Dendrochronology of Bristlecone Pine (*Pinus aristata* Engelm) as a Basis for the Extension of Dendroclimatic Indices

A Research Proposal Submitted to the

National Science Foundation

by

The Laboratory of Tree-Ring Research

of

The University of Arizona

Institution: The Laboratory of Tree-Ring Research, The University of Arizona, Tucson, Arizona.

Title: Dendrochronology of Bristlecone Pine (Pinus aristata Engelm) as a Basis for the Extension of Dendroclimatic Indices.

Objective: To establish a four millennia master tree-ring chronology for bristlecone pine and, concurrently, to conduct an exploratory investigation of the relationship of its annual ring growth to climatic conditions.

Desired Starting Date: May 1, 1961.

Time Period for Which Support is Requested: Three years. It is believed that three years should be sufficient to work out the basic dendrochronology and explore the broad dendroclimatic relationships for Bristlecone pine. The amount and direction of further research will depend on the outcome of the present project.

Approval:

Principal Investigator _____

W. G. McGinnies
Director
Laboratory of Tree-Ring Research

_____

David L. Patrick
Coordinator of Research
The University of Arizona

December 21, 1960

ABSTRACT

It is proposed to make an analysis of growth-rings of bristlecone pine, to construct a tree-ring chronology covering more than four millenia and to investigate the relationship between the tree-rings and climate with the objective of establishing precipitation indices. The research will be based on previous findings with other species and will follow techniques and methodologies developed at the Laboratory of Tree-Ring Research. The research will continue studies initiated by Edmund Schulman under NSF Grant G2274 but terminated by his untimely death in 1958. During the period Dr. Schulman was operating under the NSF Grant, the full significance of the bristlecone pine discovery became apparent, and he left a legacy of material that will make it possible to carry research further into the past than was envisioned at the time the grant was made. The present proposal has been expanded to take advantage of this enlarged opportunity.

The research will be conducted on a team basis, utilizing all the skills available at the Laboratory of Tree-Ring Research. The Director of the Laboratory will serve as Principal Investigator, but will utilize the training and knowledge of the laboratory staff in supervising the research program.

INTRODUCTION

In the period since Dr. A. E. Douglass first became interested in tree-ring research and climatic cycles nearly 60 years ago, there has been a great amount of work in the broad field of tree-ring research. Techniques have been worked out for setting up tree-ring chronologies; and various events and structures have been dated by reference to tree-ring "calendars." There has also been a great amount of attention given to the correlation between climate and ring-growth, especially to the relation between precipitation and tree-ring growth. A comprehensive review and analysis of tree-ring data as related to climate and river-flow under the title of "Dendroclimatic Changes in Semiarid America" by Dr. Edmund Schulman was published by The University of Arizona Press in 1956.

On January 18, 1956, the National Science Foundation awarded a grant (NSF-G2274) of $18,800 to The University of Arizona with Edmund Schulman as Principal Investigator for support of research entitled "Millennium-Long Tree-Ring Histories of Climatic Changes." Before his death in 1958, Dr. Schulman discovered very old bristlecone pines (some over 4,000 years old) and made preliminary analysis of their ring growth. Because of Dr. Schulman's death, the study was not completed and the unexpended balance of the grant was returned to the National Science Foundation.

The original grant was based on the premise that tree-ring indices are improved by (1) the finding and sampling of trees with ring growth more sensitive to fluctuations in the limiting climatic variable, (2) an increase in the number of such sampled trees, and (3) an increase in the length of the individual tree records.

The purpose of the present proposal is to continue the studies, started by Dr. Schulman, of the long-lived bristlecone pine, and to make such additional collections and studies as may be necessary to meet current needs for dendrochronological and dendroclimatic information and rapidly growing demands in the field of dendrohydrology.

Bristlecone pine occurs just below timberline in the high mountains of the west. This species is most abundant in the White Mountains of California, but extends into Nevada, Utah, Colorado, Arizona and New Mexico. It is usually found on dry sites and the variation in ring growth at the lower limit of its distribution shows response to moisture conditions. It reaches great age throughout its range, with the oldest recorded trees over 4,000 years found in the White Mountains. On the basis of incomplete explorations and sampling, it appears that longevity of trees decreases toward the east.

Bristlecone pine affords a unique opportunity to study growth-environment relationships extending more than four millennia into the past. Correlations of growth and environment established during recorded weather history can be projected backward through the life of the tree on the basis of variations in ring-growth, thus making it possible to obtain a better picture of the climates of the past. Whether the climate was wetter or drier and whether there have been trends or cycles can be determined by techniques that have been developed at the Laboratory of Tree-Ring Research. These correlations have been carried back several hundred years on the basis of data derived from Douglas fir and Ponderosa pine. A preliminary study of bristlecone pine samples by Dr. Schulman before his death indicated that it might be possible to note climatic variations over a period of 4,000 years or more.

DESCRIPTION OF PROPOSED RESEARCH

The proposed research will be divided into two broad approaches:

(1) A study of the bristlecone pine specimens on hand and such additional material as may be needed to complete the master tree-ring chronology over a period of 4,000 + years. This is basic to all other investigations.

(2) A study of the relationship of tree-ring growth to climatic conditions. One phase of this will be based on available weather records and the second will entail environmental and growth measurements during the study period.

The same bristlecone pine material as mentioned in (1) will serve the basic needs for (2) but will need to be supplemented by additional collections to provide a broader comparison of environmental effects.

The first task in the laboratory is to inventory and catalog the specimens and analyses left by Dr. Schulman. His collections are in good shape but no one at the laboratory, at the present time, is well acquainted with the material. At the time of his death, Dr. Schulman had completed a preliminary study of the

tree-rings in the bristlecone pines of the White Mountains of California from the present back to about 750 B.C. Establishing the chronology for the remaining two millennia will be much more difficult and time consuming because the irregular growth characteristics of bristlecone pine make it difficult to follow growth sequences, and furthermore the chronology beyond the age of sampled sequoias (3,200 years) will have to be based on intercomparisons among bristlecone pines. This means that as large a number of samples as possible will have to be studied to reduce or eliminate the effect of local variations that would modify broad tree-ring-climatic relationships. Dr. Schulman's studies showed that the general ring-growth characteristics in bristlecone pine are favorable for dendrochronologies and dendroclimatic analyses. He found that no instance of multiple rings within a single year's growth existed in the dated portion of the chronology. In some cases a ring may be small to the point of being locally or completely absent about a portion of its circuit, and this may occur as often, on an average, as six times per century along a single radius. Possible errors on account of these discrepancies can be corrected by the system of cross dating between trees worked out by Dr. Douglass. (Douglass 1940, 1941, 1943a,1943b, 1946) Bristlecone pine does not show the serious "multiplicity of characteristics" that Glock found in trees from the lower forest border. (Glock 1960)

Dr. Schulman did not finish the field exploration to find absolute age limits of bristlecone pines and there is still the possibility that there are living trees older than those sampled. There is also the possibility that well-preserved dead trees may make it possible to extend chronologies by crossdating with living trees. One of the tasks of the field crew would be to investigate the possibility of extending chronologies as far as possible.

The sample trees were only given a temporary mark at the time of sampling, and one of the important tasks will be to relocate and identify these trees, mark them and indicate their position on suitable maps. Another part of the study will be to complete regional collections so as to have the necessary material for dendroclimatic comparisons.

There are no accurate estimates of the geographical extent of bristlecone pine, because the area covered by this species has not been segregated on existing forest type maps. Nor do the Park Service or Forest Service personnel have a very good idea of its extent. It occurs at high altitudes and often in the most inaccessible areas. Locating the best specimens will involve difficult travel, most of it on foot.

The principal centers for field research will be in the White Mountains and the Telescope Peak area of the Panamint Mountains where the oldest trees have been found, but it is planned to obtain material for comparison from other areas.

Separate regional chronologies will be established for the Telescope Peak area and other sites in Nevada and Utah.

Because of fewer trees and shorter life span of bristlecone pine in these areas, chronologies can be completed with less work than will be needed for the older trees in the White Mountains. Establishing the longer chronologies will be facilitated by the completion of the shorter chronologies first, which can be used as comparative material.

Specimens for ring studies will be in the form of 3/16" diameter cores taken with a Swedish increment borer. Because the standard 18" borer is not adequate for sampling trees of a 40-50" radius, specially ordered borers of 30" and 40" length will be used when needed.

The collection made by the late Dr. Schulman included three basal cross-sections of near maximum age trees, used for the study of the full circuit of each ring as a guide to the interpretation of the ring sequence in the cores which represent a single radius. It is believed that the material on hand is adequate for this purpose. Because of the great scientific value of these living trees, further cutting will be avoided except as it may be needed on a very limited scale to provide material for Carbon 14 and other analyses, and for educational and exhibit purposes. It is possible that the needed sections can be obtained from dead trees.

One or more cores, as needed to include all growth rings, will be taken from each selected tree. Specimens will be numbered and their position in the stem will be described in the field notes, along with other site information and location based upon topographical quadrangle maps. Selection criteria for the bristlecone pine will be based upon experience gained by Ferguson during the collection trips in 1954 and 1955 (Schulman and Ferguson, 1956, and Ferguson, 1960) and on the study of these and other specimens by Dr. Schulman.

The borings, after a drying period of one or two days, will be mounted in specially prepared grooved sticks and surfaced with a razor blade (Douglass, 1940, 1941, 1943a, 1943b).

The growth layers, as shown on the surfaced increment boring, will be identified as to the year in which they were formed and the decades will be marked upon the core. This identification is based upon the cross comparison of specimens within the same time period and this crossdating is verified by comparison with climatic data and previously established tree-ring chronologies in adjacent areas, such as the sequoia record in the Sierra Nevada which lies adjacent to the White Mountains on the west (Schulman, 1956; Douglass, 1949).

Dated ring series, desirable for further use, will be measured in hundredths of a millimeter with a specially designed measuring instrument. These measurements provide numerical data which can be plotted, utilized in mathematical analyses, or presented as single or group indices.

The bristlecone pine material from earlier collections by Dr. Schulman and his assistants has been treated in part as described above and will serve as the base for the present study.

The feasibility of developing bristlecone pine growth-ring indices for precipitation will be studied by statistical methods using available weather data, and by a three year field study to evaluate the effects of environmental factors on the concurrent radial growth. That there is a general relationship between tree-ring growth and precipitation was established by Schulman, with other species, and he planned to carry out comprehensive investigation with bristlecone pines. On the basis of preliminary examinations, it appears that ring-growth is sensitive to climatic changes throughout the life of the tree.

While correlations of tree-ring and weather data will show the general relationships between weather elements and tree-ring width, a more closely controlled study is needed for interpretation of the fundamental causal relationships.

The principal objective of the three year growth study will be to obtain fundamental information on the effect of various climatic elements. For example, we need to know whether temperatures modify the effects of precipitation to the extent of seriously reducing the value of tree-ring precipitation indices, and whether seasonal distribution might modify the effects of total precipitation and thus affect the accuracy of tree-ring precipitation indices.

To measure the effects of the environment on concurrent radial growth four recording dendrographs and twenty-five non-recording dendrometers will be mounted on bristlecone pines in a dry site at a low elevation and in a cooler and more moist site at higher elevation. Measurements of temperature, humidity, and solar radiation will be recorded in each location, and soil moisture storage will be ascertained from water balance calculations. Growth and environmental data will be tabulated as a series of observations, each observation representing a several-day interval, and the influence of each variable on growth will be ascertained by "least squares" multiple regression techniques using an IBM 650 digital computer. Each of the three growing seasons will be analyzed separately and then grouped in the final analysis. This procedure allows the evaluation of the relative importance of each environmental variable (Fritts, 1960a and 1960b). The problems and techniques of analyzing such time series are discussed by Quenouille, 1952.

The effect of the past climate on ring width of bristlecone pine will be evaluated by correlation and regression techniques. Weather records from the White Mountain Research Station and the nearest weather stations will be employed. A study will also be made on the intercorrelations of weather data at a wide variety of stations in California and neighboring states. These intercorrelations will be compared to the relative similarity or dissimilarity of ring chronologies in the several areas.

FACILITIES

The Laboratory of Tree-Ring Research has excellent facilities for handling this type of research, but demands for archeological and modern dating are so great that the equipment is kept in continual use; so, it will be necessary to make some additions to handle the bristlecone pine study. With an additional microscope and another Addo-X measuring instrument, we should be able to take care of the laboratory measurements without any delays because of equipment shortage. The Addo-X combines an adding machine and a micrometer measuring device with a microscope. This rapid means of recording ring width speeds up growth-ring measurements and will save several man-year's work on a study of this size. Increment borers are listed under expendable items as they last a year or less under heavy use. The University of Arizona Numerical Laboratory facilities will be used for various analyses. The services are charged to the project on a fixed fee basis.

OTHER SPONSORS

It is not planned to seek other sponsors for the bristlecone pine study at the present time.

PERTINENT LITERATURE

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_____ and C. W. Ferguson, Jr. 1956. Millennia - old pine trees sampled in 1954 and 1955, Appendix C in Dendroclimatic Changes in Semiarid America.

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PERSONNEL

Principal Investigator: William G. McGinnies, Director, Laboratory of Tree-Ring Research.

Research Associate (one-fourth time): C. W. Ferguson, Research Associate, Department of Watershed Management.

Research Associate (one-sixth time): Harold C. Fritts, Assistant Professor of Dendrochronology, Laboratory of Tree-Ring Research.

Advisory Associate: Bryant Bannister, Assistant Professor of Dendrochronology, Laboratory of Tree-Ring Research.

Advisory Associate: Marvin Stokes, Research Associate, Laboratory of Tree-Ring Research.

(Biographies of the above are attached.)

The study will be under the direct supervision of the Principal Investigator. Dr. Ferguson will spend approximately two months in the field each year, locating, labeling, and mapping Dr. Schulman's sample trees and directing the exploration for other datable material including dead trees that may lengthen the chronological record. The senior research assistant will spend four months in the field assisting Dr. Ferguson and collecting data for the environmental study. Dr. Fritts will direct the environmental studies.

The Principal Investigator will be responsible for crossdating assisted by Dr. Ferguson, Dr. Bannister and Mr. Stokes. Measuring and recording rings, the major job in terms of time, will be done by graduate assistants. While this is somewhat of a routine task, it needs to be performed by trained technicians who appreciate the necessity for great accuracy and can recognize any anomalies that require special attention.

BIOGRAPHIES OF PRINCIPAL INVESTIGATOR AND ASSOCIATES

William G. McGinnies, Principal investigator, was born in Steamboat Springs, Colorado, 1899.

Education: Graduated from The University of Arizona in 1922 with a B.S.A. degree, majoring in biology. Received the Ph.D. degree majoring in Botany with major work in Ecology from the University of Chicago in 1932.

Experience: Range Surveys and Research, U.S. Forest Service, Montana, 1923-26.
Range Ecologist and Professor of Botany, The University of Arizona, 1927-35.
Land Management Supervisor, Soil Conservation Service, Navajo Indian Reservation, 1935-38.
In charge Range Research SW Forest and Range Experiment Station, U.S.F.S., 1938-41.

Experience (Cont.):
In charge of Surveys and Investigations, GUAYULE Project, U.S. Forest Service, 1942-44.
Director, Rocky Mountain Forest and Range Experiment Station, U.S.F.S., 1945-53.
Director, Central States Forest Experiment Station, U.S.F.S., 1954 to July, 1960.
Director, Laboratory of Tree-Ring Research and Coordinator of the Arid Lands Program, The University of Arizona, August, 1960-.

Professional Societies:
AAAS fellow, Phi Kappa Phi, Sigma Xi, Gamma Alpha, Alpha Zeta, Xi Sigma Pi, Ecological Society of America, Society of American Foresters, American Society of Range Management, Soil Conservation Society of America, Tree-Ring Society.

Principal Publications:

McGinnies, W. G. with W. P. Taylor. 1928. The bio-ecology of forest and range, Scientific Monthly, 27:177-182.

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C. W. Ferguson, Research associate, was born in Los Angeles, California, July 27, 1922.

Education: B.S. (Forestry), Montana State University, 1948; M.S. (Range Ecology), The University of Arizona, 1950; Ph.D. (Range Management), The University of Arizona, 1960.

Experience: Research Assistant, Laboratory of Tree-Ring Research, 1950-1954; Research Assistant (half-time), Department of Agronomy and Range Management, 1955-1958; Research Associate (N.S.F. grant G-5368), Department of Watershed Management, 1958-1961.

Professional Societies:
Tree-Ring Society (Secretary-Treasurer), American Society of Range Management, Beta Beta Beta, Ecological Society of America, Sigma Xi.

Principal Publications:

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

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Harold C. Fritts, Research Associate, was born in Rochester, N. Y., 1928.

Education: B.A., Oberlin College, 1951; M.Sc., Ohio State University, 1953; Ph.D., (Botany), Ohio State University, 1956.

Experience: Graduate Assistant Ohio State University, 1951-1954;
Graduate Fellow, 1954-1956;
Graduate Research Assistant, Ohio Agricultural Experiment Station with Department of Botany and Plant Pathology, summer, 1951 and with Department of Forestry, summer, 1953;
Assistant Professor of Botany, Eastern Illinois University, 1956-1960;
appointed as Assistant Professor of Dendrochronology, University of Arizona, 1960;
Visiting Doctor, University of Wyoming Summer Science Camp, summer, 1956;
N.S.F. Fellow, Oregon Institute of Marine Biology, summer, 1957.

Professional Societies:
Botanical Society, Ecological Society, Society of Sigma Xi, Illinois Academy of Science, Ohio Academy of Science, Arizona Academy of Science, Illinois Technical Forestry Association.

Principal Publications:

Fritts, H. C. 1955. A new dendrograph for recording radial changes of a tree, Forest Science, 1:271-276.

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_____. 1960. The environmental controls of radial growth in a central Illinois ravine forest, American Philosophical Soc. Year Book, In Press.

Bryant Bannister, Advisory associate, was born in Phoenix, Arizona, 1926.

Education: University of Wisconsin, 1944; Yale University, 1946-1948, B.A. (Anthropology) 1948; The University of Arizona, 1949-1959, M.A. (Anthropology) 1953, Ph.D. (Anthropology) 1960.

Experience: Student Assistant, Department of Classical Civilization, Yale University, 1947-1948;
Anthropological Survey of Sonora, Mexico, 1949;
Colorado River Archaeological Expedition, 1949;
Fellow, Arizona State Museum, The University of Arizona, 1949-1950;
North Carolina Historical Reconstruction Project, 1950;
Foreman, The University of Arizona Archaeological Field School, 1951;
Student Assistant, Laboratory of Tree-Ring Research, The University of Arizona, 1949-1953;
Editor, Tree-Ring Bulletin, 1958;
Faculty, Laboratory of Tree-Ring Research, The University of Arizona, Research Assistant 1953;
Curator of Archaeological Collections, 1954-1958;
Instructor of Dendrochronology, 1959;
Assistant Professor of Dendrochronology, 1960-.

Professional Societies:
American Anthropological Association, Fellow; American Association for the Advancement of Science, Fellow; Arizona Academy of Science; Pi Mu Epsilon; Society for American Archaeology; Society of the Sigma Xi; Tree-Ring Society, Editor, Tree-Ring Bulletin.

Principal Publications:

Bannister, Bryant. 1951. Tree-ring dates for the Gallina area, New Mexico, Tree-Ring Bulletin, 17(3):21-2.

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Marvin A. Stokes, Advisory associate, was born in Aberdeen, South Dakota in 1927.

Education: Northern State Teachers College, Aberdeen, South Dakota, 1948-1949; B.A., University of Colorado, 1949-1952; The University of Arizona, 1952-.

Experience: Geodetic Computor, U.S.A.F., 1945-1948;
Ranger, Mesa Verde National Park, 1953, Research Assistant, Navajo Land Claim, 1953-1956;
Research Assistant in Prehistoric Dating, The University of Arizona, 1956-1960;
Research Associate, Laboratory of Tree-Ring Research, The University of Arizona, 1960-.

Professional Societies:
Society for American Archaeology, American Association for the Advancement of Science, Tree-Ring Society.

Principal Publications:

Stokes, M.A. with T. L. Smiley. A dendrochronological study of piñon pine growth in the southwest. In Press.