DENDROCHRONOLOGY OF BRISTLECONE PINE PRIOR TO 4000 B.C.

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INTERNATIONAL RADIOCARBON DATING CONFERENCE

Lower Hutt City
Wellington, New Zealand

18 - 25 October 1972

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ABSTRACT

A 7104-year tree-ring chronology for bristlecone pine was published in tabular form in 1969. Since then, the chronology has been improved in quality and extended in time. Twenty-one pieces of wood, representing separate trees, have been identified for the period prior to 4000 B.C. and these have made possible a chronology extension to nearly 8200 years. In this paper, the specimens are described in terms of the time range each represents and their statistical parameters relating to the quality of tree-ring record they contain. These specimens not only have extended the climatic tree-ring chronology, but also have made possible the calendar-year dating of additional samples for calibration of the radiocarbon time scale.

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INTRODUCTION

The previously reported tree-ring chronology for bristlecone pine, Pinus aristata Engelm. (Pinus longaeva, D. K. Bailey, sp. nov.) by Ferguson (1969) consisted of two existent chronology units in the recent centuries and 17 individual specimens that span the 7104-year interval from 5142 B.C. to A.D. 1962. When data were again reported by Ferguson (pp. 237-259 in Olsson, 1970), a 400-year extension was added.

Though the initial focus of the study was climatic (Schulman, 1956), emphasis soon shifted to radiocarbon. With its chronology extended to nearly 8200 years ago, bristlecone pine has been used to calibrate the C-14 time scale (various contributors in Olsson, 1970). In addition to expected short-term fluctuations, a major deviation, with radiocarbon dates being as much as 1,000 years too recent, became evident. The direction of this anomaly beyond the present tree-ring chronology poses intriguing questions, and interest focused upon the search for even earlier bristlecone pine remnants as well as for material of a different species and in other and varied situations that might predate the bristlecone pine chronology.

FIELD AND LABORATORY PROCEDURES

Radial growth-ring sequences in core samples extracted with a Swedish increment borer have been the primary source of chronologic data, even when the emphasis shifted from the living trees to standing or fallen snags or large, eroded remnants of trees. Now, with the search for wood in the range of 7000 years old, we may collect entire smaller remnants having the appearance of age and without specific known origin in relation to any tree, living or dead. These remnants are highly valuable in that they provide more surface area for detailed study of the very narrow and often locally absent rings that are critical in chronology building. They also constitute the principal source of tree-ring material for radiocarbon analyses.

Dendrochronological dating of the specimens follows standard practices at the Laboratory of Tree-Ring Research (Ferguson, pp. 183-200, in Berger, 1970; Stokes and Smiley, 1968). Greater use is made of plotted ring measurements than of the skeleton-plot techniques. Visual correlations of the plotted ring-width measurements are attempted with the master chronologies and between individual specimens. Apparent matches are confirmed by re-examining the wood. Finally, all of the dated ring series are standardized to simplify comparisons and to facilitate statistical analysis.

RESULTS

Twenty-one bristlecone pine remnants with all or a portion of their tree-ring record earlier than 4000 B.C. have been dendrochronologically dated. These are summarized in Table 1, along with the related mean sensitivity, which expresses the relative year-to-year variation in the ring index values, and first-order serial correlation, which measures the degree of dependence of a single growth-ring index upon the index of the preceding ring. For most of the specimens, the means are completely developed on the basis of measurements from many radii and/or sections. For those that are not, the existent statistical parameters have been averaged rather than presented as component parts. And a few, as indicated by the blank spaces in the statistical columns, are still in process of completion.

Crossdating between specimens is shown (Fig. 1) in the plotted ring-width measurements for the outer part of TRL 67-202D and the inner part of TRL 70-20 for the computer-year interval 2750-2883 (5251 to 5118 B.C.). Visual inspection of the plots, focusing on the small rings such as for the computer-years 2762, 2788, 2806, 2816, and 2850, shows the similarity in ring patterns. This illustrative unit is representative of the much longer sequences contained in these long-lived trees.

The specimen depth in the range prior to 4000 B.C. is quite adequate (Fig. 2), but the earliest 340 years are represented by only one specimen.

The 508-year "floating" sequence of 67-40 is above average in quality and is included because of its great radiocarbon age. Apparently it is separated from the 8253-year sequence by a gap of about 1000 radiocarbon years. The size of this gap depends upon the rate of C-14 production in that time interval.

TABLE 1. Components of the bristlecone pine chronology prior to 4000 B.C., with the related interval in years B.C., mean sensitivity, and serial correlation.

Specimen TRL no.	Interval years-B.C.	Mean Sensitivity	Serial Correlation
65-F131	4205-3102	.33	.28
71-52	4251-4001	.42	.42
69-209	4315-4000	---	---
65-F117	4401-3271	.28	.53
63-92	4462-4023	.26	.58
69-203A	4463-4000	---	---
69-202A	4641-4441	.35	.22
70-37	4741-4358	.45	.28
63-34	4796-2900	.47	.30
70-40	4894-4500	.44	.43
69-203B	4894-4613	---	---
70-98	4909-4511	.52	.33
69-202C	4929-4681	.43	.23
69-202B	5005-4897	---	---
70-97	5006-4631	---	---
63-92E	5142-4561	.35	.45
70-20	5452-4706	.51	.33
67-35	5525-4715	.49	.31
71-59	5951-5481	---	---
69-202D	6291-5106	.54	.32
67-40	508 years (undated)	.29	.50

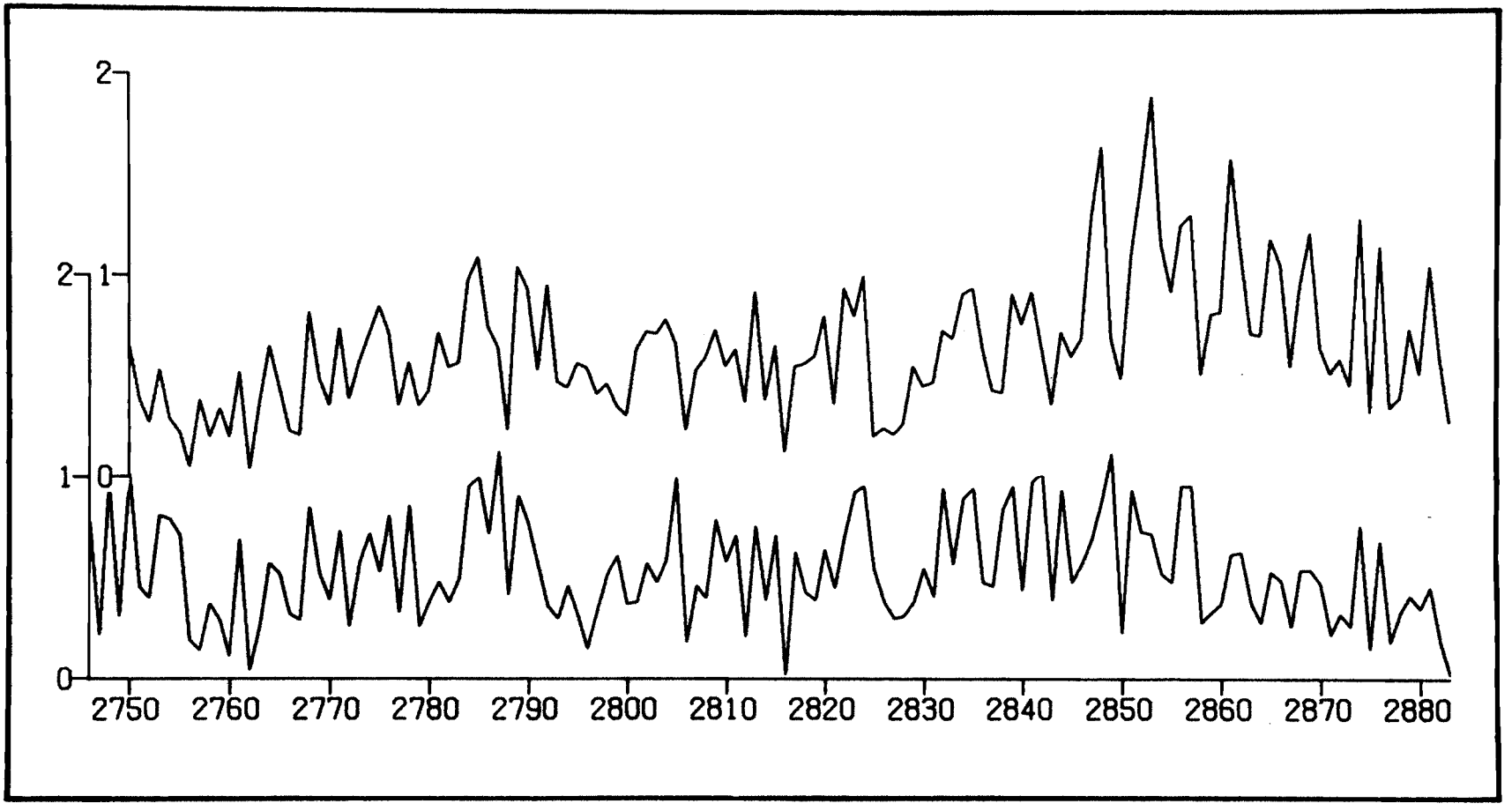

Figure 1. Plotted ring-width measurements for 69-202D (upper) and 70-20 (lower) for the computer year interval 2750-2883 (5251-5118 B.C.) illustrating crossdating between specimens. Vertical scale in millimeters.

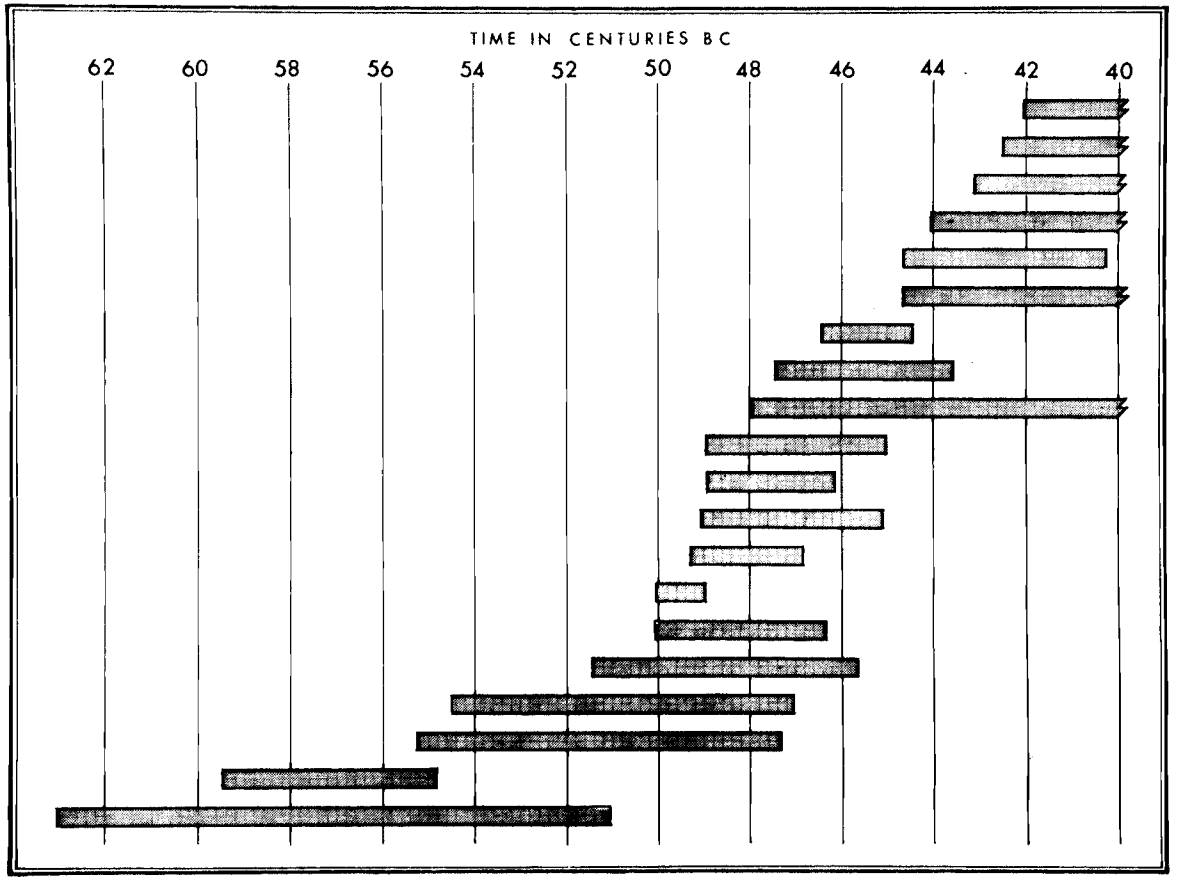

Figure 2. Components of the master chronology prior to 4000 B.C.

RADIOCARBON ANALYSIS

Studies in cooperation with radiocarbon laboratories at the universities of Arizona, California (San Diego), and Pennsylvania are a major aspect of the present project. These related radiocarbon studies have been reported by Damon, Long, and Grey; Ralph and Michael; and Suess in the proceedings of the Nobel Symposium XII (Olsson, 1970) and in this volume.

The Laboratory of Tree-Ring Research provides precisely dated wood, in 10-year, 20-gram samples as it becomes available throughout the total range of the established chronology for the calibration of dates derived by radiocarbon analysis. As of 1 June, 1972, 612 samples, representing the broad time intervals listed in Table 2, had been sent to the cooperating radiocarbon laboratories. Since then, 23 samples in the 4000-5500 B.C. range have been sent out, but with arbitrary "floating" sequences, pending precise tree-ring dating. Two bulk specimens collected in May 1972--capitalizing upon analysis of the 1971 collections--are making wood available in two critical time ranges: 3000-4000 and 5400-5900 B.C.

The continuing search for old wood has also been aided by C-14 data (Fig. 3). Dendrochronological dating of tree-ring specimens of unknown age can be greatly facilitated by the time placement made possible through radiocarbon analysis interpreted in terms of the known calibration.

TABLE 2. Dated samples submitted for radiocarbon analysis.

Interval	Number of samples
A.D. 1972-1001	47
1000- 1	53
1-1000 B.C.	72
1001-2000 B.C.	155
2001-3000 B.C.	96
3001-4000 B.C.	82
4001-5000 B.C.	87
5001-5500 B.C.	20
Total	612

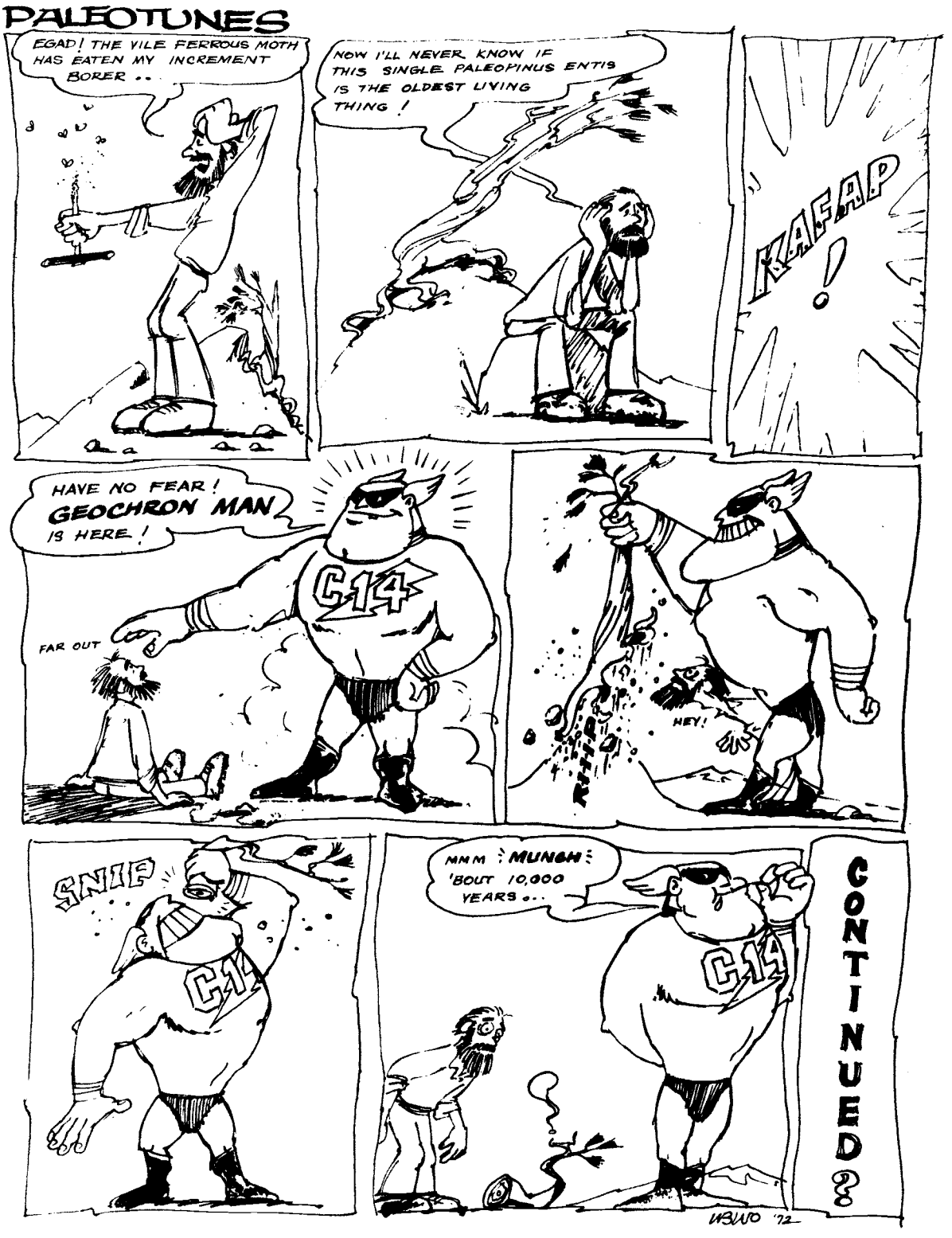

Figure 3. Support of tree-ring dating made possible by C-14 analysis (original drawing by Wallace B. Woolfenden, 1972).

With the present master chronology as a guide to dating, with the constantly increasing supply of bulk wood throughout the known time range, with the slow but steady improvement in the quality of the collected wood, and with the hundreds of 20-gram decade units now on hand, we are in a continuously better position to supply dated wood for radiocarbon analysis and other isotopic methods, as well as for studies involving remnant magnetism, trace elements, and supernova explosions.

ACKNOWLEDGMENTS

The bristlecone pine study has had the continued support of the National Science Foundation, most recently NSF grant GA-20618.

Work in the White Mountains (California) is conducted with the permission and cooperation of the Inyo National Forest.

Specimen preparation and laboratory analysis were done by Dennie O. Bowden, Donna Marcynyszyn, and Judith Mikevich (now Bowden) at the Laboratory of Tree-Ring Research. Computer analysis has been effectively administered by Linda G. Drew of the Laboratory's data processing section. And I would like to express gratitude to my colleagues at the Laboratory and to my wife Eileen for their continued interest and support.

ERRATA

Page 2, line 1 under RESULTS should read twenty remnants, not twenty-one.

Page 2, line 2, second paragraph under RESULTS should read TRL 69-202D, not TRL 67-202D.

ADDENDUM

The correlation coefficient is .53 for the 134-year series of ring widths plotted in Fig. 1.

Final resolution of the tree-ring chronologies of the 20 specimens dated prior to 4000 B.C. and reported in this paper will permit the chronology data to be presented in tabular form and to be used as a plotted series. And because additional specimens obviously add to the numerical strength of the chronology, there is a continual search for old wood. Two such remnants were recently identified by radiocarbon analysis and were subsequently tree-ring dated. The first (TRL 71-61), collected *en toto* in the spring of 1972, spans the interval of 5400 to 4450 B.C. and is the fifth oldest dendrochronologically dated piece of wood. The second (TRL 72-23), an exploratory sample taken from a larger remnant, has a ring series from 4006 to 3420 B.C. Thus, there are now 22 dendrochronologically dated specimens with all or a portion of the wood prior to 4000 B.C.

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