UNSOLICITED PROPOSAL SUBMITTED TO
THE DEPARTMENT OF ENERGY

by

Laboratory of Tree-Ring Research
University of Arizona
Tucson, Arizona 85721

for

Dendrochronology of Bristlecone Pine

Proposed Duration: 3 years

Amount Requested: $272,601

Requested Starting Date: 1 October, 1980

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Make Grant to: University of Arizona
IRS Number 86-6004791 Cong. District Number 2

Date of Submission: 29 April, 1980

This proposal may be subjected to external review.

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ABSTRACT

Since 1953 the Laboratory of Tree-Ring Research has conducted dendrochronological studies of bristlecone pine (Pinus longaeva D. K. Bailey, sp. nov.) in the White Mountains of California. This research resulted in the establishment of a continuous tree-ring sequence of 8,680 years which proved to be a unique source of chronological data and provided precisely dated wood specimens essential to certain paleoenvironmental and geophysical investigations. Dendrochronologically dated decade samples of bristlecone pine continue to be supplied to C-14 laboratories for the calibration of the radiocarbon time-scale, a development of far reaching consequences in the fields of archaeology and geology. To more fully understand the causative factors, especially the activity of the sun, a critical need exists to better define the fluctuations and trends of the C-14 curve through even stronger and earlier bristlecone pine controls. In addition, recent advances in other methods of analyzing past climatic variability--particularly techniques involving stable isotope ratios--have greatly increased the demand for wood of known age and, hence, for chronology development.

During the past 18 months, the early portions of the chronology have been greatly strengthened and extended. The objective of the proposed research is to continue the extension of the bristlecone pine chronology further into the past and to strengthen it by incorporating additional dated specimens from the White Mountains and nearby areas. Prospects for a 10,000-year chronology appear increasingly possible.

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October 1, 1980 - September 30, 1983

DENDROCHRONOLOGY OF BRISTLECONE PINE[1]

C. W. Ferguson

Since 1953 the Laboratory of Tree-Ring Research has conducted dendrochronological studies of bristlecone pine (Pinus longaeva D. K. Bailey, sp. nov.) in the White Mountains of east-central California where living trees reach ages in excess of 4,000 years. Extension of the chronology, made possible by the crossdating of the ring patterns of remnants with those of living trees, has resulted in the establishment of a continuous tree-ring sequence of 8680 years from the present back to 6701 B.C. The millennia-old pines are a unique source of chronological data and the dendrochronologically dated wood is essential to certain paleoenvironmental and geophysical investigations. More than 1,000 decade samples of bristlecone pine supplied to three radiocarbon laboratories have been essential for the calibration of the radiocarbon time scale, primarily in the B.C. era, a development of far reaching consequences in the fields of archaeology and geology. In addition, recent advances in other methods of analyzing past climatic variability--particularly techniques involving stable isotope ratios--have greatly increased the demand for wood of known age and, hence, for chronology extension.

1) Previous grants by the National Science Foundation to the University of Arizona in support of the bristlecone pine project have been: G-2274 (1956), G-19949 (1961), GF-2171 (1963), GP-4892 (1965), GA-20618 (1969); EAR76-14782 (1976), and EAR78-04436 with the assistance of the Department of Energy contract no. EE-78-A-28-3274.

OVERVIEW

Collection and analysis during 1978-1979 have more than doubled the number of dated remnants in the period before 4000 B.C. Figure 1 diagrammatically summarizes, as of 10 December 1979, the 69 dendrochronologically dated specimens that partially or entirely predate 4000 B.C. Thirty-seven of these predate 5000 B.C. and 10 predate 6000 B.C. The earliest dated remnant, weighing 90 pounds (41 kilograms), entirely predates 6000 B.C. and extends the chronology to 6701 B.C.; it is still being studied.

The greater length and numerical depth of the present chronology has increased our ability to date additional specimens. Fourteen tree-ring sequences have been merged to extend the master chronology to 6329 B.C. When the 10 specimens that predate 6000 B.C. are completely studied, the master chronology will be extended to 6701 B.C.

The innermost rings of the earliest specimens are progressively greater in age as shown in Fig. 1. A 508-year "floating" sequence, dated by four radiocarbon laboratories as over 9,000 years old, indicates the potential of a continuous tree-ring chronology of 10,000 years once a gap estimated at less than 1,000 years has been crossed.

Long-term chronologies are in hand or in the process of development for other bristlecone pine sites in California, Nevada, and Utah (see pp. 7 to 8). These could form a temporal and geographic grid of tree-ring sites for climatic reconstruction and the interpretation of the 22-year solar cycle (Mitchell, Stockton, and Meko, 1979, Dicke, 1979).

As the tree-ring chronology developed, so too has our stockpile of bulk wood. The usual sample submitted for the C-14 calibration studies is a ten-year unit weighing 20 grams. As the samples were prepared, the extra wood -- that over the 20 grams and that from intervening decades --

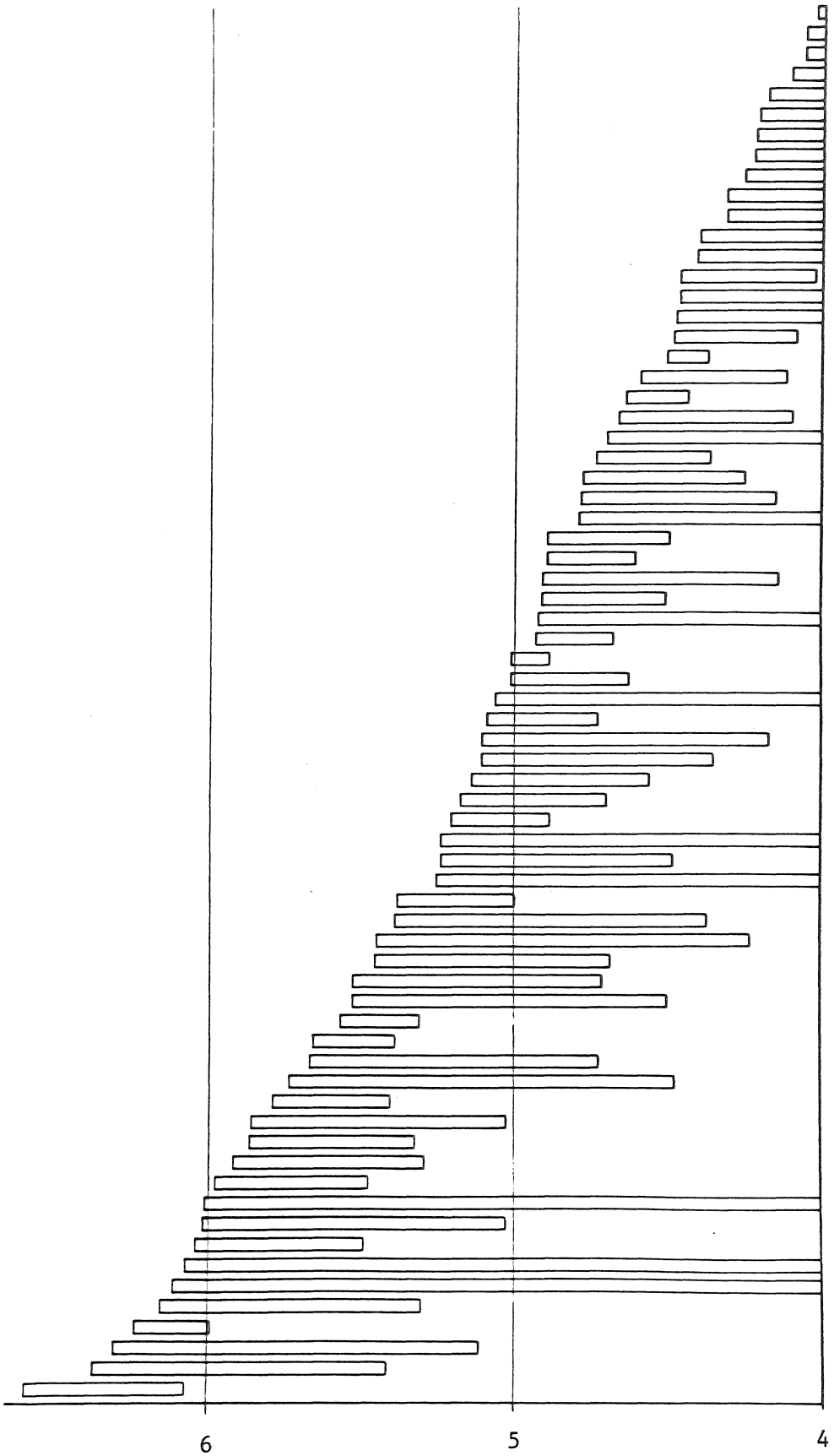

Fig. 1. Time span of 69 specimens partially or entirely predating 4000 B.C. Each bar represents one specimen. The time scale is in units of 1000 years B.C.

was stockpiled. These units, ranging from one to about 100 grams, span the past 7,500 years. A recent computerized inventory (Table 1), listing 1,138 prepared samples with a total weight of nearly 16,000 grams, is available upon request and these "off-the-shelf" samples can be supplied to qualified investigators (Ferguson, in press).

TABLE 1. Dated samples available for radiocarbon analysis.

Interval	Number of Samples	Grams
A.D. 1974-1001	85	1931
A.D. 1000-1	75	1160
1-1000 B.C.	147	1079
1001-2000 B.C.	115	1121
2001-3000 B.C.	304	4270
3001-4000 B.C.	264	3916
4001-5000 B.C.	128	2192
5001-5500 B.C.	20	89
Total	1138	15758

PROGRESS REPORT, 1978-9

A storage and retrieval system was developed for all measurements, indices and other descriptive statistics that are normally produced for specimens. More than 160,000 records (card images) have been entered into our computer system.

White Mountains

In the summer of 1979, a collection of multiple cores from full-bark trees, 90 cores from 30 trees, was made in Methuselah Walk to provide a greater length for the modern base for the extension of the chronology into the past. These are being dated and measured and the improved modern chronology should be completed during the spring of 1980.

Approximately 100 bulk specimens were collected in 1978-9. Forty-four of these have been dated, measured and plotted (Table 2); 22 predate 4000 B.C. Twenty-one have a C-14 date only; six of these predate 4000 B.C. The remaining specimens are still under study.

Table 2. Time ranges represented by tree-ring and radiocarbon dates for individual bulk specimens collected in the White Mountains 1978-9.

Interval, B.C.	Tree Ring	C-14	Total
1-1000	3	3	6
1001-2000	4	3	7
2001-3000	7	6	13
3001-4000	8	3	11
4001-5000	6	5	11
5001-6000	10	1	11
6001-6600	6		6
Totals	44	21	65

We have in hand about 75 specimens, each having from 500 to over 1000 annual rings, that are partially or entirely prior to 4000 B.C. In many cases, the total specimen has been collected; the others could be relocated and also collected in bulk. This volume of wood makes possible a more detailed tree-ring study and provides the quantity necessary for C-14 analysis.

Previously, with the emphasis on old wood, not much bulk material in the A.D. period had been collected. As a result of requests for the more recent wood, the 1979 collections included about 500 pounds selected to fulfill these requests.

The major collection area, in Methuselah Walk, had previously been mapped in ten-foot contours and 458 specimens -- trees, snags, and large remnants -- have been tagged and mapped. Thus, any new specimen can simply be added to the map by triangulation with specimens of known location. The mapping has greatly facilitated our work which very often includes resampling. With this control and with the increased number of sampled specimens, we feel, for the first time, that we are in a position to essentially collect on order.

In the 1980 field season (only partially covered by the present grant), we plan to revisit each collected specimen (or site, if the total material has been collected) and evaluate it in terms of its physical appearance, general provenience, growth characteristics, and age in an effort to improve our site and specimen criteria in terms of the conditions that are producing the old wood. Concurrent with this, we are plotting on the Methuselah Walk map the provenience of the specimens with innermost rings in the 6,000's, 5000's and 4000's B.C. Perhaps the 69 dated specimens (most of which are from Methuselah Walk) will show some significant grouping and provide a guide for the location of additional old wood.

Panamint Mountains

Analysis of data from paired cores from the Panamint Mountains, California, is nearly ready for merging into site chronology. Single records from older trees (one, for example, with 1360 rings) will be added for chronology development. Radial sections from old stumps gave bark dates in the 1870's, showing that an upper treeline area of bristlecone pine was logged during the period of mining activity at the nearby Panamint City.

Sheep Range

Master chronologies for four species have been completed for the Sheep Range, Nevada. The species and the beginning dates are: bristlecone pine, A.D. 760; ponderosa pine, A.D. 1313; white fir, A.D. 1606; and pinon pine, A.D. 1681.

Spring Mountains

The modern collections from the Spring Mountains, Nevada, include 32 cores from 24 bristlecone pines and 24 cores from 9 white firs. The bristlecone pine cores have been dated and measured. A final chronology from A.D. 1080 to 1979 will be completed in January, 1980. A recently acquired cross section, provided by the Forest Service, dates to A.D. 850. The white fir cores have been dated and measured. A chronology from A.D. 1650 to 1979 will be completed in spring of 1980.

White Pine Range

The collection from the White Pine Range, Nevada, consists of nine bulk specimens. All have been surfaced, measured and plotted on an arbitrary time scale. This site will be a major part of future work (see pp. 18 and 19).

Other Sites

Fifteen trees were sampled in the Schell Creek Range near Ely, Nevada and a site chronology is near completion.

A new site in the Mammoth Creek drainage in southwestern Utah was collected in the fall of 1979, and is now being studied.

A newly reported stand of bristlecone pine, at the north end of the Potosi Range near Las Vegas, Nevada, was visited and duly recorded as a range expansion for the species. The very few trees were associated with white fir and were not of sufficient age, sensitivity, and numerical depth for sampling.

RADIOCARBON STUDIES

Initial emphasis of the bristlecone pine project, in 1956, on the establishment of an accurate tree-ring chronology for climatic analysis soon expanded to include the provision of accurately dated samples for the calibration of the radiocarbon time scale. By the late 1960's, radiocarbon analysis of wood of historically known age and of dendrochronologically dated wood had resulted in sufficient data to show that radiocarbon dates were not in total agreement with our conventional solar calendar. Reasons for the discrepancy, described in Olsson (1970), are now fairly well understood (Damon, Lerman and Long, 1978).

Workshop on Calibration of the Radiocarbon Time Scale

Radiocarbon specialists, dendrochronologists, statisticians, representatives of archaeological, geophysical, and geological users groups and the National Science Foundation (whose support made the conference possible) met at the University of Arizona in Tucson January 28 to February 2, 1979 to review the current data bearing on the calibration of the radiocarbon time scale.

The principal stimulus for the workshop was the recognition that there was a critical need to generate a consensus radiocarbon calibration framework to replace the various calibration charts, tables, and curves now current in the literature. Three radiocarbon research facilities, the Arizona, the La Jolla and the Pennsylvania radiocarbon laboratories, have been responsible for producing most of the radiocarbon data on dendrochronologically-dated bristlecone pines. Present were Minze Stuiver, director of the University of Washington laboratory and senior editor of Radiocarbon, and Douglas Donahue, co-principal investigator of the accelerator facility now in construction at the University of Arizona for the analysis of radiocarbon and trace elements.

The goals of the workshop were (1) the formulation of a calibration table for users who have single radiocarbon determinations of varying statistical precision, (2) the formulation of a series of graphs describing the high frequency components of the calibration curve, and (3) publication of revised radiocarbon determinations on bristlecone pine samples in the same format by all laboratories. Graphs and tables presenting such data with detailed instructions for their use will be published in Radiocarbon.

The significance of the workshop is that, for the first time, those principally involved in the issues surrounding the calibration of the radiocarbon time scale have agreed to a single calibration scheme utilizing a coherent set of data expressed with respect to the same set of standards. For almost a decade, all laboratories working on the calibration problem have been in essential agreement about the nature of the long-term variations and the existence of short-term, or high frequency variations in C-14 activity. As a result of the workshop, there is considerable agreement as to the frequency and magnitude of these short-term variations during the last few millennia.

Tandem Accelerator Mass Spectrometer

The National Science Foundation has begun a pilot program to develop regional, state-of-the-art instrumentation facilities that can be shared by researchers at different institutions and in different disciplines.

The first six regional facilities include a carbon-14 dating and trace element analysis accelerator facility at the University of Arizona. The Tucson facility is an example of the inter-disciplinary research that these regional labs encourage. It is operated jointly by the departments of geosciences and physics and offers analytical capabilities useful in geology, archaeology, biology, medicine, chemistry, forensic science, and environmental studies (N.S.F. grant CHE78-18576).

The primary function of the tandem accelerator is carbon-14 dating. Using the accelerator, an investigator can date 1- to 2-mg samples of 19th century carbon within half an hour with a precision of 1%, compared with conventional techniques that require 1000 mg and 10 hours of counting time.

The technique makes it possible to date samples too small or too old for dating by conventional methods. We now have the capability to obtain a year-by-year record of carbon isotopes in the cellulose of tree rings providing the data base for a much more detailed record of solar activity and geomagnetic field variations.

Until there are results of known quality with the new program, the calibration prior to 6000 B.C. will be done by the conventional method. Initial work will focus on the analysis of one-year samples in which there are extreme fluctuations or sudden changes, as indicated by the results of the calibration workshop. Anticipating a functioning laboratory by September 1980, at that time, they would like to have 20 samples ready to run. They would like to have 50 samples in 1980 and 150 in 1981. Assuming that the

periods of critical interest would be in time ranges in which we had usable wood (ideally, with large rings) is not covered in their budget. Based upon the long-term cost of specimen preparation for the calibration program, the cost per sample has been roughly $150.00 to $200.00 if the cost of specimen collecting and chronology development is taken into consideration. Current distribution of decade samples from our inventory requires an investment of $5.00 to $10.00 just to check, clean up, weigh, annotate, package and mail a sample. This figure includes no research and development and soon the supply would be exhausted. The needs, however, tend to be in new time periods where there is little or no wood on hand; this requires the R and D investment to make the material available.

Cooperative Studies

There have been increasing needs for dated wood in various isotopic studies. As various contributors in Climatic Change and Variability: a Southern Perspective (Pittock, et al, eds. 1978) point out, it is important to understand the rising concentration of atmospheric CO_2 and its relationship to climatic change. To this end, the proposed project may be of assistance by strengthening and lengthening the bristlecone pine chronology and by making dated wood available for isotopic studies.

A sample from A.D. 1500 to the present has been sent to Dr. Roger J. Francey, C.S.I.R.O. Melbourne, for C-13/C-12 studies in comparison with wood from Tasmania.

From the point of view of the bristlecone pine project, there was one immediate agreement resulting from the calibration workshop. Four radiocarbon laboratories, at the universities of Arizona, California (San Diego),

Pennsylvania, and Washington, agreed to collaborate on the calibration from 5400 B.C., the present limit, to 6000 B.C., a point where four laboratories have analyzed 20 decade samples (Ferguson, Gimbutas, and Suess, 1978; Suess, 1979). To provide the most unified control so far, I am providing every third decade sample to each of three laboratories; larger samples through this time range will go to the fourth laboratory (Washington). Their cooperative results are to be published in Radiocarbon.

In an effort to provide for an inter-laboratory comparison, I have distributed to eight laboratories alternate decade samples for a 200-year period, 4100 to 3900 B.C. Half of these are duplicate sets; the other half is from the alternate decades. The 200-year span, however, should make each set of 10 samples a comparable unit. The source, a log from a tree that started growing prior to 4250 B.C., is of such ample quantity that additional sets can be provided to other laboratories, perhaps on a worldwide basis.

Drs. Damon and Long, at the University of Arizona; Dr. Suess, at the University of California, San Diego; and Dr. Michael, at the University of Pennsylvania, are similarly involved with the calibration of the radiocarbon time scale based upon the early bristlecone pine. Current cooperative research encompasses the period 5400 to 6000 B.C. All three laboratories continue to aid in the exploratory dating of bristlecone pine remnants.

Secondary interests focus upon gaps and possible anomalies in the present calibration curve. A recent tabulation, resulting from the calibration workshop, showed that there were many decades that were represented by one or zero samples. It is felt that, ideally, each decade should be represented by two dates. Thus, additional samples would be required to double the single counts; to fill in the decades with no representation;

and to provide two dates for these decades. Currently, the inventory is being checked and many of these weak or questionable intervals will be filled by the relatively immediate analysis of these off-the-shelf samples.

Stuiver and Quay (1980) report on their radiocarbon analysis of 860 years of tree-ring material from Northwest Douglas-fir. The record is interpreted in terms of a variable sun and indicates three episodes when sunspots apparently were absent. To extend this study, they currently are working on sequoia extending to A.D. 200 and are interested in securing earlier dated sequoia or other (non-bristlecone) species. One of our 1979 "bristlecone pine" remnants was a pinyon pine that dated 1000-600 B.C. Its ring size is far greater than in the bristlecone pine. The time period it represents and the fact that it is a new species for the calibration makes it ideal not only for Stuiver's purposes (extending through the first millennium B.C.), but for other uses as well.

Some questions have arisen concerning the possible deposition of C-14 at the heartwood-sapwood boundary (Cain and Suess, 1976; Long, et al, 1976) and a possible hemispheric difference at about the same time, ca. A.D. 1900. A solution to both questions may lie in the analysis of sound sapwood in the trees that died 50, 100, 150, and 200 years ago. For some time, I have been collecting stump material from logging about the turn of the century. Many of the stumps represent not living trees, but snags--trees that had died decades or even centuries before. Many of these still have sound sapwood (in at least part of their circuit) and could be used for this type of study. I have recently sent Stuiver descriptions of these stumps, especially of the 1979 collections, so that he can evaluate them in terms of his specific needs; then we will process the required samples.

Stuiver has recently been sent a continuous series, from the present back to more than 700 years, for the analysis of Carbon-13. This will provide a duplication of the work by Wilson and Grinsted (1978). Stuiver's laboratory is one of four cooperating on the calibration in the period 6000-5400 B.C. The other three laboratories are each analyzing every third decade. Stuiver, who requires a 50-gram sample in contrast to the usual 20-gram sample required by the other laboratories, will receive nearly a comparable number of samples, but at more random intervals and perhaps from different specimens.

Stuiver is currently analyzing oak, provided by Dr. Becker from alluvial gravels in southern Germany, with a C-14 age of 8400 B.P. This is still "floating" in time, both in relation to the Germany tree-ring chronology and to calibrated radiocarbon dates. Bristlecone pine at 6000 B.C. provides C-14 dates of 7500 B.P. By dating some of the earliest bristlecone pine wood, at 6600 to 6500 B.C., we should be able to get close to the calibration for the Becker wood.

To continue previous work (Epstein and Yapp, 1976), Dr. Samuel Epstein at the California Institute of Technology is being provided with dated wood from the present back into the past. The initial piece for extension was a section from a tree recently removed by a snow avalanche. The section dated from the present back to 814 B.C. Other bulk material in hand should enable this analysis to be extended back to 6600 B.C.

Archaeological Relationships

Scientific investigations of bristlecone pine provide several types of information that are important to not only the Southwest, but to the worldwide archaeological community.

Tree-ring calibration of radiocarbon dates has permitted drastic revisionsof temporal sequences of cultural developments in western Europe (Renfrew, 1973, 1974, 1977; Wilson, 1975). On this side of the Atlantic, the ongoing calibration in the 7th to 9th millennium B.P. will ultimately provide North American archaeologists with a basis for refining the chronological framework of most of the Archaic period of cultural development. As the bristlecone pine chronology is extended beyond the current limit of 6700 B.C., it will be possible to extend the calibration into the period of Paleo-Indian activity in the western hemisphere. Simultaneously it will then be possible to compare C-14 activity of the bristlecone with that of oak chronologies from continental Europe (Becker, 1979; Beer, et al, 1979; Lambert and Orcel, 1979), and the British Isles (Pilcher, et al, 1977). This will permit the temporal placement of the earlier segments of the European chronologies and of archaeological materials that crossdate with them or have similar C-14 activity. This type of work has a number of precedents (Cain and Suess, 1976; Ferguson, Gimbutas and Suess, 1976) and appears to be the best procedure at this time for developing calibration of C-14 activity in the range of 9- 11,000 B.P.

On a regional scale, bristlecone pine provides a unique resource for both chronology control and paleoclimatic reconstruction in the Great Basin. Dendrochronological dating of wood from archaeological sites, using bristlecone pine, has been accomplished (Graybill and Ferguson, manuscript),

and other potentials can now be explored. More than 20 bristlecone chronologies from the area are in varying stages of development. Most are continuous for the past thousand years. We have found that they crossdate well among themselves and with lower elevation species such as pinon pine (Pinus monophylla) and ponderosa pine (Pinus ponderosa). Thus the possibility of dating a variety of species of wood that might occur in archaeological sites, using a bristlecone chronology for a master control, is quite good.

As the number of bristlecone sites over the basin expands it will be possible to develop paleoclimatic reconstructions similar to those produced by Fritts (1965, 1976) for western North America, but with much greater geographic resolution. While these data will provide a paleoclimatic record of the past 800-1000 years, there is potential for a limited number of longer term perspectives. The Methuselah Walk chronology from the western edge of the Great Basin and a chronology under development in eastern Nevada will eventually permit a two-point comparison of growth trends in drought-stressed bristlecone pine over the past 5000 years. As climatic trends become discernible it will provide prehistorians with new data for understanding the background of human adaptations in the area.

OBJECTIVES AND SIGNIFICANCE

The objectives of this proposal are to continue the dendrochronological studies of bristlecone pine in terms of time (chronology extension) and space (into new geographic areas). The basic significance lies in its unique and critical role in relation to other disciplines, especially those of radiocarbon dating and paleoclimatic interpretation; without dated samples as controls, major laboratories would not be able to continue the radiocarbon calibration and related studies.

PROPOSED RESEARCH

This proposal is designed to make possible the continued development of the bristlecone pine chronology by strengthening the present chronology of 8,680 years, by possibly extending it even further into the past, and by the development of other bristlecone pine chronologies in new areas. The resultant publications will be of interest to the climatologist and to those involved in radiocarbon analysis and in related dating techniques where precisely dated tree-ring material can serve as a control for calibration.

Recent and continuing development in techniques of climatic reconstruction and the impending refinement in radiocarbon dating combine to make the development of a long bristlecone pine chronology an immediate need. To provide dated wood for these projects is the primary objective of the proposal.

Chronology Development

The major focus of proposed field research will be the collection of bulk specimens in the White Mountains of California. The funding in 1978-9

made possible more intensive sampling than had been possible in recent years. Correspondingly, it resulted in a longer and more reliable chronology. Intensive collections again in 1980-81 should provide even more material in the 6-7000 B.C. range and hopefully from the preceding millennium.

In conjunction with collection at known sites, some time will be devoted to exploration in new localities in the White Mountains for materials that may provide even greater age than has yet been attained. There are numerous localities in the area that would have been favorable to lower timberline growth of bristlecone 10,000 years ago. The remoteness of these sites makes the task of searching them time consuming and costly, yet these endeavors are necessary in order to ascertain both the promise and the limits of chronology extension.

A second focus of proposed field research will be the collection of bristlecone at a site, in the White Pine Range of east-central Nevada, that has the potential of providing more than 5200 years of continuous chronology. Limited research on only nine different bulk (dead) specimens from the site, initially produced two chronologies. The earliest, a 2080-year series, has been dendrochronologically dated from 3240 to 1160 B.C. The second, a 1268-year series, has a C-14 date that would place it in roughly the first 1300 years A.D.

As controls for the dating of wood from this and other sites in east-central Nevada, we have three chronologies from the Snake Range: C-114, 4875 years; #352, 3200 years; and Hill 10,842, 2000 years. These independently derived chronologies crossdate quite well and already have been of use in dating remnants.

The White Pine unit and possibly a second Nevada area will be used to substantiate the White Mountain chronology and to start a mini-network of long-term chronologies. The site contains a full spectrum of

bristlecone forms: young full-bark trees, older strip-barks, snags and numerous remnants. The first task will be to core large numbers of the standing trees in order to develop a modern chronology that overlaps the more recent floating chronology and that can provide a basis for climatic calibration with recent records. The second goal will be to collect a large number of bulk samples to connect, strengthen and extend the chronology units.

This ultimately would provide the second longest continuous record of isotopic and paleoclimatic variation at the lower, rainfall-dependent range of the bristlecone pine. This would be valuable for several reasons. It provides a second major source of wood for isotopic and calibration work. It could be used for comparative or replicative studies that provide cross-checks on variations for corresponding time periods in the bristlecone from California. The site tends to have larger ring widths than does the Methuselah Walk wood which would facilitate preparation of samples less than ten years in length.

From the standpoint of paleoclimatic research this long-term time series would be of great interest in terms of its variance spectrum. It would also provide a much-needed candidate for cross-spectral analysis with the Methuselah Walk chronology. A proposal is currently being submitted by C. W. Ferguson, Donald A. Graybill, and Geoffrey A. Gordon to develop this site as a paleoclimatic unit and to compare it with the White Mountain chronology.

Paleoclimatic research

The initial focus of the bristlecone pine project was climatic, but as the need increased for dated wood for radiocarbon studies and the emphasis

changed to chronology development and extension, the search for old wood led from stress sites at the lower limit of the species--the ideal area for climatic interpretation--to even lower sites now totally devoid of living bristlecone pines. This broke the continuity of the chronology as a tool for long-term climatic interpretation. To remedy this, a single site--Methuselah Walk--has been selected for intensive study.

The process of selecting specimens of the best quality from the present back to 4000 B.C. is almost complete. Recent progress in chronology development will eventually permit selection of samples in the 4-6000 B.C. range for an extension of the original interpretation. Various methods of merging the ring-width records to best preserve the true variance spectrum of the series are being investigated. Analysis in the spring of 1980 should provide the basic data for an 8000-year time series that is appropriate for use in climatic reconstruction and that can be intensively investigated in the frequency domain.

Development of the 5200-year series from the White Pine Range in Nevada will provide comparative data for paleoclimatic investigation (see the previous section). The 5200-year period of overlap would provide data in one of the five major problem areas -- that of the climate of the past 5000 years -- discerned in a recent assessment of the status of paleoclimatic research (Hecht et al. 1979: 11-12).

These studies, encompassing long-term low-elevation chronologies from two major geographic areas, would provide a control for the areal extension of such chronologies. A separate proposal by Charles W. Stockton, C. W. Ferguson, and Donald A. Graybill is designed to develop a mini-network of about 20 sites with chronologies of 500-1000 years as a basis for evaluation of the 22-year sunspot cycle.

PROCEDURE

Field work

Collections and surveys will continue and exploratory work will be conducted in new or critical areas. Radial growth-ring sequences in core samples extracted with a Swedish increment borer will continue to provide most of the chronologic data, but bulk sections for both tree-ring and isotopic studies will be collected from standing or fallen snags or large, eroded remnants of trees of proven age and quality.

Laboratory analysis

Dendrochronological dating of the specimens follows standard practices at the Laboratory of Tree-Ring Research (Ferguson 1970a, Stokes and Smiley, 1968). All of the dated ring series are standardized to simplify comparisons and to facilitate statistical analysis. Sensitive, critical, and early samples will be intensely studied and specimen means will be derived for incorporation into the master chronology or for the establishment of dendroclimatic records.

SCHEDULE

Early Summer, 1980 (present grant)

In addition to our scheduled work in the White Mountains -- with the allotted sum of 50-80 exploratory radiocarbon dates -- we plan to spend two weeks at our site in the White Pine Range during the 1980 field season. The Forest Service will provide the total facilities of a F.S. field residence and possibly a four-wheel drive vehicle. Our objective will be to collect both modern samples (cores) and cross sections from remnants in an effort to fill in gaps and provide a complete series for the site.

Other proposed collection sites include the Spring Mountains and Spruce Mountain in Nevada.

First Year

Field work in the fall of 1980 in the White Mountains will focus on the intense sampling of old wood as indicated by the surveys conducted in the early summer. Additional collecting may be done in the Inyo Mountains (essentially a more arid and southern extension of the White Mountains) in California and various ranges in east-central Nevada.

Field collecting will focus on old wood with a view to further strengthening and extending the chronology. Hopefully, by this time, cooperative projects with various radiocarbon and stable isotope laboratories will have been initiated so that project-oriented collecting can be done.

Analysis of the present collections will continue. Emphasis will be on publication of the chronology prior to 4000 B.C. As the number of specimens per site increase, separate chronologies will be developed for individual sites within the White Mountains as an aid to the dating of additional specimens. As separate bristlecone pine chronologies are developed, they will be made available to the International Tree-Ring Data Bank and published in the Chronology Series of the Laboratory of Tree-Ring Research and will be available for climatic analysis.

Upon the completion of the present calibration program, from 5400 to 6000 B.C., decade samples back to 6600 B.C. will be provided to the cooperating radiocarbon laboratories. In the meantime, samples from the present inventory will be distributed upon request and, when possible, bulk material in hand will be processed to meet specific requests.

The first year of the proposed project coincides with the third year of the TAMS project. As indicated on pages 10 and 11, the bristlecone pine

project would be involved. The second year would be the fourth and last year of the TAMS project and we assume the cooperative efforts would be intensified.

Second and Third Years

The goals for the second and third years will be generally the same: to continue to supply dated wood, to extend the chronology in time and space, and to publish the extensions as they become firmly documented. Some of the distribution objectives will be guided by the consumer's needs. The tandem accelerator program, with its milligram sample size, may cause us to modify our procedures.

Two other proposals -- for paleoclimatic analysis and for the establishment of an expanded network of sites with trees of 500 to 1000 years in age -- would relate to the present study and proposal and may guide or modify the plans for the second and third years.

RELATED REFERENCES

Becker, Bernd, Holocene Tree Ring Series from Southern Central Europe for Archaeologic Dating, Radiocarbon Calibration, and Stable Isotope Analysis, pp. 554-565 in Rainer Berger, and Hans E. Suess, 1979, Radiocarbon Dating, Proceedings of the Ninth International Conference, Los Angeles and La Jolla, U. of California Press, Berkeley.

Berger, Rainer, and Hans E. Suess, Editors, 1979, Radiocarbon Dating, Proceedings of the Ninth International Conference, Los Angeles and La Jolla, U. of California Press, Berkeley.

Berr, J., V. Giertz, M. Moll, H. Oeschger, T. Riesen and C. Strahm, The Contribution of the Swiss Lake-Dwellings to the Calibration of Radiocarbon Dates, pp. 566-585 in Rainer Berger, and Hans E. Suess, 1979, Radiocarbon Dating, Proceedings of the Ninth International Conference, Los Angeles and La Jolla, U. of California Press, Berkeley.

Cain, W. F. and H. E. Suess, 1976, Carbon-14 in Tree Rings. Journal of Geophysical Research 81:3688-3694.

Damon, P. E., C. W. Ferguson, A. Long and E. I. Wallick, 1974, Dendrochronologic Calibration of the Radiocarbon Time Scale. American Antiquity 39(2):350-366.

de Jong, A.F.M., W. G. Mook and B. Becker, 1979, Confirmation of the Suess wiggles: 3200-3700 B.C., Nature 280:48-49.

Dicke, R. H., 1979, Solar luminosity and the sunspot cycle, Nature 280:24-27.

Eckstein, D., 1972, Tree-ring research in Europe. Tree-Ring Bulletin 32:1-18.

Eddy, John A., 1976, The Maunder Minimum. Science 192:1189-1202.

_____, P. A. Gilman and D. E. Trotter, 1976, Solar rotation during the Maunder Minimum. Solar Physics 46:3-14.

Epstein, Samuel and Crayton J. Yapp, 1976, Climatic implications of the D/H ratio of hydrogen in C-H groups in tree cellulose. Earth and Planetary Science Letters 30:252-261.

Ferguson, C. W., 1968, Bristlecone pine: science and esthetics. Science 159(3817):839-46.

_____, 1969, A 7104-year annual tree-ring chronology for bristlecone pine, Pinus aristata, from the White Mountains, California. Tree-Ring Bulletin 29(3-4):3-29.

_____, 1970a, Concepts and Techniques of Dendrochronology. In Scientific Methods in Medieval Archaeology, edited by Rainer Berger, pp. 183-200. UCLA Center for Medieval and Renaissance Studies, Contributions IV. University of California Press, Berkeley.

_____, 1970b, Dendrochronology of Bristlecone Pine, Pinus aristata: Establishment of a 7484-Year Chronology in the White Mountains of Eastern Central California, U.S.A. In Radiocarbon Variations and Absolute Chronology, edited by Ingrid U. Olsson, pp. 237-259. Nobel Symposium 12, Almquist and Wiksell, Stockholm.

_____, 1970c, Dendrochronology of Bristlecone Pine in East-central Nevada, 56 pp. Terminal Report submitted to the Regional Forester, U.S. Forest Service, Ogden, Utah.

_____, 1972, Dendrochronology of Bristlecone Pine Prior to 4000 B.C. Vol. 1, pp. 1-16 in Proceedings of the 8th International Radiocarbon Dating Conference, Wellington, New Zealand.

_____, Dendrochronology of Bristlecone Pine, Pinus longaeva. Environment International (in press).

_____, Dendrochronology of Bristlecone Pine. Carbon Dioxide Research Progress Report (Department of Energy, 4 pages, in press).

_____, Marija Gimbutas and Hans E. Suess, 1976, Historical dates for Neolithic Sites of Southwest Europe. Science 191:1170-1172.

Fritts, Harold C., 1965, Tree-Ring Evidence for Climatic Changes in Western North America. Monthly Weather Review 93(7):421-43.

_____, 1976, Tree rings and climate. Academic Press, London, New York and San Francisco.

Graybill, D. A., 1979, Program operating manual for RWLIST, INDEX and SUMAC. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

_____, Revised computer programs for tree-ring research (Accepted for publication in the Tree-Ring Bulletin).

_____ and C. W. Ferguson, Dendrochronology of Crooked Creek Cave (ms).

Grinstead, M. J., A. T. Wilson, and C. W. Ferguson, 1979, $13_C/12_C$ variations in Pinus longaeva (bristlecone pine) cellulose during the last millennium. Earth and Planetary Science Letters 42(2):251-253.

Hecht, Alan D., Ed., Roger Barry, Harold Fritts, John Imbrie, John Kutzbach, J. Murray Mitchell and Samuel M. Savin, 1979, Paleoclimatic Research: Status and Opportunities. Quat. Research 12:6-17.

LaMarche, Valmore C., Jr., 1974, Paleoclimatic Inferences from Long Tree-Ring Records. Science 183(4129):1043-48.

_____ and Thomas P. Harlan, 1973, Accuracy of Tree Ring Dating of Bristlecone Pine for Calibration of the Radiocarbon Time Scale. Journal of Geophysical Research 78(36):8849-58.

_____ and Harold A. Mooney, 1967, Altithermal timberline advance in western United States. Nature 213(5080):980-982.

Lambert, G. and C. Orcel, 1979, Dendrochronology of Neolithic Settlements in Western Switzerland: New Possibility for Prehistoric Calibration, pp. 585-590 in Rainer Berger and Hans E. Suess, Radiocarbon Dating, Proceedings of the Ninth International Conference, Los Angeles and La Jolla, U. of California Press, Berkeley.

Lerman, J. C., W. G. Mook and J. C. Vogel, C-14 in tree rings from different localities, pp. 275-301 in Olsson (1970), Radiocarbon variations and absolute chronology, Proceedings, 12th Nobel Symposium, Uppsala, Sweden. John Wiley and Sons, New York.

Libby, Willard F., 1971, Radiocarbon Dating - Twenty Years Later. Field Museum of Natural History (Chicago), Bulletin 42(7):2-5.

_____, 1973, The Radiocarbon Dating Method. Pensee 3(2):7-11.

Long, A., L. D. Arnold, P. E. Damon, C. W. Ferguson, J. C. Lerman and A. T. Wilson, Radial Translocation of Carbon in Bristlecone Pine, pp. 532-37 in Rainer Berger and Hans E. Suess, 1979, Radiocarbon Dating, Proceedings of the Ninth International Conference, Los Angeles and La Jolla, U. of California Press, Berkeley.

Mehringer, Peter J., Jr. and C. W. Ferguson, 1969, Pluvial occurrence of bristlecone pine (Pinus aristata) in a Mohave Desert mountain range. Journal of the Arizona Academy of Science 5(4):284-292.

Mitchell, J. Murray, Jr., Charles W. Stockton and David M. Meko, 1979, Evidence of a 22-year Rhythm of Drought in the Western United States Related to the Hale Solar Cycle since the 17th Century, pp. 125-43 in B. M. McCormac and T. A. Seliga (Eds.): Solar-Terrestrial Influences on Weather and Climate.

Olsson, Ingrid U. (Editor), 1970, Radiocarbon variations and absolute chronology. Proceedings, 12th Nobel Symposium, Uppsala, Sweden. John Wiley and Sons, New York.

Pilcher, J. R., 1973, Tree-ring research in Ireland. Tree-Ring Bulletin 33:1-5.

_____, J. Hillam, M.G.L. Baillie and G. W. Pearson, 1979, A Long Sub-Fossil Oak Tree-Ring Chronology from the North of Ireland. New Phytol. 79:713-729.

Ralph, E. K., H. N. Michael, and M. C. Han, 1973, Radiocarbon dates and reality. MASCA Newsletter 9:1-20.

Renfrew, Colin, 1977, Europe's Culture is Older Than We Thought. National Geographic Magazine, Nov., pp. 516-522.

_____, 1974, British Prehistory. A New Outline. Noyes Press, Park Ridge, 348 pp.

_____, 1973, Before Civilization: the Radiocarbon Revolution and Prehistoric Europe. Alfred A. Knopf, New York.

Schulman, Edmund, 1956, Dendroclimatic changes in semiarid America. University of Arizona Press, Tucson.

_____, 1958, Bristlecone pine, oldest known living thing. The National Geographic Magazine 113(3):355-372.

Stokes, M. A., and Terah L. Smiley, 1968, An introduction to tree-ring dating. University of Chicago Press, Chicago.

Stuiver, M. and H. E. Suess, 1966, On the Relationship between radiocarbon dates and true sample ages. Radiocarbon 8:534-540.

Stuiver, Minze and Paul D. Quay, 1980, Changes in Atmospheric Carbon-14 Attributed to a Variable Sun, Science 207(1426):11-19.

Suess, Hans E., 1967, Bristlecone pine calibration of the radiocarbon time scale from 4100 B.C. to 1500 B.C. In Radioactive Dating and Methods of Low-Level Counting, pp. 143-151. International Atomic Energy Agency, Vienna.

_____, 1970, Bristlecone pine calibration of the radiocarbon time scale 5200 B.C. to present. In Radiocarbon variations and absolute chronology, edited by Ingrid U. Olsson, pp. 303-309. John Wiley and Sons, New York.

_____, 1979, La Jolla Measurements of Radiocarbon in Tree-Ring Dated Wood. Radiocarbon 20:1-18.

_____, A Calibration Table for Conventional Radiocarbon Dates, pp. 777-84 in Rainer Berger and Hans E. Suess, Editors, 1979, Radiocarbon Dating, Proceedings of the Ninth International Conference, Los Angeles and La Jolla, U. of California Press, Berkeley.

Tans, P. P., A.F.M. deJong and W. G. Mook, 1979, Natural atmospheric ^{14}C variation and the Suess effect. Nature 280:826-828.

Watkins, Trevor, Editor, 1975, Radiocarbon: calibration and prehistory. Edinburgh University Press.

Wendland, W. M., and D. L. Donley, 1971, Radiocarbon-calendar age relationship. Earth and Planetary Science Letters 11:135-139.

Wilson, David, 1975, The New Archaeology. Alfred A. Knopf, New York.

FACILITIES

The facilities of the Laboratory of Tree-Ring Research are available for specimen preparation, measurement, and analysis of specimens. Semi-automated ring-width measuring machines provide printed tape output. These instruments and a library of computer programs facilitate rapid handling and analysis of large numbers of tree-ring specimens. Data programming and processing will be done by project and laboratory personnel at the University of Arizona Computer Center (UCC), a separate department with its own director and a complete staff. The UCC facilities consist of a 256K-word Control Data Corporation CYBER 175, operating under Scope 3.4.4, and a 512K-word Digital Equipment Corporation DECsystem-10, running under TOPS-10. The machines are linked and are accessed through batch and interactive terminals. Peripheral equipment includes two CALCOMP digital plotters, 12-inch and 30-inch.

Current computing charges are: CYBER 175: $800./system hour; DEC-10: $350./system hour; and CALCOMP: $10./plot-hour. Other miscellaneous charges for paper and systems usage are approximately $100.-$200. per hour.

The laboratory will provide adequate office and laboratory facilities, but storage space, especially for bulk specimens required for C-14 material, is at a critical minimum, and may require the construction of shelves.

COOPERATING AGENCIES

U. S. Forest Service, primarily the Inyo National Forest, Bishop, California and the Humboldt National Forest, Elko, Nevada.

The Bureau of Land Management, primarily the Ely District, Ely, Nevada.

Radiocarbon laboratories at the universities of Arizona, California (San Diego), Pennsylvania, and Washington.

In a phone conversation 26 December 1979 with Robert Rice, Supervisor of the Inyo National Forest in Bishop, California, we discussed the possibility that the U. S. Forest Service pay a half-time salary for a graduate student on the bristlecone pine project to serve as a "resident scientist" in the Ancient Bristlecone Pine Forest. In this dual capacity, the student would work on the preparation and dating of tree-ring material and be available to the visitor as an on-the-site scientist in action and for scheduled talks, especially to classes and tour groups. The 100-day visitor count in the summer of 1977 was 66,800.

PERSONNEL

Principal Investigator:

C. W. Ferguson, Professor of Dendrochronology (biographical sketch attached)

Research Associate:

Donald A. Graybill (biographical sketch attached)

Laboratory Technician: James M. Burns

Dr. Ferguson will serve as Principal Investigator. He has devoted one-half to three-quarter time to the bristlecone pine study for the past 18 years. Under the terms of this proposal, he would spend half time on the project. He is on a fiscal year appointment.

CURRENT AND PENDING SUPPORT

I. C. W. Ferguson, Principal Investigator

A. Current Support

1. National Science Foundation

Dendrochronology of Bristlecone Pine

$109,000 (EAR78-04436 with assistance of Department of Energy contract no. EE-78-A-28-3274)

Two years, beginning 15 August 1978

Half time

University of Arizona

2. National Science Foundation

Radiocarbon and Climate (with Damon, Donahue, Lerman, and Long)

$75,000 (ATM79-23259)

One year, beginning 1 March 1980

One-twelfth time

University of Arizona

B. 1. Dendrochronology of Bristlecone Pine (this proposal)

2. A proxy record of climatic variability based upon an 8000 year bristlecone pine chronology (with Graybill and Gordon)

II. Donald A. Graybill, Research Associate

A. National Science Foundation

Dendrochronology of Bristlecone Pine

$109,000 (EAR78-04436 with assistance of Department of Energy contract no. EE-78-A-28-3274)

Two years, beginning 15 August 1978

Nine-tenths time

University of Arizona

B. None

III. No transfer of support

IV. This proposal will be submitted to both the National Science Foundation and the Department of Energy

BIOGRAPHICAL SKETCH AND BIBLIOGRAPHY

For

CHARLES WESLEY FERGUSON

Personal:

Born in Los Angeles, California, July 27, 1922; married Eileen J. Boecklen November 26, 1960; one child, Erica Lynne, born May 22, 1968.

Education:

Fullerton Junior College, California: 1940-1942. Montana State University, Missoula: B.S. (Forestry) 1948. University of Arizona, Tucson: M.S. (Range Ecology) 1950; Ph.D. (Range Management) 1960.

Career Summary:

1941-1942:	California Division of Forestry
1942-1945:	U.S. Army, E.T.O.
1946-1950:	Student
1950-1954:	Research Assistant; Laboratory of Tree-Ring Research, University of Arizona
1954-1955:	Student, part-time jobs
1955-1958:	Research Assistant (half-time); Department of Agronomy and Range Management, University of Arizona
1958-1961:	Research Associate; Department of Watershed Management, University of Arizona
1961-1963:	Research Associate; Laboratory of Tree-Ring Research, University of Arizona
1963-1969:	Assistant Professor of Dendrochronology; Laboratory of Tree-Ring Research, University of Arizona
1969-1974:	Associate Professor of Dendrochronology; Laboratory of Tree-Ring Research, University of Arizona
1974- present:	Professor of Dendrochronology, Laboratory of Tree-Ring Research, University of Arizona

Jan.-June 1974:	Sabbatical Leave
Jan.-Feb. 1974:	Scientist, Institute of Nuclear Sciences, Department of Scientifice and Industrial Research, Lower Hutt, New Zealand
March-June 1974:	Honorary Fellow, Dept. of Biogeography and Geomorphology, Research School of Pacific Studies, the Australian National University, Canberra, A.C.T., Australia

Professional Societies:

American Association for the Advancement of Science (Fellow, life member), American Forestry Association, Arizona Academy of Science, Arizona Archaeological and Historical Society, Arizona Native Plant Society, Ecological Society of America, International Wood Collectors Society, Sigma Xi, Society for American Archaeology, Society for Range Management, Tree-Ring Society.

Publications:

Ferguson, C.W. 1949. Additional Dates for Nine Mile Canyon, Northeastern Utah. Tree-Ring Bulletin, 16(2) 10-11.

_____. 1951. Early Height Growth in Douglas Fir. Tree-Ring Bulletin, 17(3) 18-20.

_____ and D.M. Black. 1952. Tree-Ring Chronologies on the North Rim of the Grand Canyon. Tree-Ring Bulletin, 19(2) 12-18.

_____ with Edmund Schulman. 1956. Millennia-Old Pine Trees Sampled in 1954 and 1955. In Dendroclimatic Changes in Semiarid America, by Edmund Schulman, pp. 136-138. The University of Arizona Press, Tucson.

_____. 1958. Growth Rings in Big Sagebrush as a Possible Aid in Dating Archaeological Sites. In "Recent Developments in Navajo Project Salvage Archaeology," by A.E. Dittert, Jr., pp. 210-211. El Palacio, 65(6) 201-211.

_____. 1959. Growth Rings in Woody Shrubs as Potential Aids in Archaeological Interpretation. The Kiva, 25(2) 24-30.

_____ and R.R. Humphrey. 1959. Growth Rings of Big Sagebrush Reveal Rainfall Records. Progressive Agriculture in Arizona, 11(2) 3.

_____ and R.A. Wright. 1962. Tree-Ring Dates for Cutting Activity at the Charcoal Kilns, Panamint Mountains, California. Tree-Ring Bulletin, 24(1-2) 3-9.

_____ and R.A. Wright. 1962. Botanical Studies. In "Johnny Ward's Ranch: A Study in Historic Archaeology," by B.L. Fontana and J.C. Greenleaf, pp. 108-114. The Kiva, 28(1-2).

_____ and R.A. Wright. 1963. Tree-Rings in the Western Great Basin. 1962 Great Basin Anthropological Conference, The Nevada State Museum Anthropological Conference, The Nevada State Museum Anthropological Papers, No. 9, pp. 10-16.

_____. 1964. Annual Rings in Big Sagebrush, Artemisia tridentata. Papers of the Laboratory of Tree-Ring Research, No. 1. The University of Arizona Press, Tucson.

_____, B. Huber, and H.E. Suess. 1966. Determination of the Age of Swiss Lake Dwellings as an Example of Dendrochronologically-Calibrated Radiocarbon Dating. Zeitschrift fur Naturforschung, 21a(7) 1173-1177.

_____ with David P. Adam, and Valmore C. LaMarche, Jr. 1967. Enclosed Bark as a Pollen Trap. Science, 157(3792) 1067-1068.

Ferguson, C.W. 1968. Bristlecone Pine: Science and Esthetics. Science 159(3817) 839-846.

_____. 1968. Comments on Age Determination and Durability of Ironwood, Olneya Tesota. pp. 165-166 in Bernice Johnston, 1968. Seri Ironwood Carving. The Kiva, 33(3) 155-168, Tucson.

_____. 1968. (Book Review) The Changing Mile: An Ecological Study of Vegetation Change with Time in the Lower Mile of an Arid and Semiarid Region. J.R. Hastings and R.M. Turner, University of Arizona Press, Tucson, 1965. The Kiva, 34(1) 51-52.

_____. 1969. A 7104-year annual tree ring chronology for bristlecone pine, Pinus aristata, from the White Mountains, California: Tree-Ring Bulletin, 29(3-4) 3-29.

Mehringer, Peter J., Jr. and C.W. Ferguson. 1969. Pluvial Occurrence of Bristlecone Pine (Pinus aristata) in a Mohave Desert Mountain Range. Journal of the Arizona Academy of Science 5(4) 284-292.

_____. 1970. Aspects of Research on Bristlecone Pine. In The Ancient Bristlecone Pine Forest, by Russ and Anne Johnson, pp. 47-51. Chalfant Press, Bishop, California.

_____. 1970. Bristlecone Pine Chronology and Calibration of the Radiocarbon Time Scale. In "Tree-Ring Analysis with Special Reference to Northwest America," edited by J. Harry G. Smith and John Worrall, pp. 88-91. The University of British Columbia, Faculty of Forestry, Bulletin No. 7.

_____. 1970. Concepts and Techniques of Dendrochronology. In Scientific Methods in Medieval Archeology, edited by Rainer Berger, pp. 183-200. UCLA Center for Medieval and Renaissance Studies, Contributions IV. University of California Press, Berkeley.

_____. 1970. Dendrochronology of Bristlecone Pine, Pinus aristata: Establishment of a 7484-Year Chronology in the White Mountains of Eastern Central California, U.S.A. In Radiocarbon Variations and Absolute Chronology, edited by Ingrid U. Olsson, pp. 237-259. Nobel Symposium 12, Almquist and Wiksell, Stockholm.

_____. 1970. Dendrochronology of Bristlecone Pine in East-central Nevada, 56 pp. Terminal Report submitted to the Regional Forester, U.S. Forest Service, Ogden, Utah.

_____. 1971. Jahrringchronologie bei der Borstenkiefer. Naturwissenshaftlic Rundschau (Stuttgart), Col. 24, No. 1. (Cover picture and caption).

_____. 1971. Tree-Ring Dating of Colorado River Driftwood in the Grand Canyon. Hydrology and Water Resources in Arizona and the Southwest, Vol. 1, pp. 351-366. Proceedings of the 1971 Meetings of the Arizona Section - American Water Resources Assn. and the Hydrology Section - Arizona Academy of Science, Tempe, 1971.

_____. 1972. Dendrochronology of Bristlecone Pine Prior to 4000 B.C. Vol. 1, pp. 1-16, in Proceedings of the 8th International Radiocarbon Dating Conference, Wellington, New Zealand.

_____. 1972. Contributor in Linda G. Drew, Editor. Tree-Ring Chronologies of Western America. II. Arizona, New Mexico, Texas, Chronology Series 1, Laboratory of Tree-Ring Research, University of Arizona, Tucson.

_____. 1972. Contributor in Linda G. Drew, Editor, Tree-Ring Chronologies of Western America. III. California and Nevada, Chronology Series 1, Laboratory of Tree-Ring Research, University of Arizona, Tucson.

_____. 1973. Contributor in M.A. Stokes, Linda G. Drew, and C.W. Stockton, Editors. Tree-Ring Chronologies of Western America. I. Selected Tree-Ring Stations, Chronology Series 1, Laboratory of Tree-Ring Research, University of Arizona, Tucson.

_____. 1973. Dendrochronology of Bristlecone Pine Prior to 4000 B.C. (abstract). Ninth Congress International Union for Quaternary Research, Abstracts. Christchurch, New Zealand 2-10 December, p. 95.

_____, with P.E. Damon, A. Long, and E.I. Wallick. 1973. Dendrochronological Calibration of the Radiocarbon Time Scale (abstract). Ninth Congress International Union for Quaternary Research, Abstracts. Christchurch, New Zealand 2-10 December, p. 75.

_____. 1974. Contributor in Linda G. Drew, Editor. Tree-Ring Chronologies of Western America. IV. Colorado, Utah, Nebraska, and South Dakota, Chronology Series 1, Laboratory of Tree-Ring Research, University of Arizona, Tucson.

_____, with Valmore C. LaMarche, Jr. and W.B. Woolfenden. 1974. Holocene Climatic Correlations in Western United States: Tree-Ring and Glacial Evidence (abstract). Proceedings, American Quaternary Association, University of Wisconsin, Madison July 30 - August 1, pp. 77-78.

_____, with P.E. Damon, A. Long, and E.I. Wallick. 1974. Dendrochronological Calibration of the Radiocarbon Time Scale, American Antiquity, 39(2):350-366.

_____. 1975. Contributor in Linda G. Drew, Editor. Tree-Ring Chronologies of Western America. V. Washington, Oregon, Idaho, Montana and Wyoming. Chronology Series 1, Laboratory of Tree-Ring Research, University of Arizona, Tucson.

_____. 1975. Contributor in Linda G. Drew, Editor. Tree-Ring Chronologies of Western America. VI. Western Canada and Mexico, Chronology Series 1, Laboratory of Tree-Ring Research, University of Arizona, Tucson.

_____, M. Gimbutas and H. E. Suess. 1976. Historical Dates for Neolithic Sites of Southwest Europe. Science 191:1170-1172.

_____, with M. J. Grinsted and A. T. Wilson. 1979. $^{13}C/^{12}C$ variations in Pinus longaeva (bristlecone pine) cellulose during the last millenium. Earth and Planetary Science letters, 42(2):251-253.

_____, with A. Long, L. D. Arnold, P. E. Damon, J. C. Lerman, and A. T. Wilson. Radial translocation of carbon in bristlecone pine (ms. submitted for publication in the Proceedings of the 9th International Radiocarbon Conference, University of California, Los Angeles and San Diego-June, 1976).

_____. Dendrochronology of Bristlecone Pine, Pinus longaeva. Environment International, Vol. 2 (6 pages, in press).

_____. Dendrochronology of Bristlecone Pine. Carbon Dioxide Research Progress Report (Department of Energy, 4 pages, in press).

CURRICULUM VITAE

For

DONALD ALAN GRAYBILL

Personal:
Born in Council Bluffs, Iowa, July 3, 1942

Professional address:
Laboratory of Tree-Ring Research, University of Arizona, Tucson 85721

Education:
Iowa State University: B.S. (Anthropology) 1964
University of Arizona, Tucson: M.A. (Anthropology) 1970
University of Arizona, Tucson: Ph.D. (Anthropology-Geosciences) 1973

Career Summary:

1967-1970 Graduate Assistant in Research, Laboratory of Tree-Ring Research, University of Arizona. Research with Dr. C. W. Ferguson and Dr. V. C. LaMarche involved the development of chronologies based on Pinus longaeva for use in radiocarbon calibration and paleoecological-climatological studies.

1970-1971 Graduate Assistant in Teaching, Department of Anthropology, University of Arizona. Teaching duties were with Dr. Herman Bliebtreu for Introductory Anthropology and with Dr. A. J. Jelinek for a course entitled "World Prehistory."

1971-1973 Graduate Assistant in Research, Department of Anthropology, University of Arizona. Research involved computer programming, statistical description and analysis, and basic techno-typological analysis of lithic materials from the recent Et Tabun cave excavation project, Dr. A. J. Jelinek, Director.

1973-1977 Assistant Professor, Department of Anthropology, University of Georgia; courses taught were 5 credit hours, 50 class meetings per course. Course load was 2 per quarter: Introduction to Archaeology; Western North American Prehistory; North American Archaeology; Old World Prehistory; African Prehistory; The Paleolithic of Asia and Europe; Quantitative Research Methods in Archaeology; Laboratory Methods in Archaeology; Lithic Analysis; Settlement Systems Analysis; Graduate thesis-dissertation committee work: MA committee member (7); MA thesis director (2); Ph.D committee member (8); Ph.D. dissertation director (2).

1978-present Faculty Research Associate, Laboratory of Tree-Ring Research, University of Arizona (90% time) and Faculty Research Associate, Arizona State Museum (10% time).

Archaeological Field Experience:

Student, Summer, 1963. Archaeological Field School, University of New Mexico. Excavation at Sapawe. Dr. F. H. Ellis, Director.

Field Assistant and Student, 1964. Excavation and survey, salvage work, Red Rock Dam, Des Moines River Basin, Iowa. Dr. D. M. Gradwohl, Director. (Iowa State University)

Graduate Field Assistant, Summer, 1967. Excavation at the Murray Springs Clovis Site, Arizona. Dr. C. V. Haynes, Director. (University of Arizona)

Personally directed survey of archaeological and environmental evidence in the Mimbres area, southwestern New Mexico, part time 1966 - 1971, full season with NSF and Wenner-Gren grants during Summer, 1972.

Graduate Field Assistant, Summer, 1968. Excavation at Et Tabun, Israel. Dr. A. J. Jelinek, Director. (University of Arizona)

Graduate Field Assistant, Summer, 1970. Direction of field crew during excavation of Acheulean occupations at Isimila, Tanzania and survey in Lake Manyara Basin, Tanzania. Co-directors - Dr. C. M. Keller, Anthropology, University of Illinois, Urbana and Dr. C. Hansen, Physical Geography, University of California, Riverside.

Grants

1971 Wenner Gren grand-in-aid for dissertation research
1971 NSF Summer Traineeship for Graduate Assistants
1970 Sigma Xi travel grant
1976 Director of dissertation improvement grant (NSF BNS 76-23059)

Professional Societies:

American Association for the Advancement of Science, Sigma Xi, Society for Africanist Archaeologists in America, Society for American Archaeology.

Publications:

Graybill, D. A. with Meade F. Kemrer. 1970. Navajo warfare and economy, 1868-1970. Western Canadian Journal of Anthropology. Fall, 1970.

_____. 1974. Note in "Computer Programs". Newsletter of Computer Archaeology, September, 1974.

_____. 1975. Mimbres-Mogollon adaptations in the Gila National Forest, Mimbres District, New Mexico. Archaeological Report, No. 9, USDA Forest Service, Southwestern Region, Albuquerque, New Mexico.

_____. 1975. Final report on archaeological survey 1, Chattahoochee National Forest. USDA-USFS, Southeastern Region, Atlanta, Georgia.

_____. 1977. Illegal site destruction in Southwest New Mexico. Journal of Field Archaeology 4(4):481-484.

Publications (cont.)

Graybill, D. A. 1979. Program operating manual for RWLIST, INDEX and SUMAC. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

_____ no date (a) Revised computer programs for tree-ring research. Accepted for publication in the TREE-RING BULLETIN.

Manuscripts in preparation

Graybill, D. A. and C. W. Ferguson. Dendrochronology of Crooked Creek Cave.