Project file

Continuation of Studies on the Dendrochronology of Bristlecone Pine (*Pinus aristata* Engelm.)

(Continuation of Research Grant NSF-G 19949)

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: Continuation of Studies on the Dendrochronology of Bristlecone Pine (*Pinus aristata* Engelm.).

Objective: To complete studies underway in the establishment of a 4600-year tree-ring chronology for bristlecone pine in the White Mountains of California, and to complete a three-year study of the relationship of annual ring growth to climatic conditions in the same area; to extend the study of bristlecone pine to major sites throughout the range of the species; and to cooperate with the University of Arizona Radiocarbon Laboratory in the establishment of a joint control for the long-term dendroclimatic calendar.

Desired Starting Date: October 1, 1963.

Time Period for Which Support is Requested: October 1, 1963 to June 30, 1965.

Approval:

Principal Investigator ______________________
W. G. McGinnies
Director
Laboratory of Tree-Ring Research

____
David L. Patrick
Coordinator of Research
The University of Arizona

May 10, 1963

ABSTRACT

The original research grant NSF-G 19949, effective October 1, 1961, for the dendrochronology of bristlecone pine has made it possible: (1) to develop a workable chronology extending back 3850 years, (2) to carry out studies of tree growth as related to environmental parameters through two field seasons, and (3) to make some statistical comparisons which indicate (a) that there is no significant difference between young and old trees in radial growth response to environmental variables, (b) that there are significant correlations between bristlecone pine and other coniferous species extending up to 1000 miles east and southeast, and (c) that there is strong evidence that bristlecone pine will provide a good basis for extending climatic interpretations to at least 2600 B.C.

The present request is for funds: (1) to complete an exact chronology made possible through the study of both living and dead material in the White Mountains of California; (2) to extend the chronology building to other key tree-ring areas in the Colorado River Basin with the aim of determining the past climatic chronology; (3) to statistically evaluate the various chronologies thus established for interrelations with climate and with other tree-ring series; (4) to continue the environmental studies and evaluations through a third growing season, 1964; (5) to determine the biological model of cause and effect and its statistical counterpart for estimating climate from these tree-ring series; and (6) to provide for the closely integrated radiocarbon analysis of tree-ring material.

The results will be used (1) to strengthen dendrochronological dating and to provide a master tree-ring chronology which can be used by climatologists, archaeologists, radiocarbon investigators, and others; (2) to strengthen and geographically extend the dendroclimatological studies of Schulman (1956), especially in the Colorado River Basin; (3) to provide, when integrated with various environmental studies now being conducted, a stronger basis for environmental interpretations, based on the difference in radial growth shown by trees that respond primarily to differences in precipitation. This information will be of great value to meteorlogists, hydrologists, and others, including the Inter-Union Commission on Solar and Terrestrial Relationships.

CURRENT STATUS OF RESEARCH

The present study, conducted under Research Grant NSF-G 19949, has two broad phases that were outlined under "Description of Proposed Research." These are:

(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 4000+ 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.

<u>Chronology Building</u>: Because the original request was reduced from three years to two years, and the funds reduced by approximately a third, the study was concentrated in the White Mountains of California, where the oldest known trees occur. For the same reason, phase (2) was limited to local environmental studies.

The inventory of specimens left by Dr. Schulman has been completed, and his dating back to 780 B.C. has been checked and verified. The objective of these particular collections was to develop chronologies of the greatest possible length from living trees. As a result, most of the trees sampled were slow growing and the average ring width was so small and the frequency of missing rings was so high that dating was difficult.

The methodology used to produce a chronology of absolute dating was as follows:

(1) Field surveys and observations were made to locate stands close enough to the forest border so that the chronologies between trees were similar, but the environment was not so dry that growth was extremely slow and locally absent rings frequent.

(2) Collections were made from these areas and all specimens were intensively cross-dated. The growth-ring sequences were measured and plotted. The plots and the associated specimen then were used for further cross-dating. Even though double rings are exceedingly rare in the White Mountain bristlecone pine, it is desirable to have each year represented by a ring in more than one specimen to exclude the possibility of such a ring being part of a double. When a sufficient number of specimens exhibited good cross-dating, measurements of the best specimens were averaged into a mean. These data were plotted to be used for comparison and checking with all subsequent specimens.

(3) The chronology then was checked against other chronologies which had been independently derived. This is done after the specified sample is finished to avoid preconceived ideas of the actual chronological sequence. Sequoias, limber pines, and bristlecone pines from other areas have been used in this way.

(4) During the cross-dating process, all questionable time periods and any discrepancies between chronologies were noted and examined in detail.

As of May 1, 1963, a usable master chronology had been established for a total period of 3850 years. This has been cross-checked with the other long chronologies (limber pine, 1900 years; giant sequoia, 3200 years), as well as against intervals of rapid growth of the bristlecone pine in successively earlier time periods.

All of the specimens, approximately 550, in the Laboratory now have been examined. About 60 cores have been dated for modern times. About 15 of the most desirable of these cores have been measured and plotted from A.D. 400 to 1954. It should be noted that although only a few cores were used in plots, the process of dating takes into account all available samples. Approximately 15 to 30 cores were dated for the 400 B.C. to A.D. 400 period, and 5 were measured and plotted. From 800 to 400 B.C., nineteen specimens have been dated, measured and plotted -- 14 of these to 780 B.C. We are presently concentrating our work in the period 2500 to 800 B.C. There are 14 specimens in this range which have been partially measured and plotted, but there is not yet enough documentation to be certain of the earlier chronology beyond the range of the sequoia control.

Commonly, up to 5% of the annual rings were missing on a single radius of the older, slow growing trees (Table I). Of three cross-sections studied, specimen 501 had the largest average ring width. The presence of the only ring totally absent on the cross section was authenticated by its occurrence on other specimens. A single radius on a specimen with a ring sequence having more than 100 rings per inch, as occurred in number 001, would be impossible to date by itself, but could be dated easily with a few specimens such as number 501 as controls. Because of this relationship between site, average ring width, and completeness of ring sequences, field collections in 1962 were largely aimed toward finding trees which showed faster growth and fewer absent rings during critical and early time periods. These chronology units usually covered shorter, specific periods, but could be cross-dated and fitted into the master chronology. They became an essential part of the total chronology, as these open-ring sequences generally have only a few extremely small rings. Rarely, rings are locally absent or totally missing on the specimen, and, in these cases, their occurrence can be verified by checking other specimens of comparable quality.

A partial analysis of the missing ring problem is presented in Tables II and III. Two cores were taken from each of 22 full-bark trees, ranging from 6 to 36 inches in diameter, and the century from 1862 to 1961 was dated. The frequency of missing rings during the century in relation to the average ring width during the period is shown in Table II. The greatest frequency of missing rings occurred in the slower growing specimens. There was no relation between missing rings and the size of the tree.

Table III shows that only one year (1960) could have presented a problem in identification of missing rings if the chronology had been unknown. Assuming that this collection is typical of bristlecone pines, the probability of extracting a core with 1960 missing is approximately 0.50. If a single core were to be taken per tree, it would take a minimum of 7 cores in order to achieve a 99 percent confidence in obtaining a sample which has all rings present in at least one core. If we grant that there may be years more severe than 1960, then it would appear that an arbitrary number of 10 cores might be a reasonable minimum-depth chronology if the specimens in Table III exhibit growth-ring characteristics comparable to specimens used in chronology building. Actually, a sample frequently 2 to 3 times greater than this minimum is used and these are supplemented whenever possible by a study of available cross-sections for many intervals, which allow the scanning of a sizeable circumference and increase the probability of finding the locally

Table I. Percentage of annual rings missing on a single radius, locally absent, and totally absent for a 600-year chronology (800 to 200 B.C.) on cross sections from three bristlecone pines.

Specimen	Missing on a radius	Locally absent on the section	Totally absent on the section
	Percent	Percent	Percent
501	0.5	0.3	0.2
502	2.8	1.8	1.0
001	4.7	3.0	1.7

Table II. Frequency of missing rings per century for 22 trees, two cores per tree, as related to average ring width.

Average Ring Width	Number of Missing Rings 0	1	2	3	4
Millimeters					
.00 - .35		8	2	2	1
.35 - .70	13	8		2	
.70 -	7	1			

Table III. Frequency of missing rings per year, based upon two cores from each of 22 trees.

Year	Number of trees		Total missing rings
	With missing rings on one or two cores	With missing rings in both cores	
1873	1		1
1881	1		1
1899	4		4
1929	2	1	3
1934	1		1
1950	4	1	5
1960	15	7	22

absent rings, as was indicated by the data in Table I. Essentially, no double rings have been found in bristlecone pine materials. Since we are dealing with approximately 46 centuries of data with a sample size much larger than 10, including in many cases, both cross-sections and increment cores and specimens with a variety of growth rates, it would appear that for any particular interval the bristlecone pine chronology has a very small probability that it is off by even a single year.

Considerable progress has been achieved during the present study in developing new techniques to aid chronology building. This has been greatly facilitated by the use of the University's Numerical Analysis Laboratory IBM 1401-7072 computer system. Computer programs now are used to standardize and average ring widths and calculate for each sample parameters such as serial correlation, standard deviation, and mean sensitivity. Correlation and analysis of variance programs are used to evaluate similarities and dissimilarities among any sampled series of cores. A plotting program is available to facilitate drafting of the results.

Environmental-Growth Studies: Environmental studies, as outlined in the earlier study proposal (NSF-G 19949), have been carried out essentially as originally proposed. They have been strengthened by ecological studies in the same area by Dr. Harold Mooney and students from U.C.L.A. and by statistical studies using techniques recently developed at the Laboratory of Tree-Ring Research. Data collection has benefited from experience with similar studies on other species.

Tree-growth data have been compiled for the summer of 1962. Figure 1 shows the diurnal changes in radial size of six measured trees, indicating the synchrony among trees on divergent sites. The data from six dendrographs, 18 dendrometers, cambial samples, and terminal growth are summarized in Figure 2.

All measurements indicate that growth started approximately June 20th and that radial growth was 95% completed by July 21st. Two major storms created hydration peaks in radial size on June 15th and July 13th, but the late storm did not appear to prolong growth. In fact, radial growth ceased before soil moisture reached limiting values and before terminal growth and needle elongations were complete.

It appears, from one season's observations, that the growth ring of these high elevation, drought-sensitive conifers is produced within a growing period of approximately one month and that this growth is not significantly prolonged by mid-July precipitation. This would indicate that the ring patterns reflect the environment prior to July. The cool summer temperatures at this high elevation might also suggest that differences in yearly evapo-transpiration may be negligible when considering the large variability between winters with heavy and light snowfall. Such a model of response to winter and early spring precipitations is compatible with results being obtained on pinyon pine, ponderosa pine and Douglas-fir stands at lower elevations in southwestern Colorado and northern Arizona. This model is further substantiated by the high degree of similarity between the pinyon pine and the bristlecone pine chronologies of the White Mountains. Indices for the bristlecone pine for a 271-year chronology (1650-1920) and similar data from other species (Schulman 1956) at varying distances from the White Mountains were correlated. The results are presented in Figure 3, along with the boundary of the 99 percent confidence limits for random correlations of this sample size. Correlations with stations to the east and south are distinctly higher than with stations to the north of the White Mountains, while the northeastern stations are intermediate. These chronologies show significant correlations, and hence significant cross-dating of bristlecone pines with chronologies, up to approximately 1000 miles eastward and southward, while the limit declines to approximately 700 miles to the northeast and 300 miles to the north. The development of a 4000-year bristlecone pine chronology should make it possible to date -- if not by visual inspection, then by means of correlation procedures (Fritts 1963) -- early archaeological samples throughout Arizona, New Mexico, Nevada, Utah, southern Idaho, the Rocky Mountains of Wyoming and Colorado, and as far south as northern Mexico. The procedure uses a cross-correlation technique which checks the match of an undated chronology with all possible dates of a master chronology and provides a test of significance.

Further work is underway to evaluate and measure the similarity of limber pine and pinyon pine chronologies to the bristlecone pine series of the White Mountains. Present knowledge suggests that the growth response of these species is not greatly different from that of bristlecone pines. The climatic relationships for these species already are under study in other areas and may be applied as collaborating evidence for the bristlecone pine relationships.

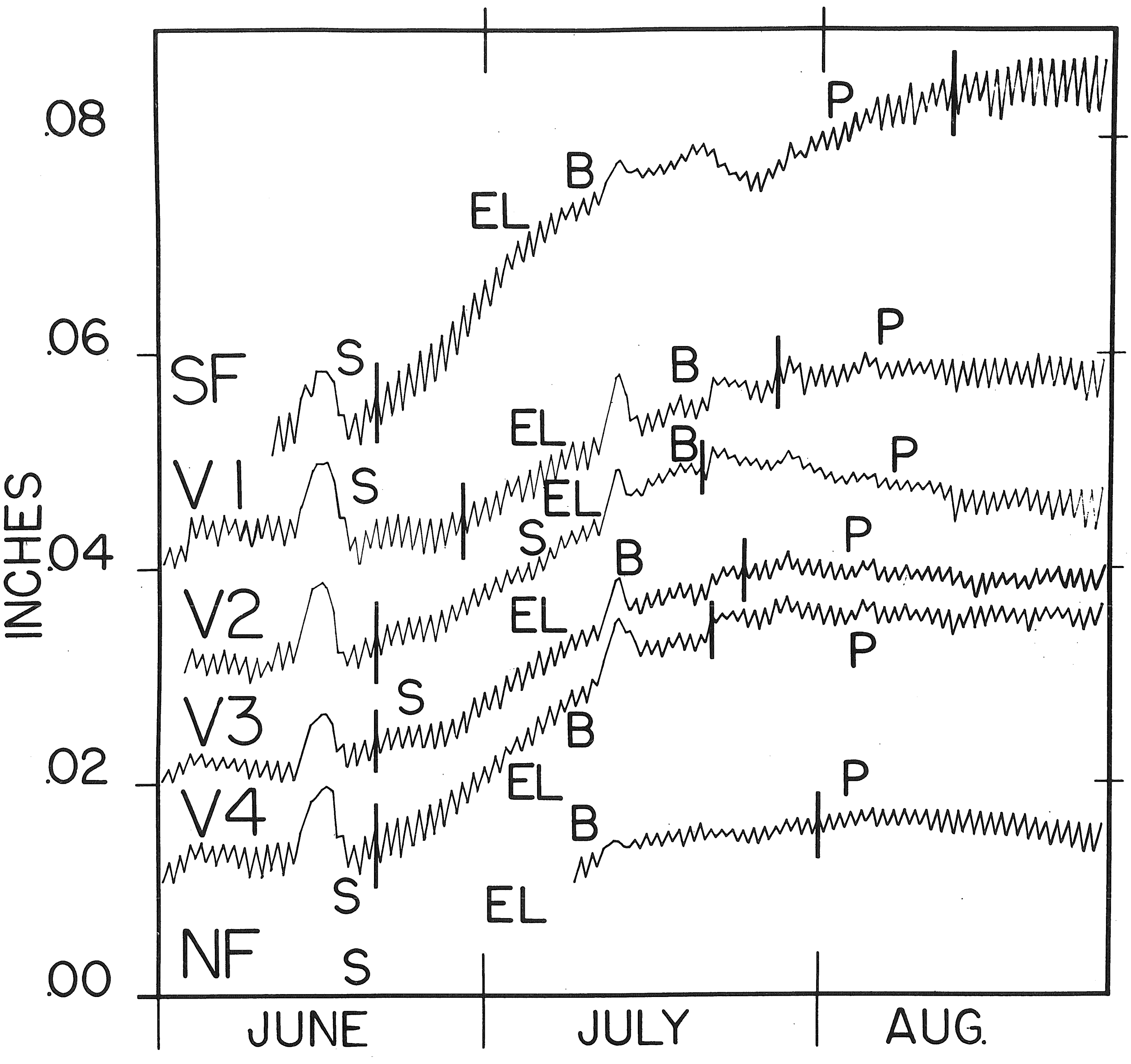

FIGURE 1. Daily maximum and minimum stem size as recorded by dendrographs for six bristlecone pine trees during 1962. SF - south-facing slope, V - valley site, NF - north-facing slope, S - buds starting to swell, EL - buds starting to elongate, B - buds opening, P - pollen shedding.

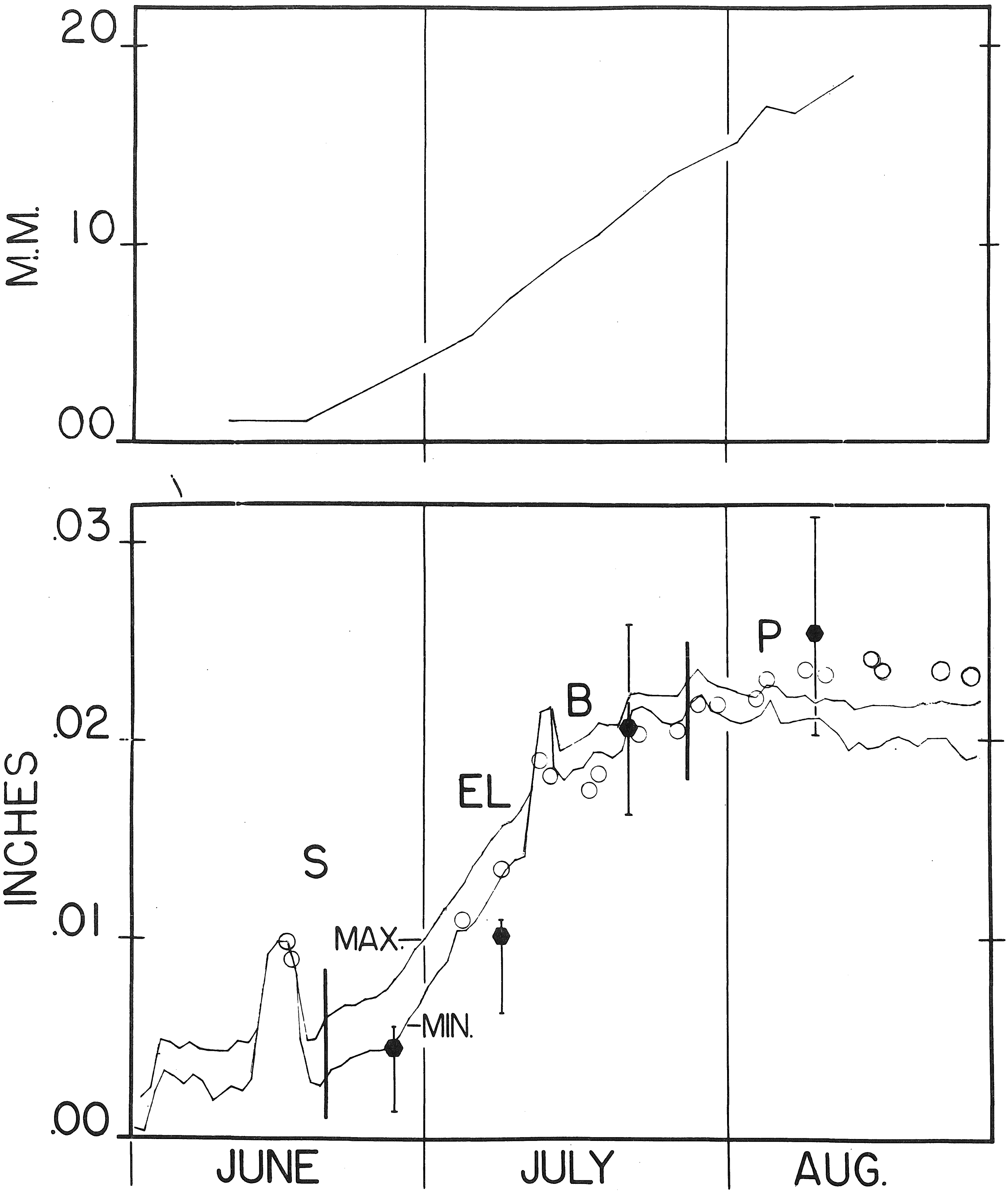

FIGURE 2. (Bottom) Average daily maximum and minimum size for one radius in six bristlecone pine during 1962, as recorded by dendrographs. CIRCLES - average dendrometer measurements, HEXAGONS and BARS - average cambial measurements and range, VERTICAL BARS - delineate the growing period.
(Top) Terminal growth.

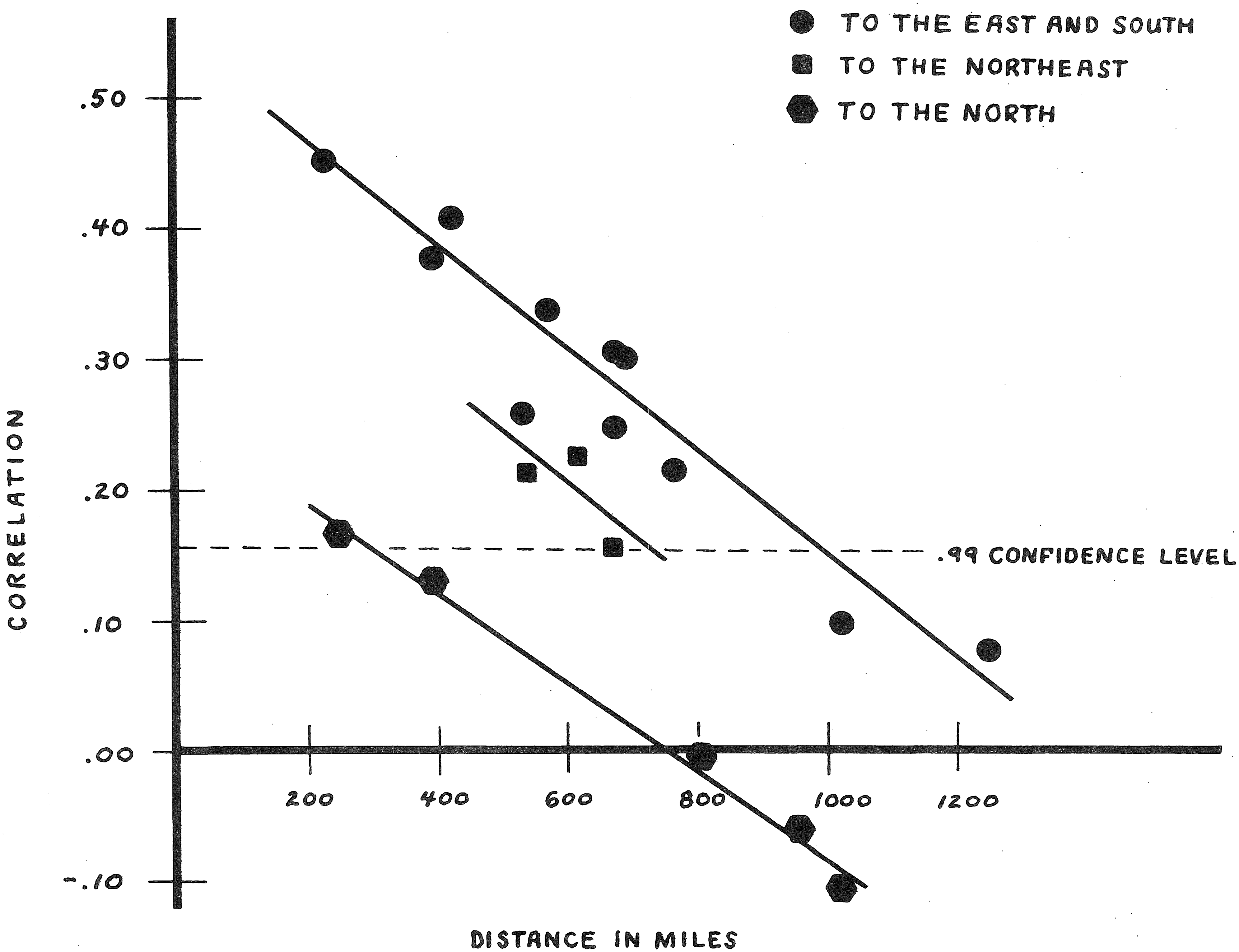

Figure 3. Correlations of bristlecone pine indices with those of other modern chronologies at varying distances and directions from the White Mountains.

PROPOSED RESEARCH

The proposed research will have five broad objectives:

1. Complete an accurate master chronology for bristlecone pine in the White Mountains of California for the maximum period.

2. Extend dendrochronological investigations of bristlecone pine to Nevada and as far east as Mt. Evans, Colorado.

3. Complete three full seasons' environmental and growth observations; complete the compilation and analyses of these data, and project the findings into the long-term record provided by dendrochronological studies.

4. Investigate climatic relationships on the basis of the extensive environmental studies and available weather records in the bristlecone pine areas.

5. Establish, in cooperation with the University of Arizona Radiocarbon Laboratory, a dendrochronological calendar as related to radiocarbon dating of the same material.

1. Completion of the White Mountain chronology. The problems involved and procedures and methods used are discussed under Chronology Building. Field work in the summer of 1963 will consist solely of additional work in the White Mountains. During the winter of 1963-1964, the field data will be analyzed. In addition, Dr. Schulman's collections and data from the survey sites outside of the White Mountains will be studied as a guide to field collections to be made in the summer of 1964 throughout the range of bristlecone pines. These data will be analyzed during the following fall and winter (1964-1965).

2. Extension of bristlecone pine chronologies to other areas. The White Mountains are geographically near the Panamint Mountains and other ranges in Nevada where additional chronologies may be developed. The White Mountain master chronology is sufficiently long to crossdate with and encompass any maximum ages that may be found; thus, individual chronologies will not have to be worked out for the additional sites. In this manner, chronologies will be developed farther east, in Nevada, Utah, and Colorado, where the bristlecone pines do not reach such great ages. There may be some anomalies, but the fact that significant cross-dating correlation has been found between bristlecone pines and other species for distances up to 1000 miles, indicates that the present chronology will be usable for a rapid examination of each area.

3. Environmental Interpretation from Ring Series. In addition to continuing the environmental growth studies into a third season to provide more data on the biological growth-environmental relationships, it is proposed that a closer look be taken at possible statistical relationships as follows: (1) determination by analysis of variance those sites in the White Mountains which produce the highest similarity of growth response and which, therefore, will produce the best climatic index with the fewest individual samples, (2) determination of the similarities and dissimilarities among bristlecone, limber, and pinyon pines (The dendroclimatic relationships for these species in other areas are being studied in other projects, and they will provide a control for interpretation.), (3) determination of the predictive equations

with corresponding error estimates for estimating prehistoric climatic parameters from the bristlecone pine indices (Fritts 1962a,c).

We also propose that we are now in a position to determine what local differences within the White Mountains may contribute to differences in the chronology, For example, growth differences may occur due to exposure and geographical distribution, which is generally the same as geologic substratum in the White Mountains. Dr. Harold Mooney, an ecologist at U.C.L.A., and Mr. John Cardis, a graduate student at the University of Arizona, are working on this aspect. Mr. Cardis will carry out this phase of the study for his master's thesis.

4. Climatic Correlations. Since climatic records for the White Mountain area only go back to 1950, it is proposed that a minimum of 100- to 200-year chronologies be obtained from bristlecone pines growing in the Bryce Canyon, Utah, area and on Mt. Evans, Colorado. These will be analyzed by statistical screening techniques (Fritts 1962a,c) using the longer and more homogeneous climatic information from adjacent weather stations at Bryce Canyon National Park, Utah, and at Idaho Springs, Colorado.

Therefore, it is felt that the biological model for dendroclimatic relationships derived from the growth studies in the White Mountains will provide the necessary cause-and-effect model underlying the statistical relationships in areas where longer weather records are available. The statistical equations derived elsewhere can be tested for the study trees of the White Mountains, using the 14-year record from the White Mountains research station and the 18-year record for Bishop. The final result should be two generalized equations. The first is for predicting tree growth from monthly climatic data which provides a means of determining the climatic complex related to growth. The second is for predicting this climatic complex from the tree-ring series and providing us with proper confidence limits and error of estimate.

Our preliminary survey of the climatic analysis indicates great promise in the possibility of deriving reliable inferences from bristlecone pines of the climatic chronology for the entire Colorado River Basin for the past 4600 years. The importance and wide application of a chronology with this length is illustrated by a closely associated study (supported by U. S. Geologic Survey) by Mr. Val LaMarche, a doctoral condidate at Harvard, who is using the chronology to derive ages of exposed roots and of trees as an aid to estimating erosion rates in the White Mountains.

The Laboratory of Tree-Ring Research has avoided studies on cycles during recent years, but recently Professor C. W. Allen, President, and D. K. Baily, Secretary (U. S. Bureau of Standards, Boulder, Colorado) of the Inter-Union Commission on Solar and Terrestrial Relationships, have shown an interest in the reexamination of data using the more sophisticated analytical equipment now available. They are also very much interested in the long chronology of bristlecone pine. We have told them that the data in our files and those derived from the bristlecone pine study would be available in the event that such studies were undertaken.

5. Correlation of radiocarbon and tree-ring dating. Dated bristlecone pine material is being used for radiocarbon investigations at The University of Pennsylvania and The University of Arizona. Glock (1963) and Libby (1963) have emphasized the need for careful, detailed, and extensive studies of tree-rings to assure exact dating. Glock has pointed out the possibility of double rings and of missing rings, which could result in an error in dating. Libby has stressed the importance of accurate tree-ring dating where comparisons are made with radiocarbon materials.

Our part of the cooperative studies with the University of Arizona Radiocarbon Laboratory is to furnish exactly dated tree-ring material that can be used to check radiocarbon determinations over a span of 4500 years. In return, the radiocarbon laboratory will provide dates on "floaters," pieces of wood that are remnants of former trees and have no provenience in relation to any living tree. These pieces were chosen from sites having a sensitive chronology and producing trees in the 4000-year range. The floaters could be the inner portions of trees of the maximum age class that have been dead for a thousand years or more. Three specimens dated so far, at 2692 $\pm$ 36, 3000 $\pm$ 300,and 3334 $\pm$ 58B.P. (5730 half life), are within the range of the present tree-ring chronology, but time has not yet permitted their study.

Carbon-14 dating of wood of unknown age may be useful in either of two ways: (1) if the Carbon-14 date falls within the range of the existing tree-ring chronology it would simplify the process of correctly identifying the exact time span in which the floater falls, or (2) should the date be prior to the existing tree-ring chronology, this material would provide a basis for ultimately extending the tree-ring chronology back in time by cross-dating individual specimens and, by filling in the gaps, tying it into the chronology based on living trees.

RELEASE OF RESEARCH RESULTS

No technical publications have been completed on the work to date, but the following papers have been presented at scientific meetings:

Cardis, John W. - Tree-growth Studies on Bristlecone Pine. Arizona Academy of Science Meeting, March 30, 1963.

Ferguson, C. W. - Tree-Ring Chronology Building in Bristlecone Pine, Pinus Aristata. Southwestern and Rocky Mountain Division AAAS Meeting, April 29, 1963.

Fritts, Harold C. - A Physiological Program for Evaluating the Use of Tree Rings as Climatic Indicators. Arizona Academy of Science Meeting, March 30, 1963.

________________. - Statistical Evaluation of Tree-Ring Series. Arizona Academy of Science Meeting, March 30, 1963.

Wright, Robert A. - Characteristics of the Tree-Ring Chronology in Bristlecone Pine. Arizona Academy of Science Meeting, March 30, 1963.

PROPOSED PUBLICATIONS

The present White Mountain study and the proposed survey study will be written as separate but related reports. The environmental studies will be published as a separate report, and the climatic studies will combine parts of the dendrochronological and environmental studies with statistical material for an overall report. It is expected that at least four major and several minor publications will result from this study.

AVAILABLE FACILITIES

The Laboratory of Tree-Ring Research will furnish all office and laboratory space. Existing shop and laboratory equipment will be used. Out-of-state transportation will be provided by public carrier or by privately owned cars.

OTHER SPONSORS

This proposal has not been submitted to any other possible sponsor. Many aspects deal with past programs that have continued over a period of time and have been sponsored by many agencies.

COOPERATING AGENCIES

The University of Arizona Radiocarbon Laboratory and various land-owning agencies, such as the U. S. Forest Service, within whose jurisdiction specimens are collected.

PERTINENT LITERATURE

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Ferguson, C. W. 1963. Annual rings in big sagebrush <u>Artemisia tridentata</u>, University of Arizona Press. In Press.

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Glock, Waldo S.; Paul J. Germann, and Sharlene Agerter. 1963a. Uniformity among growth layers in three ponderosa pine. Smith Misc. Col.: illus. 145(4): 375 illus.

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Libby, W. F. 1963. Accuracy of Radiocarbon Dates, Science 140(3564):278-280.

McGinnies, W. G. 1963. Dendrochronology. Journal of Forestry 61(1):5-11.

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________________. 1958. Bristlecone pine, oldest known living thing, The National Geographic Magazine, 113(3):354-372.

PERSONNEL

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

Harold C. Fritts, Assistant Professor of Dendrochronology, Laboratory of Tree-Ring Research. (one-fifth time contributed)

C. W. Ferguson, Research Associate in Dendrochronology, Laboratory of Tree-Ring Research, one-half time (one-quarter time contributed)

Advisory Associate: Paul E. Damon, Professor of Geochronology and Geology, in charge of radiocarbon dating at the University of Arizona.

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 major participants are attached.)

The Principal Investigator will provide general supervision and coordination. Dr. Ferguson will be in charge of developing chronologies and providing collections for radiocarbon analyses. Dr. Fritts will direct the environmental and statistical studies. Dr. Damon will advise on radiocarbon collections, and Dr. Bannister and Mr. Stokes will review chronologies and cross-dating. Measuring and recording rings, collecting and routine analyses of environmental data will be done by graduate assistants.

BIOGRAPHIES

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 Associate 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. Forest Service, Tucson, Arizona, 1938-41.
In charge of Surveys and Investigations, Guayule Project, U.S. Forest Service, Los Angeles, California, 1942-44.
Director, Rocky Mountain Forest and Range Experiment Station, U. S. Forest Service, Fort Collins, Colorado, 1945-53.

Experience (cont.):

Director, Central States Forest Experiment Station, U. S. Forest Service, Columbus Ohio, 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, American Society of Range Management, Soil Conservation Society of America, Tree-Ring Society, International Society of Biometeorology, Arizona Academy of Science.

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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Harold C. Fritts, Assistant Professor, was born in Rochester, New York, 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

Experience (cont.):

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;
NSF Fellow, Oregon Institute of Marine Biology, summer 1957.

Professional Societies:

Ecological Society, Society of Sigma Xi, Arizona Academy of Science, American Association of University Professors, Society for Social Responsibility in Science, Tree-Ring Society.

Principal Publications:

Fritts, H. C. 1955. A new dendrograph for recording radial changes of a tree. Forest Science 1(4):271-276.

____________. 1956. Radial growth of beech and soil moisture in a central Ohio forest during the growing season of 1952. Ohio Jour. Sci. 56(1):17-28.

____________. 1956. Relations of radial growth of beech (Fagus grandifolia Ehrh.) to some environmental factors in a central Ohio forest during 1954-55. Dissertation. Ohio State Univ. 1956. Microfilm #56-2077 ($1.80), Univ. Microfilms, 313 No. First St., Ann Arbor, Michigan.

____________. 1958. An analysis of radial growth of beech in a central Ohio forest during 1954-1955. Ecol. 39:705-720.

____________. 1959. The relation of radial growth to maximum and minimum temperatures in 3 tree species. Ecol. 40(2):261-265.

____________. 1959. Some soil factors affecting the distribution of beech in a central Ohio forest. Ohio Jour. of Sci. 59(3):167-186.

____________. 1959. The growth-environmental relationships of mature forest trees. Year Book Am. Philos. Soc. 269-270.

____________. 1960. Multiple regression analysis of radial growth in individual trees. For. Sci. 6(4):334-349.

____________. 1960. The distribution of river birch in Cumberland County, Illinois. Trans. Ill. Academy of Sci. 53(1-2):68-70.

____________. 1960. Daily radial growth in mature forest trees. Year Book Amer. Philos. Soc. 311-314.

____________. 1961. An analysis of maximum summer temperatures inside and outside a forest. Ecol. 42(2):436-440.

Principal Publications (cont.):

Fritts,H. C. 1961. Recent advances in dendrochronology in America with reference to the significance of climatic change. UNESCO/WMO Symposium on Changes in Climate with Special Reference to the Arid Zones. Oct. 2-7. Paper No. 35. 10 pp.

__________. 1962a. An approach to dendroclimatology: screening by means of multiple regression techniques. Journal Geophysical Res. 67(4):1413-1420.

__________. 1962b. The relevance of dendrographic studies to tree-ring research. Tree-Ring Bulletin 24(1-2):9-11.

__________ with David G. Smith. 1962c. Analysis and evaluation of the sources of variation in tree-rings from Mesa Verde National Park. Mimeographed paper presented at Annual Meeting of the American Institute of Biological Sciences, Corvallis, Oregon. 13pp. August 30, 1962.

__________. 1962d. The relation of growth ring widths in American beech and white oak to variations in climate. Tree-Ring Bulletin 25(1 and 2):2-10.

__________. 1963. Computer Programs for Tree-Ring Research. Tree-Ring Bulletin 25(3 and 4): In Press.

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

Education: B.D. (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 (Research Grant NSF-G 5368), Department of Watershed Management, 1958-1961; Research Associate (Research Grant NSF-G 19949), Laboratory of Tree-Ring Research, 1961-1963.

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.

______________. 1951. Early height growth in Douglas fir. Tree-Ring Bulletin, 17(3):18-20.

______________. 1958. Growth rings in big sagebrush as a possible aid in dating archaeological sites, pp. 210-211 in Dittert, A.E., Jr. Recent developments in Navajo Project salvage archaeology. El Palacio, 65(6):201-211.

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______________. 1963. Annual rings in big sagebrush, *Artemisia tridentata*, Manuscript in Press, University of Arizona Press, May, 1963.

______________ with D. M. Black. 1952. Tree-ring chronologies on the north rim of the Grand Canyon, Tree-Ring Bulletin, 19(20):12-18.

______________ with E. Schulman. 1956. Millennia-Old pine trees sampled in 1954 and 1955, Appendix C in Schulman, E., 1956, Dendroclimatic Changes in Semi-arid America, The University of Arizona Press, Tucson, Arizona.

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

______________ with R. A. Wright. 1962b. Botanical Studies (in Fontana, Bernard L., and J. Cameron Greenleaf with collaboration of Charles W. Ferguson, Robert A. Wright, and Doris Fredrick. Johnny Ward's Ranch: A Study in Historic Archaeology). The Kiva, 28(1-2):108-114.

BUDGET

Salaries:	1st. yr. Oct. 1, 1963- June 30, 1964	2nd. yr. Jul. 1, 1964- June 30, 1965	Total
W. G. McGinnies, principal investigator	--	--	--
Harold C. Fritts (1/5 time contributed)	--	--	--
C. W. Ferguson, assistant professor-1/2 time (1/4 time contributed)	3,200	4,400	7,600
2 half-time graduate research assistants (full-time summer 1964)	5,400	6,400	11,800
1 one-quarter time graduate assistant-conducting dendroclimatic analysis	1,400	1,600	3,000
Clerical assistance and labor	1,300	1,300	2,600
TOTAL	$11,300	$13,700	$25,000
Payroll taxes and insurance(6.5% of above)	$ 734	$ 891	$ 1,625
Permanent equipment:			
Power increment borer (a new product)	$ 480	$	$ 480
Swedish increment borer replacements	240		240
TOTAL	$ 720		$ 720
Supplies and Services:			
Computations, programming, computer costs	$ 4,850	$ 4,850	$ 9,700
Radiocarbon analyses (20 runs @ $150)	1,500	1,500	3,000
Photo supplies, graph paper, sand paper, groove mounting sticks, razor blades, etc.	400	300	700
Processing progress reports and purchase of reprints	200	300	500
TOTAL	$ 6,950	$ 6,950	$13,900

	1st. yr. Oct. 1, 1963- June 30, 1964	2nd. yr. Jul. 1, 1964- June 30, 1965	Total
Travel:			
Ferguson - July 1964, White Mountains, Calif. - August 1964, Nevada	--	$ 700	$ 700
Fritts - 2 trips to White Mountains, Calif.	$ 150	150	300
McGinnies - trips to White Mountains, Calif. and Nevada	150	150	300
Research Assistant to Dr. Fritts - 3 months in the White Mountains, Calif.	300	500	800
Attendance at conferences and meetings (three leaders)	300	300	600
TOTAL	$ 900	$ 1,800	$ 2,700
TOTAL of Direct Costs	$20,604	$23,341	$43,945
25% Overhead	$ 5,151	$ 5,835	$10,986
GRAND TOTAL	$25,755	$29,176	$54,931