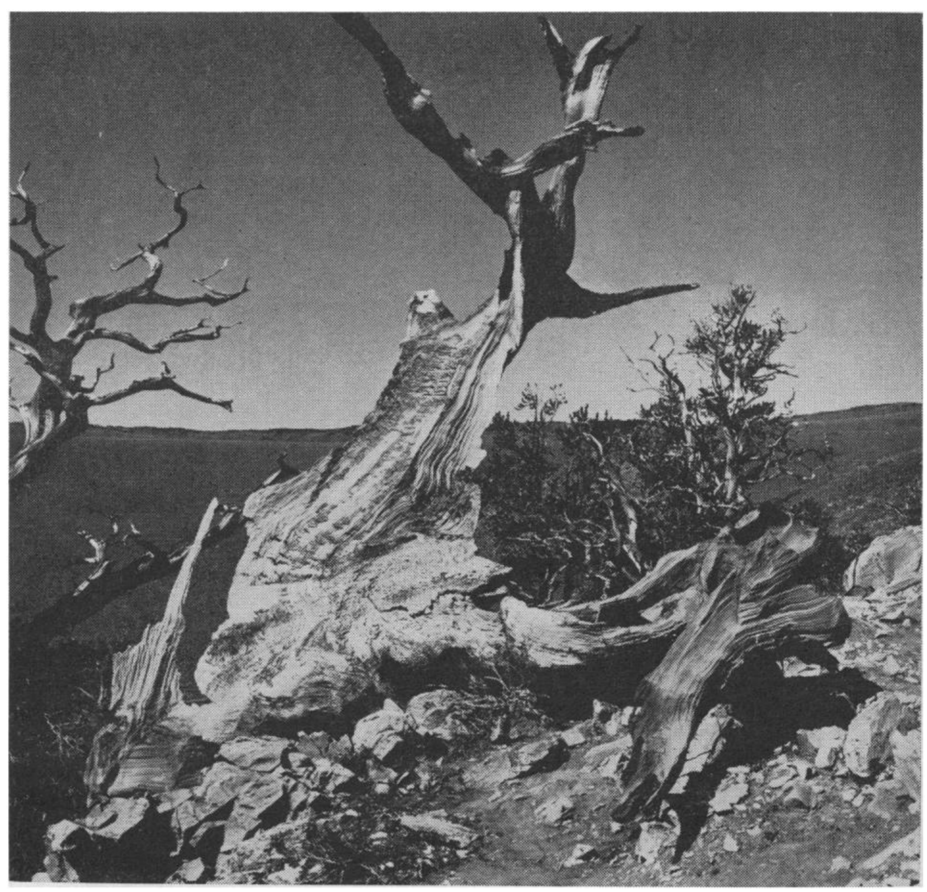

Fig. 4. An eroded snag of bristlecone pine which ceased growing shortly after A.D. 200. This tree was possibly 4000 years old at the time of its death.

Table 1. Comparative data for short and long tree-ring series of (i) "complacent" and (ii) "sensitive" components of the bristlecone pine chronology in the White Mountains of California.

Sample	Mean ring width (mm)	Rings missing (%)	Standard deviation	Mean sensitivity	First-order serial r
		1860–1962			
Complacent		1.44	0.24	0.24	0.11
Sensitive		3.42	.29	.32	.11
		1600–1962			
Complacent	0.29	0.86	.25	.24	.30
Sensitive	.23	2.62	.30	.33	.27

reaches ages of more than 200 years (*14*). Beyond the age limit of each of these controls, however, cross-dating among bristlecone pines themselves became increasingly important. As the number of trees decreases with each successively older age class, therefore, the location and dating of remnants, especially those with more open ring records, becomes of greater concern.

Our intense study of the very early material has, in fact, made the tree-ring chronology for the two millennia prior to 3000 B.C. better known to us than that of some portions of the more recent B.C. period. Tree-ring records of eight remnants of sufficient size to provide cross sections and of one cored snag span all or part of the known interval earlier than 3000 B.C. The earliest 200 years of the record, which then extended back to 4732 B.C., were based on the study of many radii in a series of cross sections from a single specimen. A second specimen, dating back to 4515 B.C., and a third (Fig. 5), to 4466 B.C., made it possible, through cross-dating, to develop a base sufficiently broad to give us confidence in the tree-ring sequence as a chronology. Of the total data prior to 1330 B.C., 55 radii, representing seven specimens, have been dated and measured in hundredths of a millimeter. These measurements, plotted to facilitate comparison, have been individually standardized (that is, the absolute ring widths are expressed as a percentage of deviation from a trend line) and averaged to form both specimen means and a master chronology. These procedures, recently described (*15*), are adapted to standard computer programs (*12*).

Prior to the 1967 field season, the most exciting finding in any cross section had been a 625-year sequence which radiocarbon analysis indicated to be "floating" in a time period earlier than the then-existent chronology. The remainder of this specimen, collected in July 1967, contained over 300 additional rings of more recent time and cross-dated with the known record. Consequently, we were able to extend the chronology back to 5150 B.C. When these data are summarized by the computer, we will have a continuous tree-ring chronology of 7117 years.

Radiocarbon analysis (in December 1967) of a single, small specimen that contains a 400-year, high-quality ring series indicates that the specimen is approximately 9000 years old. This holds great promise for the extension of the tree-ring chronology farther back in time.

Statistical Analysis

We have developed routine computer programs for calculating certain statistical measurements from tree-ring series (*12*). The entire set of rings from the lower trunk of a mature tree can be related to yearly climatic variation by removing, statistically, the gradual changes associated with the age of the tree. An exponential curve is fitted to each series of ring-width values, and measured ring widths are divided by yearly values of the fitted curve. This process transforms the ring-width values to tree-ring indices which exhibit a mean of 1.00 and a variance that is independent of tree age, position within the trunk, and mean growth of the tree. Additional programs include (i) correlation coefficients, which give a measure of common relative variability of indices for pairs of cores from one tree or for different trees; (ii) mean sensitivity, which expresses the relative year-to-year variation in the ring index values; (iii) first-order serial correlation, which measures the degree of dependence of a single growth-ring index upon the index of the preceding ring; and (iv) standard deviation, which measures the variation about the sample mean. A recently developed application of the chi-square test for goodness of fit evaluates the normality of ring widths in any given series (*16*).

From application of these statistical measurements to a particular site, one can infer how certain ecological condi-

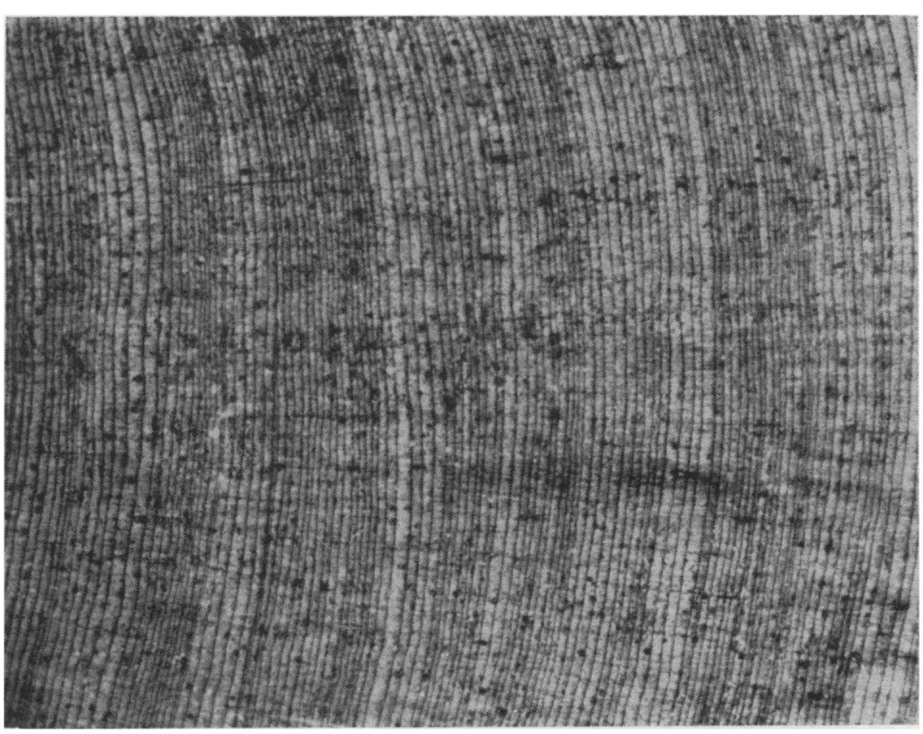

Fig. 5. Growth-ring sequences in the interval from 4290 to 4180 B.C. in a sanded cross section of bristlecone pine.

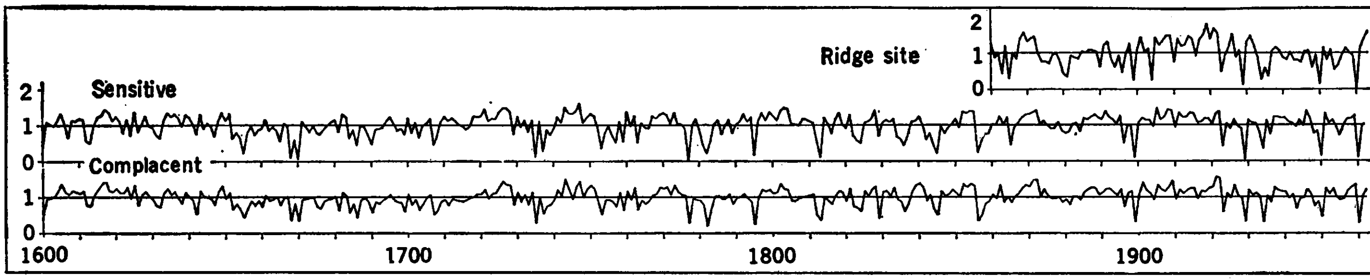

Fig. 6. Tree-ring chronologies for a ridge site (16 trees) and a "sensitive" and "complacent" set (nine trees each). Low points on the plots are diagnostic narrow rings.

tions have limited ring growth (*17*). An understanding of these relationships facilitates the search for sites and trees that contain sensitive records.

As part of the White Mountain study, Fritts examined and compared statistical data from relatively young trees on 19 tree-ring sites. For each site, cores were taken from opposite sides of at least ten trees old enough to provide a 100-year chronology.

I made an independent collection of paired cores from older trees to provide a comparison which would represent site conditions favoring ring growth of a kind we had found to be ideal for chronology building. Most of the trees in my sample had trunks completely enclosed by live bark; in some older specimens, however, the cores were taken from live portions of partially dead trunks. The sample of 18 trees was divided into two groups, representing the most variable ("sensitive") and the least variable ("complacent") chronologies. The two classes of trees (actually comprising components of a gradient rather than representing two distinct sets of site conditions) were intermixed within the site. In my analysis, the standard 100-year chronology was extended back to A.D. 1600.

In Fig. 6, mean standardized values, plotted by a Benson digital computer, provide a visual comparison of the chronologies of a highly sensitive ridge site (*18*) and my "sensitive" and "complacent" sets. The ridge-site chronology, a mean of two cores from each of 16 trees from A.D. 1860, is typical of chronologies from exposed sites with trees which reach great age and contain highly sensitive climatic records.

The statistics for my "complacent" and "sensitive" sets are summarized (Table 1) for a short series, from 1860 to 1962, and for a long series, from 1600 to 1962. The relation of low average ring width to a high percentage of missing rings, high standard deviation, and mean sensitivity fits the generally accepted pattern described by Fritts (*15*). In addition, the correlation of ring-index patterns within trees and correlation of patterns between trees was higher for the sensitive group in both my analysis of the long series and in Fritts's analysis of the short series.

Mean sensitivity, defined as the average ratio of the absolute difference between each two successive widths divided by their mean (*11*), is used as an index of the limiting effects of climate on tree-ring growth (*2*). Standard deviation, which measures variability about the sample mean, resembles the mean sensitivity when the serial correlation is low and where, as in the more complacent series, there are few very narrow rings. The mean sensitivity values become relatively greater in a sensitive series, especially when rings are missing (missing rings are expressed as zero values for single years).

The quality of sensitivity is illustrated for two types of trees by photographs of cross sections of bristlecone pine (Fig. 7). The "complacent" record exhibits little or no variation in ring width from year to year and is typical of trees on sites with characteristics favoring optimum growth. The fairly "sensitive" record, showing variability in ring width, is about midway in quality between that from exposed ridges (Fig. 6) and the sensitive component in my statistical sample.

As sensitivity increases, so, too, does the probability that rings will be missing (*17*). A tree-ring sequence exhibiting extreme sensitivity, having almost the appearance of erratic growth, may contain less than 90 percent of the annual rings along a single radius and thus be too difficult to use initially in chronology building, but ultimately it may provide an excellent climatic record.

The serial correlation (*r*) for both the complacent and the sensitive samples in the short (103-year) series is very low (.11) in comparison with values of .30 and .27, respectively, for the longer (363-year) series. The value for the shorter period is relatively low because a certain amount of the trend which is measured by serial correlation is removed when a growth curve is fitted to a shorter series. The

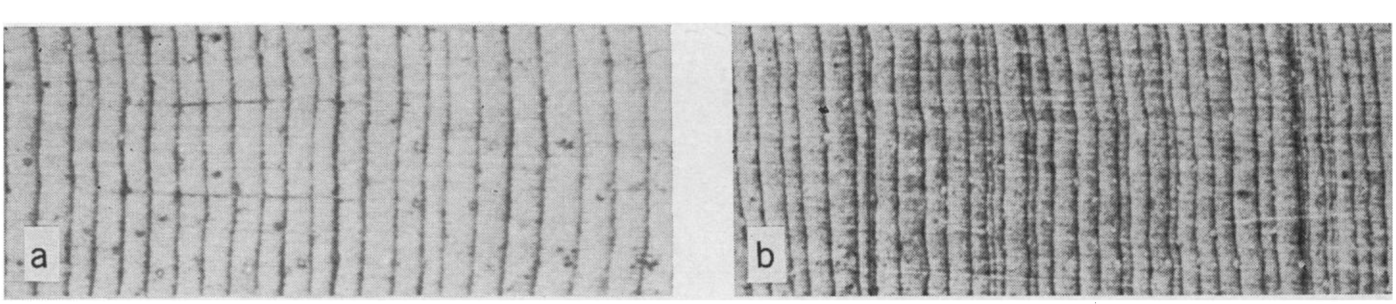

Fig. 7. Sanded cross sections of bristlecone pine showing (a) complacent and (b) moderately sensitive growth-ring response.

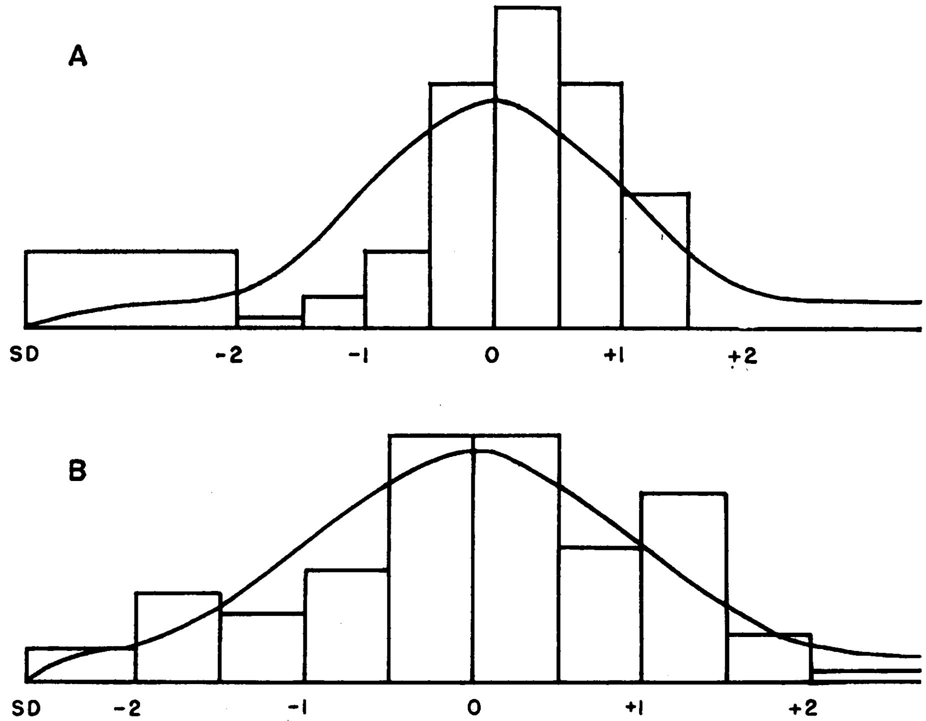

Fig. 8. The frequency distribution of bristlecone pine ring-width indices for (A) a significantly nonnormal and (B) a normal pattern. The curve represents the theoretical frequency and the histogram the observed frequency. The longitudinal axis represents the index values, but the histogram units equal half the standard deviation.

Fig. 9. "The Patriarch," the largest of its species, though, at 1500 years, scarcely the oldest.

higher values, however, are representative of the longer cores collected for chronology building.

In our chronology building we noticed that cores from the site where I collected my sample for statistical analysis were generally complacent but contained a small percentage of diagnostic narrow rings. A chi-square test for goodness of fit may be used to describe and illustrate this unusual distribution of ring widths (*16*). In Fig. 8A the observed frequencies of ring-width index values in the sensitive component of my statistical analysis group are plotted relative to the normal curve of distribution. The observed distribution is significantly nonnormal ($P = .01$), as indicated by a larger-than-normal observed frequency of small rings below two standard deviations, the remaining values being displaced toward the upper range. In a chronology with these characteristics, only the small rings represent the limiting effects of climate; the remainder vary about the mean and serve primarily to indicate the passage of time (*19*).

The ridge site (Fig. 8B) exhibits a stronger climatic relationship, in which all or nearly all of the rings are more or less limited in growth by climate. Such a sensitive site has a chronology in which the observed distribution of index values does not differ significantly from the theoretical normal curve. Two standard deviations encompass a greater range of index values.

Now that we have established a 7100-year chronology, we are strengthening this tree-ring record by incorporating specimens which are more sensitive to climate. As specimens are dated, measured, and standardized, we evaluate them in terms of measures of sensitivity, correlation, and the chi-square test for goodness of fit, and thus are able to describe the specimens in terms of variability and distribution of ring width. On the basis of this evaluation we are selecting specimens that will provide maximum information about climate for incorporation into the master chronology.

Relation to Radiocarbon

The rate of production of radioactive carbon-14 in the atmosphere has varied only slightly throughout the past two millennia. But at a point about 2000 years ago these variations unilaterally depart from the hypothetical

1 : 1 ratio, the dates obtained by the carbon-14 method being consistently more recent than those of established chronologies (*20*). The discrepancy indicated by radiocarbon analysis of dated sequoia wood and of material from early Egyptian dynasties is substantiated by the results of carbon-14 dating of bristlecone pine wood from comparable time periods. Dual dates, derived from the radiocarbon analysis of tree-ring-dated bristlecone pine wood show that, for material in the period 4000 to 3000 B.C., dates obtained by the conventional carbon-14 method are about 800 years more recent than dates established dendrochronologically (*21*). There is at present a spirited debate concerning the possible direction and causal nature of this relationship, a point that may be resolved when even earlier wood is found and dated, as we expect it will be.

A study of these variations and trends as far back as the bristlecone pine record now goes offers an opportunity to perceive changes in the magnitude of solar activity and the number of sunspots, and in the related cosmic-ray flux, rate of production of carbon-14, and terrestrial climate.

Studies made in cooperation with radiocarbon laboratories at the universities of Arizona, California (San Diego), and Pennsylvania are a major aspect of the present project (*20*). The Laboratory of Tree-Ring Research provides precisely dated wood in 10-year unit samples throughout the 7100-year tree-ring chronology, for the calibration of dates derived by radiocarbon analysis in terms of cycles and trends. As of 1 October 1967, 369 tree-ring-dated samples of wood, representing the broad time intervals listed in Table 2, had been sent to the various laboratories engaged in this work.

Occasionally, a sample from a specimen not yet dated by tree-rings is submitted for radiocarbon analysis. The date obtained indicates the general age of the sample; this gives a clue as to what portion of the master chronology should be scanned, and thus the tree-ring date may be identified more readily. Since the plot for the master chronology (scale, 2 millimeters = 1 year) is 14.2 meters long, the advantage of such a clue from radiocarbon dating is apparent. Of 18 undated remnants that have been submitted for carbon-14 analysis, seven were subsequently tree-ring-dated and the remainder are still being studied.

Since early in its development as a science, dendrochronology has been strongly associated with archeology. Tree-ring dating, indeed, was until recently almost exclusively a tool for archeologists in dating timbers and other wood from sites in the Southwest.

Table 2. Number of 10-year unit samples for various periods of the 7100-year tree-ring chronology which have been submitted for radiocarbon analysis.

Interval	Number of specimens
A.D. 1570–1	27
1–1000 B.C.	47
1001–2000 B.C.	96
2001–3000 B.C.	86
3001–4000 B.C.	71
4001–4400 B.C.	35
5001–5110 B.C.	7

Use of the bristlecone pine chronology in dating past events has so far been limited. A small wood fragment from an upper level in Crooked Creek Cave, an archeological site (*22*) recently excavated by the Eastern California Museum at an elevation of 3000 meters in the White Mountains, indicated a date in the early 1600's. Other specimens from the cave are being studied.

The bristlecone pine chronology developed by Schulman (*23*) for the Panamint Mountains and White Mountains aided in establishing the fact that single-leaf pinyon pines were cut in the 1870's for use in the charcoal kilns in Death Valley National Monument (*14*).

In a specifically designed program, dated bristlecone pine wood, dated by the tree-ring method, served for calibrating the results of radiocarbon dating of oak used in Swiss Lake dwellings. By comparing ages obtained by carbon-14 dating of eight samples of bristlecone pine from the period 4078 to 3595 B.C. with a series of dates obtained by carbon-14 analysis of eight specimens from a 311-year sequence from the Thayngen and Burgäschisee-Süd settlements, it was demonstrated that the dwellings were constructed during the 38th century B.C., about 1000 years earlier than had been previously estimated on the basis of radiocarbon dating alone (*21*). This suggests that, as more and more dual radiocarbon and tree-ring age determinations are made and as the fluctuations and trends are defined, it will be increasingly possible to interpret dates obtained by the carbon-14 method from other woody materials, on a worldwide basis.

Bristlecone pine chronologies are being used in other disciplines. For example, they have been used to determine the rate of short-term geologic erosion (*24*). The ages of trees are equated against the observed amount of surface lowering and corresponding root exposure. For two different substrates—dolomite in the White Mountains and limestone in the Cedar Breaks area of southwestern Utah—the resulting value for rate of slope erosion is roughly 0.3 meter per thousand years. A combination of radiocarbon dating and a study of annual rings in the remains of bristlecone pine trees has been used to establish the retreat of forests from subalpine mountains in California and Nevada during the past 5000 years, probably indicative of a long-term temperature decline (*25*). Counts made of pollen in traps formed by enclosed bark in two remnants of bristlecone pine have recently been reported (*26*).

Esthetics and Recreation

Growing in esthetically appealing environments, worn by time and weather, and unique for their longevity, bristlecone pines are indeed one of nature's attractions. It is not surprising, therefore, that increasing numbers of people tour the bristlecone pine area. In 1965 the U.S. Forest Service officially tallied 18,000 visitors in the Ancient Bristlecone Pine Forest; the estimate for 1966 exceeds 20,000 (*27*).

The Forest Service itself played a part in initiating interest in the trees. Twenty years ago, Alvin E. Noren, then forest ranger, discovered a large, multistemmed bristlecone pine, which he named "The Patriarch" (Fig. 9), and submitted its measurements to the American Forestry Association (*28*). The tree was entered, in September 1951 (*29*), as the largest of its species. Following this action and an official survey, the Forest Service, in 1953, designated 2330 acres (930 hectares) adjacent to the Patriarch as the White Mountain Natural Area for the preservation of the bristlecone pine.

As a consequence of Schulman's research, an additional 27,160 acres were established, in April 1958, as the Ancient Bristlecone Pine Forest, for "the purpose of protecting and preserving the ancient specimens of bristlecone pine found within the area and for public enjoyment thereof." The Forest Service has made considerable progress in developing the area under the recreation phase of its multiple-use program. Besides a paved road, constructed with the cooperation of the county, there are camping facilities, picnic facilities, and self-guided trails and interpretive displays; a naturalist is on duty in Schulman Grove during the summer.

Increasing publicity, especially in travel magazines and local communication media, has made the public aware of bristlecone pines and their esthetic qualities. The work of our Laboratory, in particular, has increased public awareness of these trees. Consequently, bristlecone pine areas, no matter how remote, are subject to man's activities. For example, there is a long tradition (considered by many a moral right) that visitors to the forest, desert, and seashore may collect ornamental wood, and the general multiple-use policy of the Forest Service does not discourage such collecting in any except designated areas. The beautiful sculpturing of the bristlecone pine wood makes it particularly desirable, and even in areas where collecting is restricted, wood is still disappearing. In our research in the White Mountains and other bristlecone pine areas, we have noted that the more accessible the area is, the less wood there is on the ground and the more saw cuts there are on the trees. As a dendrochronologist, therefore, I must compete with the public for my basic research material; a small, often quite attractive piece of wood that may hold the solution to a dendrochronological problem may become someone's personal memento.

Science and esthetics can continue hand-in-hand in the bristlecone pine areas through interpretation and education. As our scientific knowledge increases, its essentials can be conveyed to the public. The need for protection may be lessened by such education of the visitor, which might lead him to appreciate the beauties of nature in terms of the interests of posterity rather than his immediate personal gain.

Summary

A 7100-year tree-ring chronology has been developed for bristlecone pine, *Pinus aristata* Engelm., in the White Mountains of east-central California by the addition of data from long-dead specimens to the 4600-year record from living trees. These dendrochronological studies have major applications to climatic interpretations, radiocarbon analysis, and the dating of past events.

The great age of these trees and the esthetic appeal of both the trees and their environment are drawing increasing numbers of visitors to the bristlecone pine areas. Concern is expressed for the preservation of this ancient wood.

References and Notes

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