SELECTED READINGS IN DENDROCHRONOLOGY

C. W. Ferguson, Editor

Orientation Program

11-15 October 1982

Laboratory of Tree-Ring Research

University of Arizona

Tucson, Arizona

85721
**TABLE OF CONTENTS**

**Articles and Reports:**

<table>
<thead>
<tr>
<th>Title</th>
<th>Total Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglass Memorial</td>
<td>9</td>
</tr>
<tr>
<td>Dramatic Moment (Haury)</td>
<td>4</td>
</tr>
<tr>
<td>Schulman Memorial</td>
<td>5</td>
</tr>
<tr>
<td>Dating Prehistoric Ruins (Stallings)</td>
<td>16</td>
</tr>
<tr>
<td>Pre-Douglass Dendrochronology</td>
<td>7</td>
</tr>
<tr>
<td>Maximum Ages</td>
<td>1</td>
</tr>
<tr>
<td>Shrubs and Non-Conifers</td>
<td>1</td>
</tr>
<tr>
<td>Site-Specimen Criteria</td>
<td>3</td>
</tr>
<tr>
<td>Data Processing</td>
<td>1</td>
</tr>
<tr>
<td>Accuracy in Measurement</td>
<td>1</td>
</tr>
</tbody>
</table>

**Topic Bibliographies:**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dendroclimatic Research</td>
<td>3</td>
</tr>
<tr>
<td>X-ray Densitometry</td>
<td>2</td>
</tr>
<tr>
<td>Fire History</td>
<td>3</td>
</tr>
<tr>
<td>Dendrogeomorphology</td>
<td>3</td>
</tr>
<tr>
<td>Great Basin</td>
<td>3</td>
</tr>
<tr>
<td>Alaska-Yukon</td>
<td>1</td>
</tr>
<tr>
<td>New Zealand</td>
<td>6</td>
</tr>
<tr>
<td>Australia</td>
<td>3</td>
</tr>
<tr>
<td>Europe</td>
<td>4</td>
</tr>
<tr>
<td>Africa</td>
<td>1</td>
</tr>
<tr>
<td>Addendum</td>
<td>Total Pages</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Laboratory of Tree-Ring Research</td>
<td>1</td>
</tr>
<tr>
<td>Dendrochronology</td>
<td>1</td>
</tr>
<tr>
<td>Ecology and Age of Creosote, <em>Larrea</em></td>
<td>1</td>
</tr>
<tr>
<td>Tamarisk Bibliography</td>
<td>2</td>
</tr>
<tr>
<td>Tree Rings and Fire History</td>
<td>1</td>
</tr>
<tr>
<td>Forensic Dendrochronology</td>
<td>3</td>
</tr>
<tr>
<td>Dendrochronology of Bristlecone Pine</td>
<td>2</td>
</tr>
<tr>
<td>Ecology of Bristlecone Pine</td>
<td>1</td>
</tr>
<tr>
<td>Bristlecone Pine and Radiocarbon Dating</td>
<td>1</td>
</tr>
<tr>
<td>C-14 Dating</td>
<td>1</td>
</tr>
<tr>
<td>The NSF-Arizona Regional Accelerator Facility</td>
<td>1</td>
</tr>
</tbody>
</table>
Subscription $2.00 per Volume

THE TREE-RING BULLETIN
Editor . . . . . Bryant Bannister
Assistant Editors . . J. L. Giddings
Erik Holmgaard
Harold C. Fritts

THE TREE-RING SOCIETY
President . . . John C. Mc.Gregor
Secretary-Treasurer . C. W. Ferguson

Manuscripts and inquiries should be directed to the Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona.

ANDREW ELICOTT DOUGLASS
1867-1962

Charles W. Herbert, Western Ways
ANDREW ELLICOTT DOUGLASS
1867-1962

Andrew Ellicott Douglass died March 20, 1962, in Tucson, Arizona, at the age of 94. It can be said that he lived as full and productive a life as any man of this era. To some, he will be remembered as an astronomer of the first magnitude, to others he was a physicist, a philosopher, an inventor, a judge, a mountain climber, a college president—and to all a scientist and teacher. But to readers of the Tree-Ring Bulletin, Douglass will be remembered as the father of dendrochronology. It cannot be said that he created tree-ring research, but it can be truly stated that he pioneered, developed, and stimulated the study and application of tree-ring data.

Douglass was born in Windsor, Vermont, on July 5, 1867, the son of the Reverend Malcolm and Sarah E. (Hale) Douglass. He grew up in New England and attended Trinity College in Connecticut. In later years, he often cited his New England heritage as responsible for his first interest in tree-rings; the contrast between the moist country of his childhood and the arid Southwest aroused his curiosity as to what story the rings of trees might tell. After graduating with the B.A. degree in 1889, he started his career in astronomy as an assistant in the Harvard College Observatory, a position he held until 1894. During this time he spent several years as a member of the Harvard Expedition to Peru, where, in addition to helping decide the site of the Peruvian Station of the Harvard College Observatory near Arequipa, he became the first man to measure the rate of movement of Peru's famous crescentic sand dunes.

In 1894, at the request of Percival Lowell, Douglass selected the location for the Lowell Observatory in Flagstaff and became First Assistant at the observatory. Traveling by buckboard across the then wild Territory of Arizona, he became familiar with the country he was to know so intimately in future years. In the beginning of the twentieth century, Douglass served three years as Probate Judge for Coconino County (1903-1906), and taught at Northern Arizona Normal, now Arizona State College at Flagstaff, in 1905 and 1906. It was during this period that he married Ida E. Whittington, in 1905.

Douglass moved to the University of Arizona in 1906 and remained as a member of the faculty until his death. He began as Assistant Professor of Physics and Geography and advanced to Professor of Physics and Astronomy a year later, a title held until 1922. In 1910 and 1911, he served as Acting President of the University, and from 1915 to 1917, as Dean of the College of Letters, Arts, and Sciences. After designing and being instrumental in the establishment of Steward Observatory, he became its first director in 1917. Here it was that tree-ring specimens and telescopes existed side by side and Douglass' mastery of two sciences brought world-wide attention. In 1936, the title of Professor of Dendrochronology was added and he became Director of the newly established Laboratory of Tree-Ring Research in 1938. Also in 1938, he became Director Emeritus of the Steward Observatory but returned as Acting Director during the war years 1942-1946. From 1946 to 1958, he was Director Emeritus of the Steward Observatory; Director of the Laboratory of Tree-Ring Research; Professor of Astronomy and Dendrochronology half-time; and, after 1958, he also became Director Emeritus of the Tree-Ring Laboratory, continuing all assignments on a part-time basis.

To trace the beginnings of Douglass' tree-ring work, one must go back to 1901 when, seeking an answer to the problem of extending sun-spot records into the past, he turned to trees as possible recorders of solar phenomena. During these early years in Flagstaff, Douglass examined
scores of ring series, often traveling out to lumbering areas and making crude rubbings from the tops of freshly cut stumps. A portent of future events came about in 1904 when Douglass recognized a characteristic ring pattern in an old stump and confidently announced the year in which the tree had been felled—much to the amazement of the farmer who had done the cutting. By 1907 a considerable group of Flagstaff trees had been studied and measured and the results were published in 1909, the first of Douglass' long list of tree-ring citations. He had thoroughly committed the Flagstaff ring series to memory and it came as a revelation when in 1911 he recognized the same ring patterns occurring in trees near Prescott. When the significance of the crossdating principle was fully realized, Douglass turned to his tree-ring research with the exceptional vigor that characterized his entire scientific career. He collected and studied groups of trees in northern Europe and then from 1915 to 1919 focused his attention on the giant sequoias of California, hoping at the time that their chronologies would crossdate with the trees of northern Arizona. A major summary report of all his tree-ring work to that date, “Climatic Cycles and Tree-Growth, Volume I” was published in 1919 by the Carnegie Institution of Washington.

Meanwhile, an odd alliance with a field far removed from astronomy was beginning to take form. Clark Wissler of the American Museum of Natural History heard Douglass talk at a Washington meeting in 1914 and a few years later arranged to have Douglass look at some wood samples from prehistoric ruins in New Mexico. Douglass evidently liked what he saw, for in 1919 he received six additional beam sections collected from Aztec Ruin in New Mexico by Earl H. Morris and promptly announced that the Aztec specimens crossdated with each other. The next step followed a year later when Douglass studied some Pueblo Bonito logs and quickly determined that they too could be crossdated with the Aztec pieces and, in fact, the relative time relationship of the two ruins could be stated. This was exciting news indeed to the archaeologists and there then began an association between Douglass and the archaeological profession, helped along by the National Geographic Society, which attained its highest point in 1929 with the successful dating of Pueblo Bonito and the assignment of absolute dates to some forty other major ruins in the Southwest. The Pueblo Bonito Dating Project, described in detail in Douglass' 1935 publication, “Dating Pueblo Bonito and Other Ruins of the Southwest,” stands as one of the finest examples of inter-disciplinary cooperation in the annals of American archaeology.

The relationship of Southwestern tree-growth and climate also received early attention by Douglass. His 1914 paper on a method of estimating rainfall by the growth of trees was but the first of his many publications on this subject. Greatly amplified and extended by his students, notably the late Edmund Schulman, the still expanding field of dendroclimatology has become one of the most important aspects of tree-ring research.

In addition to his other activities, Douglass maintained his keen interest in sunspots and weather cycles throughout his life. To those who knew him well, it often appeared that he considered his tree-ring work as no more than a convenient way of gathering data for cycle studies and his successful venture into archaeological dating as but a brief interlude in his search for understanding solar-terrestrial relationships. By the 1940's, when Edmund Schulman had capably taken on the bulk of dendroclimatic investigations and archaeological tree-ring dating was being practiced in several institutions by a score of former students, Douglass was devoting
nearly all of his research time to the quest for a method of long-range weather prediction—a problem he saw in terms of solar cycles affecting the meteorological patterns of Earth's atmosphere. Early in his work he constructed the ingenious cycloscope, an instrument designed to optically analyze tree-ring and other time-series data for cyclic content. Later, when in his late 80's, Douglass designed a complex planetary interpolator to aid in his investigation of planetary-solar relationships. It is entirely conceivable that Douglass' most important scientific contribution may lie in the cyclic hypotheses formulated during the last decade of his life.

Douglass received numerous honors throughout his career. In 1908, he was awarded the honorary degree of Doctor of Science by Trinity College and twenty years later the University of Arizona paid tribute in similar fashion. He was the recipient of an award by the Research Corporation of New York in 1931 and both the Society for American Archaeology and the American Anthropological Association recognized his scientific contributions with honorary resolutions passed in 1956. One measure of his standing is indicated by the many philanthropic organizations which supported his work. The Carnegie Institution of Washington, for example, in which he held the title of Research Associate from 1925 to 1938, contributed generously to his researches during the 1920's and 30's and other institutions are frequently cited for their help throughout his publications. He also had been elected to such honorary societies as Phi Kappa Phi, Psi Upsilon, Sigma Xi, and Phi Beta Kappa, at one time serving as President of the Arizona Chapters of the latter two.

His membership in professional societies reflects both the wide range of his interests and the high esteem in which he was held by his scientific colleagues. At various times, he belonged to the Royal Astronomical Society (Fellow), American Association for the Advancement of Science (Fellow and President of the Southwestern Division in 1921), American Philosophical Society, American Meteorological Society (Fellow and Vice-President in 1924-1925), Southern California Academy of Science (honorary member), Arizona Archeological and Historical Society (Vice-President in 1923 and President in 1929-1930), American Astronomical Society, Geographical Union, and Astronomical Society of the Pacific. In addition, he served as President of the Tree-Ring Society from its inception in 1935 until his retirement in 1958 and acted as Editor-in-chief of the Tree-Ring Bulletin for most of those years. Douglass was also an honorary life member of the National Geographic Society, a Rotarian, and a 33° Scottish Rite Mason.

That Douglass was an internationally famous scientist who brought great distinction to the University of Arizona is acknowledged by all. That he displayed a warmth and humaneness typical of a truly great man is known to everyone who came in contact with him. That he was an exceptional and inspirational man is attested by his associates and students. And as for his contribution to tree-ring research, perhaps the most realistic way of paying proper tribute to Douglass is to simply state that to his colleagues the man and the science will always remain synonymous.

BIBLIOGRAPHY

1892

1894
Swift's Comet, 1892. Astronomy and Astro-Physics, June.

1895
The Polar Cap of Mars. Astronomy and Astro-Physics, No. 129.
Forms of Jupiter's Satellites. Popular Astronomy, May.


1896

1897
The Lowell Observatory in Mexico. Popular Astronomy, No. 39.


1898


Stellar Bands in the Zodiac from Gemini to Scorpio. Popular Astronomy, April, pp. 511-513.


Scales of Seeing. Popular Astronomy, June.


1899

A Summary of Planetary Work at the Lowell Observatory and the Conditions Under Which It Has Been Performed. Popular Astronomy, February.

Mars. Popular Astronomy, March.

1900

Photographs of the Zodiacal Light. Popular Astronomy, No. 74.


1901


1903


1907


1909


1910

1914

1915

1916
The Callender Sunshine Recorder and Some of the World-Wide Problems to Which This Instrument Can Be Applied. Publication of the Second Pan-American Scientific Congress, Sec. 2, pp. 570-579.

1917

1918

1919

1920

1921

1922

1923

1924

1925
<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
<th>Journal/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dating Pueblo Bonito and Other Ruins of the Southwest.</td>
<td>National Geographic Society, Contributed Technical Papers, Pueblo Bonito Series, No. 1.</td>
</tr>
<tr>
<td>Year</td>
<td>Event</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>1943</td>
<td>Advances in Dendrochronology, 1943. Tree-Ring Bulletin, Vol. 9, No. 3.</td>
<td></td>
</tr>
</tbody>
</table>


1939


1940


Estimated Ring Chronology 150-1934 A.D. Tree-Ring Bulletin, Vol. 6, No. 4, insert.


1941


Notes on the Technique of Tree-Ring Analysis, III. Tree-Ring Bulletin, Vol. 8, No. 2.


1942


1943

Advances in Dendrochronology, 1943. Tree-Ring Bulletin, Vol. 9, No. 3.


1944

1945
Survey of Sequoia Studies, I. Tree-Ring Bulletin, Vol. 11, No. 4.
Survey of Sequoia Studies, II. Tree-Ring Bulletin, Vol. 12, No. 2.

1946
Precision of Ring Dating in Tree-Ring Chronologies. University of Arizona Bulletin, Vol. 8, No. 3. Laboratory of Tree-Ring Research Bulletin No. 3.

1947

1949

1950

1951
The chronicle of A. E. Douglass' experiences in developing his world-renowned studies into the growth behavior of trees is laden with the insight of a scientist, hard work, frustrations, heartwarming episodes and high drama. Although the complete story of his experiences has not been written and the full impact of his contributions to archaeology has not yet been assessed, one event, which stands out above all the rest, bears recounting on this occasion.

Let us turn time back, as Douglass so successfully did on a grand scale, to the late 1920's. Judd was putting the finishing touches on Pueblo Bonito; Morris was making his uniquely effective contributions to our knowledge of the Basketmakers by urging his battered little truck into the canyons of the Red Rock country; Colton and Gladwin were launching the Museum of Northern Arizona and Gila Pueblo respectively. And there were others, too numerous to mention. It was a time of great activity, spurred in part by the first codification of the knowledge of the Southwest by the Pecos Conference in 1927. Lacking at that time was any acceptable basis for pinning age labels on the periods of culture development, Basketmaker I to III and Pueblo I to IV, which grew out of the Pecos Conference discussions. Only Pueblo V was securely anchored in the historical present. But, for earlier periods, even the best informed estimates varied widely.

One heard reference to the Basketmakers at 2000 B.C. without provoking an argumentative ripple. Where did the great population centers of Chaco Canyon, Mesa Verde, of the Tsegi, and countless other well-known ruins fit into the Christian calendar? The uncertainty bore down on everyone's thinking, for descriptions of ruins, studies of pots and pans, and efforts to recreate ancient history were sterile without a valid sense of time. All eyes, some skeptical, were turned on the astronomer Douglass; his mind and hands were developing a method that might yield the key to unlock this chronological impasse.

By 1929 Douglass reached the break-through point in his studies. Had this been achieved a decade or two earlier, he would certainly have experienced agonizing delays for the necessary advances in archaeological knowledge had not been made and the mood of the archaeologists was not then ready for him. But, by happy coincidence in the accident of history, the man's idea and the technique were introduced to the discipline about to be vastly enriched at the right moment in its progress.

The Third National Geographic Society Beam Expedition was set into operation in 1929. Its program, arising out of the experiences of the First and Second Beam Expeditions, was to make an all-out attack on the problem of uniting two separate chronologies resulting from Douglass' work up to that moment. The first segment was the chronology beginning with the records in the then-growing trees and extending back in time to about A.D. 1260. To achieve this, Douglass had made use of the timbers from Old Oraibi and even charcoal dug from the ruins of Kawaiku. The second segment of the chronology he called the Relative Dating Series. It was developed from the ring records of wood provided him by the archaeologists, beams from Aztec, Pueblo Bonito, Cliff Palace, Betatakin and others. This series was 585 years in length. It was clear that if this sequence of rings could be joined to the ring record of known age, the time of occupancy of

these ruins would immediately become known. Bridging the gap, therefore, became the prime preoccupation, and it was this task to which the Third Beam Expedition was directed.

At this point, knowledge of regional archaeology became important, and the predictive aspect of science had to be called upon. It was known that in northern Arizona, color gradations in the evolution of pottery ranged from red, then orange to yellow. The wood providing the ring record in the oldest part of the historic sequence came from a time when yellow pottery was produced. The youngest logs of the Relative Dating sequence came from ruins that produced red pottery. The answer seemed clear: locate ruins with a predominance of orange pottery, for in them there might be found the architectural wood whose rings would bind the two sequences together.

There was also the factor of geographical location, for the right kinds of trees had to be available to the ancient builders. This presented something of a dilemma. Ruins with the strongest accent of orange-hued pottery were farthest from presumed timber sources, and ruins in the most favorable environments produced a predominance of red pottery, albeit of a different kind than the red pottery of earlier times.

Colton, Judd, and Hargrave worked closely with Douglass in selecting the most promising sites. Four were eventually decided upon: the Whipple Ruin at Showlow, the Pinedale Ruin 15 miles to the west, Kintiel and Kokopnyama more than 100 miles to the north. Hargrave and Haury were signed on to guide the field operations. The party first moved to Showlow in mid-June, 1929, and took up residence in the local hostelry, a converted two-story red brick home. Telephone service was uncertain at best and electric lights were not yet contributing to the luxury of local living. The advantage was that the hotel was just across the street from the ruin.

I cannot say that our first glimpse of the ruin filled us with a sense of destiny. The location of the site on the highest ground adjacent to the flat Showlow valley had made it attractive for homesites for the people who settled there just before the turn of the century. Three houses and sundry barns, sheds, and outhouses occupied flattened parts of the site and many of the original building stones had been put to modern use. Furthermore, much of the ruin had been turned over by one of the owners in search of pottery. It seemed a dismal prospect to do worthwhile archaeology here.

By Tuesday, June 18, a small crew of laborers had been enlisted and the first ground was broken. We had to remember that this was a charcoal-hunting junket and no matter how interesting the test, if no “black gold” appeared, it had to be abandoned in favor of another.

For several days diary entries reveal a tone of discouragement by such notations as “nothing out of the ordinary today.” To spur the laborers to maximum effort a bonus of $5 was offered to the man finding a specimen with a hundred rings or more.

Hargrave and I had devised a code system for numbering the specimens found, employing the beginning letter of our surnames, followed by a serial number, which recorded the order of discovery. The register shows HH-1 as a miscellaneous collection of 13 charcoal scraps recovered in a clean-up operation of previous testing. Most of these were no larger than a walnut, and the cataloguing of them was a sign of sheer desperation, although we would not view the keeping of small pieces in such a way today.

A stone-wall property line cut off the major part of the ruin from a small appendage at the far north end. Just what prompted digging in this inconspicuous part of the village beyond the wall I do not recall, but let’s attribute it to the desire to sample broadly. Close to the surface a laborer’s shovel brought up black, the color to which our eyes were now geared. But how could anything so shallowly buried serve our ends? Could it be a piece
of recent wood, the residue of modern occupation? Further digging soon showed it to be the surface-charred end of an ancient roof timber, the heart wood unaffected by the heat long since turned to dust. But, happily, the preserving effects of the charring extended from near the center of the log to near its outer surface. It was by all odds the largest piece of charcoal yet found. This was Saturday morning, June 22. My notes of the discovery are a model of brevity and incompleteness—"Reed Whipple opened up Test 11, Room 4 this morning and shortly exposed a good-sized timber near the surface. Douglass and Judd arrived from Flagstaff just in time to take pictures of it in situ and to help take it out." Then follows the understate-
ment of the decade: "This piece proved to be very valuable; the center ring dated 1237." The latter was obviously an afterthought but written before the full significance of the log was realized.

Douglass and Judd could not have arrived at a more opportune moment. The specimen was exceptionally fragile and its removal would require the combined skills of all hands present. Finally, carefully wrapped and treated, the log was tagged. The number was HH-39.

Douglass immediately retired to a nearby shed, commandeered as a laboratory, and proceeded to do a quick field analysis. Characteristic ring patterns of the 13th and 14th centuries in the historically anchored sequence were quickly identified, and by counting back in time the innermost ring proved to be the year 1237. The range of the historic chronology was thus extended by more than two decades. This, at least, was in the direction of the gap and Douglass made no effort to conceal his enthusiasm. He continued the examination throughout the afternoon, completely engrossed in his work, intent upon extracting the last bit of information from the carbonized fragments of the beam.

At the dinner table that evening, the conversation suffered long lapses of silence, Douglass turning over in his mind the findings of the day, the rest of us waiting for any pronouncement he might be ready to make.

We moved into the living room for a further review of the problem. Douglass seated himself near the center of the room at a small square table which provided barely sufficient space for a few charcoal fragments, his skeleton plots, and hand lens. Judd, Hargrave, and I arranged ourselves around the room, expectant, but choosing not to talk. Yet one question was uppermost in everyone's mind. Could the extension of the historic chronology by 23 years possibly close the gap? Judd finally broke the silence by the observation: "Maybe the gap is not very big." We felt certain that this thought had been in Douglass' mind most of the day, for he had with him the plots of the prehistoric sequence and was, in fact, already testing a possible overlap. We waited, listened to the uncertain hissing of the gasoline lamp that supplied the only light, watched his every move, and noted with concealed amusement the ever-enlarging smudge of charcoal on his nose as he repeatedly cross-checked the specimen against his paper records.

Finally, the answer came; and here I must quote from memory. If the words are not exact, the meaning is: "I think we have it. Ring patterns between 1240 and 1300 of the historic sequence correspond in all important respects to the patterns in the youngest part of the prehistoric sequence. This means that there was no gap at all. The overlap of the two chronologies was only 26 years and there was no possible way to join the two on the evidence we had. Beam HH-39 has established the bridge." This was a moment of great truth, and at a time like this, the truth sinks in slowly. No one spoke. Douglass was busy making mental calculations, correcting his relative dates for ruins to the years of the Christian calendar. He broke the silence in his gentle way and told the spellbound archaeologists: "This means that Pueblo Bonito was occupied in the 11th and early 12th centuries and the other large ruins of Chaco Canyon were of the same age. The ruins
of Mesa Verde, Betatakin and Keet Seel are a little younger, mid-13th century." He continued his recitation, revealing his phenomenal memory, by listing all the major sites from which he obtained wood for developing the prehistoric sequence, and delivering at the same time, a totally new and vital short course in Southwestern prehistory.

For the three of us, the experience was unforgettable. To be present at the instant of the celebrated break-through in science that set the chronological house in order for the Southwestern United States was reward enough. But beyond that, was the privilege to work for a time at the side of Douglass, the scholar, the astronomer turned archaeologist.

University of Arizona
Tucson, Arizona
Edmund Schulman, associate professor of dendrochronology and managing editor of the Tree-Ring Bulletin, was stricken with a fatal heart attack on the University of Arizona campus, January 8, 1958. On the day of his death he was actively engaged, with characteristic energy and devotion, in matters of research. Although only forty-nine years of age, Edmund had established himself as an outstanding figure in his chosen field, and the deep sense of personal loss felt at his passing is compounded by the realization that perhaps his most definitive scientific contributions were yet to be made.

Edmund Schulman was born July 19, 1908 in Brooklyn, New York. He received his early schooling there and later attended New York University and Brooklyn College during the years 1927-1930. Following a year spent at Arizona State Teachers College at Flagstaff, Arizona, he came to the University of Arizona in 1932. As an assistant to Dr. A. E. Douglass, he received his first contact with dendrochronology and aided in the development of the methods of tree-ring analysis. He was named assistant astronomer at the University's Steward Observatory in 1933 and earned the Bachelor of Science degree that year. Continuing his studies at the University of Arizona, he earned the Master of Science degree in 1935. He was encouraged to pursue his major interest in dendroclimatic work by the award of a continuing fellowship from the Carnegie Institution of Washington through the years 1934 to 1937.

A desire to broaden his academic background and to improve his effectiveness as a research scholar prompted him to enroll at Harvard University for graduate work, and he received the Master of Arts degree there in 1938. He was appointed a fellow in Harvard's Blue Hill Observatory for the years 1938 and 1939. His publications during that period indicate his strong interest in astronomy, mathematics, statistics, and cycle analysis, an interest which was to have a profound effect upon his researches in later years.

In 1939, Edmund returned to the University of Arizona where he was appointed Instructor in Dendrochronology and Assistant in the Laboratory of Tree-Ring Research. It was at this time that he became managing editor of the Tree-Ring Bulletin and an officer in the Tree-Ring Society. He was named Dendrochronologist in the Laboratory of Tree-Ring Research in 1941, the title he retained until his death. He returned to Harvard University in 1942, and, after serving as a Harvard Fellow for two years, the Doctor of Philosophy degree (in climatology) was conferred upon him in 1944. Returning to the University of Arizona, he was appointed Assistant Professor in 1945 and Associate Professor in 1947. During the years 1953-1954, Edmund was invited to serve as a Visiting Professor of Dendrochronology at the California Institute of Technology, Pasadena.

Indicative of Edmund's character was the high esteem in which he was held by his scientific colleagues throughout this country and abroad. The grants he received for his climatological studies reflect his eminent position as a research scientist and his membership in scientific societies such as the American Astronomical Society, the American Geophysical Union, the American Association for the Advancement of Science, the
American Meteorological Society, the Society of the Sigma Xi, the American Geographical Society, and the Tree-Ring Society attest both to his varied interests and to his professional standing.

Edmund's contributions to the science of dendrochronology are known to all students of tree-ring analysis. The results of his studies appeared in many professional journals and his monographic studies on the dendroclimatology of semiarid America will stand as basic contributions. His influence on the development of tree-ring analysis, through work by himself and in conjunction with Douglass, has been of importance in shaping the methodology used today in tree-ring work. The inspiration derived from his pioneering efforts in dendroclimatology will undoubtedly influence the course of much of the future research in this field.

Many of his contributions are so basic and fundamental that it is impossible to attempt to single out a particular one, yet his outstandingly successful search of western North America for long-lived trees containing "sensitive" and "faithful" tree-ring records must be mentioned. His search, while producing long, homogeneous records for many parts of the west, culminated in the spectacular discovery of the age of the bristlecone pine of east-central California, several of which contain more than 4500 annual rings, and hence are shown to be the world's oldest known living things. These discoveries brought considerable distinction to Edmund and to the University of Arizona.

Throughout his professional life Edmund Schulman was characterized by extraordinary devotion to his work. His writings show remarkable attention to detail and his insistence upon accuracy and precision was reflected in all phases of his research. Justly, his reputation as a scientist extended far beyond the limits of his own specialty. The pages of this Bulletin over the last two decades might well stand as a fitting tribute to his productive, but tragically interrupted, career.

BIBLIOGRAPHY: Edmund Schulman

B.A.M.S. for Bulletin of American Meteorological Society
C.I.W. for Carnegie Institution of Washington
T-R.B. for Tree-Ring Bulletin
U.A.B. for University of Arizona Bulletin
U of A for University of Arizona

1933b Fermat's lost theorem. The Torch, U of A, Tucson, pp.4-5. October.
1933c Coast redwoods. in Douglass, Climatological researches. Carnegie Institution Yearbook for 1932-33, 32, 206.
1935 Cyclogram analysis, with application... U of A Master's Thesis. May.
1938a Classification of false annual rings in Monterey pine. T-R.B. 4, n.3, 4-7, January.
1938c Douglass on climatic cycles and tree growth. B.A.M.S. 19, 204-211, May.
1938f Additional selected references to recent American papers (on Climatic Variations— with R. G. Stone). B.A.M.S. 19, 244, May.
1938g On Angstrom's turbidity coefficient. B.A.M.S. 19, 398-399, November.
1938h Classification of false annual rings in West Texas pines. T-R.B. 6, 11-13, October.
1940a Climatic chronology in some coast redwoods. T-R.B. 6, 22-23, January.
1940e The Tree-Ring Laboratory of the University of Arizona. Chronica Botanica 6, 63-84, November 4.
1940f Reviews of B.A.M.S. 1938 articles, sent to Zoch, United States Weather Bureau, for Wehrle; International Meteorological Bibliography, 1938, 2 pp.
1941f Centuries-long tree indices of precipitation in the Southwest. B.A.M.S. 23, 148-161, 204-217, April, May.
1942a Variations in ring chronologies in the Colorado River drainage area. T-R.B. 8, 26-32, April.
1942f The possibilities of dendrochronology in Mexico. Proceedings Third Round-Table Conference Sociedad Mexican Anthropology, Mexico City, (September 1943) pp. 305-6.
1942g Notes on dendrochronologies at the Arnold Arboretum. T-R.B. 10, 30-32, April.
1942h Tree-ring work in Scandinavia. T-R.B. II, 2-6, July.
1944c Tree-rings and runoff in the South Platte River Basin. T-R.B. 11, 18-24, January.
<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948b</td>
<td>Dendrochronology in Northeastern Utah. T-R.B. 15, 2-14, October.</td>
<td></td>
</tr>
<tr>
<td>1949b</td>
<td>Early chronologies in the San Juan Basin. T-R.B. 15, 24-34, April.</td>
<td></td>
</tr>
<tr>
<td>1951b</td>
<td>Miscellaneous ring records, III. T-R.B. 17, 28-30, April.</td>
<td></td>
</tr>
<tr>
<td>1952a</td>
<td>Definitive dendrochronologies, a progress report. T-R.B. 18, 10-18, January.</td>
<td></td>
</tr>
<tr>
<td>1952c</td>
<td>Extension of the San Juan Chronology to B.C. times. T-R.B. 18, 30-35, April.</td>
<td></td>
</tr>
<tr>
<td>1953b</td>
<td>Tree-rings and climatic history. Research Reviews, Office of Naval Research, 1-6, September.</td>
<td></td>
</tr>
<tr>
<td>1954b</td>
<td>Comment on a letter on &quot;Longevity under Adversity&quot;. Science 119, p. 884, June 18.</td>
<td></td>
</tr>
<tr>
<td>1954c</td>
<td>Tree-rings and history in the Western United States. Economic Botany 8, 234-250, September.</td>
<td></td>
</tr>
</tbody>
</table>
Dating Prehistoric Ruins by Tree-Rings

W. S. STALLINGS, JR.

GENERAL SERIES, BULLETIN NO. EIGHT
LABORATORY OF ANTHROPOLOGY
SANTA FE, NEW MEXICO
1939

REVISED EDITION PUBLISHED BY
THE TREE-RING SOCIETY
WITH THE COOPERATION OF
THE LABORATORY OF TREE-RING RESEARCH
UNIVERSITY OF ARIZONA
1960

Fifty cents
One of the first questions which enters the mind of a person interested in the prehistoric ruins which dot the Southwest is, "How old are they?" This question happily has been answered by tree-rings, through a study of which actual dates can be determined. Roof beams and other remains of wood from the ruins, including charcoal from fires, supply material. Because the study provides an accurate framework of dates for tracing and reconstructing the culture-history of the people who built the structures, it is one of the most important contributions ever made to American archaeology.

In brief outline the method may be summarized as follows. In certain regions, among them the Southwest, certain trees reflect the amount of moisture they receive during a year in the width of the annual ring each tree grows that year. Patterns composed of these annual rings of varying sizes are formed year by year as a tree grows. These patterns can be recognized in tree after tree and identify the years in which the rings were grown. The earliest ring is in the center; the latest one, on the outside under the bark.

By matching the patterns toward the centers of the old living trees with those toward the outsides of beams from an old house, and by repeating this procedure with successively older beams, a long pattern, composed of many overlapping specimens and covering hundreds of years, can be joined together. The date of the latest ring in a living tree is that of the year in which we cut the tree. The date of any other ring in the joined-together pattern, including the last ring in any beam forming a part of it, is determined by allowing one year for each annual ring in the pattern and counting back from this known date. Once such a long pattern, or tree-ring chronology, has been joined together, additional beams can be dated by matching them in along its length. In the pages that follow features of the method are described more in detail.
I. THE ANNUAL RING

A cross-section through the trunk or a branch of a tree reveals, from center to outside, the pith, the wood, and the bark. The growing part is directly beneath the bark. The wood is composed of rings, each representing a season's growth.

In the temperate regions of the earth the normal growing season is from spring into fall. The ring formed during this time normally consists of two parts: a light-colored inner part, called springwood, and a dark-colored outer part, called summerwood. The springwood is composed of large, thin-walled cells formed during the early and more active part of the growing season. As the growing season advances, the cells become smaller and thicker-walled until finally growth ceases entirely. These small cells form the dark line of summerwood. The springwood merges into the summerwood and the summerwood ends abruptly in a sharp line. A new ring is begun the next spring. In this manner the tree forms one ring a year. (Plate I).
2. RING SIZE AND MOISTURE

Like other plants, the amount and way a tree grows is determined by a number of considerations: its heredity; the amount and kind of soil and mineral food that is available to it; the amount of sunlight it receives; temperature and humidity; the amount of water it receives through its root system; its exposure to winds, fires, pests, and disease.

The tree's heredity is a factor that it shares with others of its kind. Its soil is relatively constant year after year, so that while it affects the size of a tree it is only indirectly concerned with annual variations in the amount of growth. The effects of winds, fires, pests, and disease are localized and are revealed by study of groups. The principal causes of the variations in ring growth within a tree are seen to be the climatic factors, temperature, moisture, sunlight, and perhaps solar radiation, coupled with hereditary growth responses to combinations of these factors.

In certain trees in the arctic regions there is a direct relation between mean temperature and ring size, and temperature appears as the controlling factor.

In the semi-arid zones of the Southwest occupied by the lower montane forests, the supply of moisture appears as the preponderant controlling cause. Here trees growing where there is an abundance of moisture year after year, such as along banks of streams, will grow fat, even-sized rings year after year. Trees in well drained locations, such as on the slopes of hills, will reflect the amount of snow that melts in the spring and the amount of rain they receive during the growing season in the size of the ring they grow that year. Thus, to state it simply, in a dry year a narrow ring will be formed, in a wet year a wide ring will be formed. Widespread variations in the amount of snow and rain from year to year cause the same responses in trees over large areas.

3. MATCHED RING-PATTERNS

The narrow and wide rings grown in response to a dominant climatic factor form distinctive patterns which are characteristic of the particular set of years involved. The matching of these patterns, in tree after tree, constitutes the fundamental principle of tree-ring dating. This is known as the principle of cross-identification or cross-dating.
Plate II. MATCHED RING PATTERNS. Top inset is an enlargement to show the microscopic ring. The "a" in the lower specimen marks a double ring.

In Plate II ring-patterns of two trees are so cross-identified. Because no two trees have exactly the same growing conditions and life histories, the absolute sizes of corresponding rings vary, but it will be noted that a distinctively narrow ring in one specimen is matched by a narrow ring in the other, a distinctively wide ring in one by a wide ring in the other. It is thus a matter of the relative sizes of the rings in relation to those of their neighbors in their respective trees. Narrow rings form the principal features of the patterns.

This matching of ring-patterns is fundamental for a number of reasons. It demonstrates that the trees were reacting to a common cause. The patterns can be recognized over large areas and, as we have noted, the cause is climatic. Cross-identification of a large number of specimens establishes the identity of each ring and isolates the individual peculiarities of the trees. Each matched specimen thus assists in checking, and, in certain cases, correcting, the records of others.

4. FALSE RINGS AND MISSING RINGS

Cross-identification is sometimes complicated by the presence of false rings in a specimen, and occasionally a ring is missing. That these features occur is not so serious an obstacle to dating as it might seem at first acquaintance, but their recognition requires experience and they must be identified beyond question in each case before dating can be established.
False rings are the result of a temporary slowing of growth during the growing season due to an interruption of the supply of moisture or other temporary condition. As an example, a tree starts active growth in the spring with the melting of the snows. After the snows are gone it may experience a dry period until relieved by rains. This dry period will cause the tree to grow small, dark, thick-walled cells like summerwood, and when the rains come it will again grow large, thin-walled cells. These false rings usually are easily recognized by the fuzzy and indistinct character of their outer edges as contrasted with the sharp outer edge of an annual ring: the small, dark cells merge with the large light ones that follow, while those of an annual ring do not. An annual ring containing a false ring is known as a double ring. The ring marked with an “x” in the lower specimen of Plate II is a double ring.

False rings also may be identified by attempting to trace a suspected ring around its circuit: at some point the small, thick-walled cells on the outer edge of the false ring disappear, to be replaced by large, light colored cells. A further demonstration of annual versus false rings comes from the cross-identification of the ring-patterns of many trees growing in different types of situations.

A missing ring normally is due to a shortage of moisture throughout a growing season. A tree growing in an unfavorable location may not grow a ring completely over its branches and trunk during a very dry year. It is extremely unlikely, however, that a tree will not grow cells somewhere on its trunk and branches. Should the specimen under examination have been taken from a part of the tree where no cells were grown that year, the sequence, of course, would be faulty.

The absence of a ring may be detected by matching the ring-pattern of the specimen with that of other trees. As an example, assume that the microscopic ring in the upper specimen of Plate II were missing. In comparing the patterns of the two specimens you would see that they matched up to that point, but that they were out of line one ring from that point on. It is also evident that at this point the lower specimen shows a very narrow ring, representing a very dry year, which the upper specimen lacks. By assuming that the ring for this very dry year is missing in the upper specimen the two patterns fall into perfect alignment. The next step is to search completely the hypothetical circuit
of the ring on the wood. Often the missing ring can be found, as a narrow lobe or lens next to the ring of the previous year and surrounded otherwise by the ring of the succeeding year. If a ring cannot be found it can be postulated only if the ring-pattern of the tree is sufficiently long to match with the others in such a wealth of detail as to leave no doubt of cross-identification. Thus, if an absent ring is postulated the matched ring sequence must be considerably longer than if the ring is found. This identification of missing rings logically follows the rule that only a ring of a very dry year (or of some other deficiency which has been recognized) can be assumed to be missing, and it must be represented by a narrow ring in its matched fellow specimens.

In order to establish a basic chronology and to insure that possible errors caused by missing rings and false rings have not gone undetected, it is necessary to match a large number of specimens from various situations against each other.

5. CHRONOLOGY BUILDING: DATING OLD WOOD

By matching the patterns in specimens of overlapping periods a longer pattern than is represented in any one of the specimens can be assembled. The diagram of Plate III is a simple illustration of how this is done. Each ring has its absolute calendrical date. The dating is carried back beyond the living trees by means of beams from old houses and ruins, the patterns in which successively match and overlap back in time. Such a chronology can be carried back as far as we can find old wood which will extend it. In order to simplify the illustration the diagram shows only a simple succession of overlapping specimens. In reality a large number of specimens are matched one against the other and against the critical places of overlap to insure against error. Thus the patterns of many specimens are fitted together to form a whole. The cutting date of a specimen is that of the last ring, next to the bark. Once such a chronology is established additional specimens can be dated by finding the place along its length where they match in.

Chronology building can proceed from any period represented by old wood, but such a chronology cannot be dated in terms of our calendar until it is joined with the pattern of the living trees or with a pattern which previously has been joined with the living trees. Such a chronology is often referred to as
a floating chronology, because it has not yet been anchored to our calendar.

As we have noted before, the number of rings that are necessary in a specimen before its pattern can be cross-identified with certainty varies. Patterns composed of a few rings may duplicate themselves at different points in the chronology, but a long pattern can be matched at only one place along the chronology. Fifty rings may be considered the minimum number necessary unless there are a number of specimens, all from the same location, with well marked patterns, and obviously cut at the same time; in which case one of them must be a long record. Many more than fifty rings may be required, depending on how well the details of the standard patterns have been worked out and how well the pattern is marked in the specimen.

6. SKELETON PLOTS

The life histories of no two trees are exactly the same and the absolute sizes of equivalent rings vary. To facilitate the matching of ring-patterns in a large mass of material skeleton plots, which bring the rings to a common scale, are used. They might better be called pattern plots.

These plots are made on strips of coordinate, or "graph", paper. Plate IV is an illustration of a specimen and its skeleton plot. Each one of the vertical lines of the paper represents one ring, one year. Because narrow rings are the principal features
C THIS BEAM CAME FROM AN OLD HOUSE

THE RING PATTERNS MATCH AND OVERLAP BACK INTO TIME

A THIS WAS A LIVING TREE WHEN CUT BY US

B THIS BEAM CAME FROM A HOUSE

DATE OF LAST RING IS THAT OF YEAR WHEN WE CUT TREE

THIS DATE OBTAINED BY COUNTING BACK FROM BARK OF A

THIS DATE OBTAINED BY COUNTING BACK FROM BARK OF A THROUGH B

SPECIMENS TAKEN FROM RUINS, WHEN MATCHED AND OVERLAPPED AS INDICATED, PROGRESSIVELY EXTEND THE DATING BACK INTO PREHISTORIC TIMES.
of the patterns, they are marked on the plot by heavy ink lines, the narrower the relative size of the ring the longer the line. Distinctively wide rings are marked by the letter “B” (denoting “big”) over the lines of their years. Rings neither distinctively wide nor narrow are not marked on the plot.

By sliding plots of two or more specimens along each other, the patterns are seen to match if and when the principal features coincide. Due to individual variation, minor details will vary but the plots must match in all major features.

Skeleton or pattern plots are tools to aid the observer in recognition of the ring-patterns. The tree-rings themselves are the fundamental evidence upon which a dating must be based.

After a chronology is established, a master plot—a synthesis of the individual specimens—can be constructed. A lead as to the date of a specimen of unknown age then can be obtained by sliding its plot along the master plot until its features fall into place.

7. KINDS OF WOOD

In the Southwest, ponderosa pine (sometimes called western yellow pine), Douglas fir, and pinyon pine have been the principal trees used. They grow in the lower parts of the montane forests, and are also trees which have been used by Indians and later settlers for building purposes and for firewood.

In dating small beams and firewood, pinyon is of particular archaeological importance because of its small average ring size: a small piece may contain a great number of rings. Douglas fir is of great value because of a minimum occurrence of ring anomalies and the consistency of its ring patterns. Ponderosa pine was the wood with which the system was first developed.
Fortunately, charcoal preserves rings as well as if they were in sound wood, and since the sound wood has rotted away in many of the ruins, dependence is entirely on charred beams and firewood in these cases.

Junipers, sometimes popularly called "cedars" and often found in the ruins, are only rarely datable. They have erratic growth habits. Nor is mesquite datable. Cottonwood and similar fast growing trees, which grow along stream banks and in other constantly moist situations, have little size variation in the rings from year to year and are thus of little value.

In other regions, conifers of various sorts have been the most important trees, although oaks and other deciduous trees have been usable.

8. TREE-RING CALENDARS

The discovery and basic development of this study of tree-rings, or dendrochronology as it is now known, is due to the perception and perseverance of Dr. Andrew Ellicott Douglass, of the University of Arizona. Begun in 1901 as a possible means of investigating climatic cycles, its application to archaeology did not come about until many years later, and then as a by-product of Dr. Douglass' chief interest in climatic problems. In the present day, dendrochronology has grown to include a number of branches and it has involved a number of different sciences: botany, climatology, astronomy, anthropology and geology.¹

Dr. Douglass was trained a physicist and astronomer. A native of New England, he was greatly impressed with the spectacular role of rain (and lack of it) in the Southwest. He reasoned that in such a dry climate there should be marked relation between the amount the trees grow each year and the amount of moisture they receive; and that if such a relation could be demonstrated he would have, in the form of annual rings of varying width, climatological data extending very considerably earlier in time than records of observed weather, and from localities for which there were no, or fragmentary records. Since world weather is ultimately the result of the sun's heat, he hoped then to test these tree-ring records for relation to known physical changes on the sun's surface, such as the eleven

¹In study of rings in fossil wood and of cycles in geologic phenomena.
year sun-spot cycle. The climatological implications of tree-rings, involving cycle analysis and a view to possible long-range weather prediction in the future, have continued the main theme of Dr. Douglass’ personal research.  

The idea that ring-widths give a measure of wet and dry years had occurred to men in history before Dr. Douglass. More than four hundred years ago that genius of many sides, Leonardo da Vinci, got the idea from trees in northern Italy and recorded it in his journals. Others also have had this idea. But it remained for Dr. Douglass to discover and develop its potentialities, at the same time appreciating the possible effects of other factors involved, and to solve inherent difficulties. 

The first hints of the basic principle upon which all dendro-chronological research rests were noticed by Dr. Douglass in 1904; but its fundamental significance was not realized until 1911 when he recognized the same long and definite pattern in specimen after specimen in a group of sixty-odd pines from near Prescott, Arizona. By 1913 it was fully worked out. This was the principle of cross-dating, or cross-identification, involving the matching of the ring-patterns. Its importance is evident in the preceding description of the dating method. Suffice it to repeat here that cross-identification is the indispensable foundation: it shows that the trees are reacting to a common climatic cause; it carries the conviction that abnormalities or defects are detected by the group, establishes the identity of each ring and isolates individual peculiarities; it leads to the climatic meaning of ring types and the meaning of abnormalities; until cross-dating is demonstrated in a region, dating of archaeological wood is impossible.

The contact of the method with archaeology began in 1914 when Dr. Douglass made a visit to Dr. Clark Wissler, at the American Museum of Natural History, in New York. Hearing about the work, Dr. Wissler offered to supply Dr. Douglass with specimens of prehistoric beams from the ruin of Pueblo Bonito, New Mexico, which had been collected by an archaeological expedition in 1899. In 1919, sections of six beams

*We may remark here that the study of cyclic changes on the sun, in weather, in tree-rings, and in other natural phenomena has become highly complex. To facilitate study of them and their relation to one another Dr. Douglass invented a revolutionary instrument for analysing the cycles, called a cyclograph, which operates on optical principles. This has led to new conceptions of the nature of cycles and has pointed a way to their future study.*
from the Pueblo ruin of Aztec, some fifty miles north of Pueblo Bonito, were forwarded to Dr. Douglass by Dr. Earl H. Morris, at that time also with the American Museum of Natural History. The latter cross-identified among themselves without difficulty and in 1920, with additional beams from Pueblo Bonito supplied by the American Museum of Natural History, Dr. Douglass was able to match the beams from the two ruins and to say that those from Pueblo Bonito had been cut forty to fifty years before those from Aztec.

With this development the method came to the attention of Mr. Neil M. Judd, who was then beginning the excavation of Pueblo Bonito for The National Geographic Society. Observing the possibilities of actually dating Pueblo Bonito in terms of our calendar by means of living trees and roof-beams from successively older Pueblo villages which would cross-date in an overlapping fashion to form one united ring-sequence from the current year back to the time of Pueblo Bonito, Mr. Judd took the plan before the Society and won its support. Toward its successful culmination three National Geographic Society Beam Expeditions took to the field, in 1923, 1928, and 1929, and other Southwestern archaeologists supplied additional material.

By the end of 1928 a dated chronology back to A.D. 1300 (one specimen went to 1260) and an undated, floating chronology 585 years long, composed of beams from more than thirty ruins, had been assembled. The problem was now to close the apparent gap between the dated and undated chronologies by specimens which would overlap and match into them both. It was at the ruin of Showlow, in eastern Arizona, that the 1929 expedition found material which tied the two together, and in December of that year Dr. Douglass was able to announce that a tree-ring chronology back to A.D. 700 had been established and that besides Pueblo Bonito some forty other Pueblo ruins had been dated.

Interestingly, there actually had been no gap between the two chronologies, but the period of overlap was short and included one of the most difficult periods marked in Southwestern rings, that of a great drought between 1276 and 1299. We know now this great drought was accompanied by the abandonment of the large San Juan area in northeastern Arizona, southeastern Utah, southwestern Colorado and northwestern New Mexico by Pueblo people, and that it was followed by a
floscence of Pueblo culture in the other parts of the Southwest.

Since 1929, Dr. Douglass has extended this chronology to A.D. 11 with material largely supplied by Dr. Earl H. Morris, now with the Carnegie Institution of Washington and University of Colorado. At present writing the earliest cutting date recorded by a timber is A.D. 203. This comes from a cave in southwestern Colorado which was occupied by Basketmakers, who preceded the Pueblo culture. Dr. Douglass and his students have dated specimens from some three hundred ruins in the Southwest and methods of collection and archaeological application have been developed and refined.

A chronology based on records from living trees in the extremely long-lived sequoias of the Sierra Nevada in California has been established back to 1305 B.C.

In the Rio Grande area of New Mexico an independent chronology, now extending to A.D. 930, has been established. The earliest cutting date, A.D. 1048, comes from a ruin of the Pueblo II period in the northern part of the area. Beams were first collected from this area in 1922 by Dr. Douglass and in 1923 by the First National Geographic Beam Expedition. From 1923 to 1929 major collections were supplied by Dr. A. V. Kidder, of Phillips Academy and Carnegie Institution of Washington, from the Pueblo ruins of Pecos. These failed to match satisfactorily with the patterns to the west, and in 1931 an intensive attack of tree-ring dating in the area was begun by the writer at the Laboratory of Anthropology which resulted in the establishment of the Rio Grande Chronology.

A similar project was begun in 1946 for the northeastern Utah area. Here an independent, continuous chronology from A.D. 397 to the present has now been established by Dr. Edmund Schulman of the Tree-Ring Laboratory at the University of Arizona. This chronology was built with relatively few cores from living trees and sections of archaeological beams, for some Douglas firs of very great age were found in that area.

Another important development, in an entirely different region, has resulted from the work of J. Louis Giddings, of the University of Alaska, in arctic America. A continuous chronology since A.D. 978 has been established for one part of that vast region, and a number of structures have been dated.
As we have seen, the archaeological application of the study was first worked out and has been extensively developed in the Southwest. Since the early days of the method, tests and studies, principally of living trees, have been made in many other regions of the world, especially in Scandinavia. The field of tree-ring interpretation is yet young and its future holds promise of further important contributions to several branches of learning.

SELECTED BIBLIOGRAPHY

The present essay is intended as an introductory summary of the basic method in its contact with archaeology. For those who would like to inquire further into the methodology and applications of dendrochronology the following references are appended.

Colton, Harold S.

Douglass, A. E.
The Secret of the Southwest Solved by Talkative Tree-Rings. The National Geographic Magazine, Vol. 46, No. 6, 1929. (A popular account of establishing the first prehistoric chronology.)
Precision of Ring Dating in Tree-Ring Chronologies. Laboratory of Tree-Ring Research Bulletin No. 3. Tucson, Arizona, 1946.

Giddings, J. L., Jr.

Glock, W. S.
Haury, Emil W.
The Canyon Creek Ruins and the Cliff Dwellings of the Sierra Ancha.

Haury, E. W. and L. L. Hargrave

Hawley, Florence M.

McGregor, John C.

Schulman, Edmund

Stallings, W. S., Jr.
A Basketmaker II Date from Cave Du Pont, Utah. Tree-Ring Bulletin, Vol. 8, Pages 3-6, 1941.

The Tree-Ring Bulletin, a small quarterly published by the Tree-Ring Society and now in its twenty-third year, is largely devoted to brief research reports of current investigations. Subscription is $2.00 a year. Inquiries should be addressed to Dr. C. W. Ferguson, Secretary, Tree-Ring Society, Laboratory of Tree-Ring Research, University of Arizona.
Pre-Douglass dendrochronology can be divided into five sections:

I. The annual character of tree-rings and ring count dating
II. Internal markers
III. Crossdating
IV. Chronology building
V. Dendroclimatology

Studhalter (1955, 1956) has summarized most of what is known about tree-ring work performed prior to A. E. Douglass' "invention" of the science of dendrochronology during the first three decades of the 20th century. Other useful references are listed at the end of the outline. The historic source is not always readily available; hence, the reference cited is often a secondary source. This can lead to problems, as when Studhalter (1955) fails to indicate if Duhamel and Du Hamel are the same person.

I. The annual character of tree-rings and ring count dating.

The earliest tree-ring dates were produced by the ring count method, which consists of counting all the growth increments visible in a transverse or cross section from a tree. The goal was usually to determine the age of the tree and, in some cases, to infer the age of the surface on which the tree grew. The method assumes that tree-rings are annual, that is, that each year in the life of the tree is represented by one and only one growth increment.

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>Remarks</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theophrastus</td>
<td>c.372-287 B.C.</td>
<td>recognized the existence of growth rings, but not their annual character</td>
<td>Studhalter 1955: 10-11</td>
</tr>
<tr>
<td>Leonardo da Vinci</td>
<td>1452-1519</td>
<td>recognized growth layers as annual in trees of northern Italy, but information lost until 19th century</td>
<td>Studhalter 1955: 15-16</td>
</tr>
<tr>
<td>Montaigne</td>
<td>1580-1581</td>
<td>informed of annual nature of tree-rings by an Italian craftsman; information &quot;lost&quot; for several centuries</td>
<td>Sarten 1954:383; Studhalter 1955: 15-16</td>
</tr>
<tr>
<td>Malpighi</td>
<td>1675, 1679</td>
<td>one of three who &quot;rediscovered&quot; the annual character of growth rings; that is, the information has been continuously available to the present</td>
<td>Studhalter 1955: 16</td>
</tr>
<tr>
<td>Grew</td>
<td>1682</td>
<td>one of three who &quot;rediscovered&quot; the annual character of growth rings</td>
<td>Studhalter 1955: 16-17</td>
</tr>
<tr>
<td>van Leeuwenheek</td>
<td>1632-1723</td>
<td>one of three who &quot;rediscovered&quot; the annual character of growth rings</td>
<td>Studhalter 1955: 16-17</td>
</tr>
</tbody>
</table>
II. Internal markers.

Studhalter (1956:31) defines an internal marker as "... any anatomical feature whereby an individual growth ring in a tree can be identified and often dated." Internal markers may be either natural or the result of human activity. Their recognition can make it possible to date specific events in the life of the tree and to relate those events to others with the same absolute date.

<table>
<thead>
<tr>
<th>Name, Date</th>
<th>Remarks</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bartelinus</td>
<td>cited by Goeppert (see below) as having used inscriptions of known date in bark to prove growth layers are annual</td>
<td>Studhalter 1955:</td>
</tr>
<tr>
<td>1654</td>
<td></td>
<td>53</td>
</tr>
</tbody>
</table>

Studhalter 1955:xxxvii

American Philosophical Society 1799:xxxviii
### Name, Date | Remarks | References
---|---|---
Du Hamel and De Buffen 1737 | counted back to frost ring of 1709, a year known to have had a severe winter | Studhalter 1955: 54-55
Linnaeus 1745, 1751 | counted back to narrow ring corresponding to severe winter of 1708-1709 | Studhalter 1955: 55
Duhamel 1751 | used internal markers, including strips of tin foil and silver wire, to study growth of wood and bark | Studhalter 1955: 52
Burgsdorf 1787 | "used an axe mark of a known date ... as proof that only one ring is formed each year | Studhalter 1955: 53
Candelle 1839, 1840 | in 1800 had counted back to the frost ring corresponding to the severe winter of 1709 | Studhalter 1955: 55
Goeppert 1868-1870 | "cited many cases ... in which inscriptions through the bark of trees ... were used in proving that growth layers are annual" | Studhalter 1955: 53
Hough 1882 | suggested using "certain characteristic thin rings" to date past insect injuries | Studhalter 1955: 51
Wilhelm 1883 | used tar smeared on exposed cambium as internal marker in experiments on growth of double rings following defoliation | Studhalter 1955: 53-54
Hartig 1892 | "used hail injury of a known date to determine whether annual diameter increments had reached the base of the trunk" | Studhalter 1955: 51
Mills 1904, 1909 | ring count dated events in the life of a ponderosa pine using internal markers indicating: a lightning strike, insect damage, impact of stone projectile points, cutting with axe, fire, etc. | Mills 1909

### III. Crossdating

Crossdating involves the recognition of the same internal markers in two or more ring sequences. Such internal markers are the "same" in the sense that a single external phenomenon affected all of the sequences being crossdated. The internal markers generally used in crossdating are those caused by the external
phenomenon of climate. Crossdating can involve the recognition in two or more sequences of a single common internal marker or of patterns of markers. The crossdating of patterns of markers in multiple sequences makes it possible to control for missing and double rings and to assign every ring in the sequence to the proper year. Kapteyn appears to have been the first tree-ring analyst to realize the importance of crossdating for the production of chronologies accurate to the calendar year.

<table>
<thead>
<tr>
<th>Name, Date</th>
<th>Remarks</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burgsdorf 1783</td>
<td>noted that the frost injury of 1709 occurred &quot;in beech and in most other trees&quot;</td>
<td>Studhalter 1955: 55</td>
</tr>
<tr>
<td>Twining 1833</td>
<td>crossdated hemlock trees near New Haven, Ct., noting that when comparing records &quot;'every tree told the same story'&quot;</td>
<td>Studhalter 1955: 56</td>
</tr>
<tr>
<td>Babbage 1838</td>
<td>suggested dating of strata using incorporated wood; felt it should be possible to crossdate samples through detailed analysis of patterns of large and small rings</td>
<td>Heizer 1956</td>
</tr>
<tr>
<td>Kuechler 1859</td>
<td>sampled three Texas post-oaks: &quot;'for each section I prepared a table which gave the relative proportions of the tree-rings. When compared, these three tables showed complete agreement'&quot;</td>
<td>Campbell 1949: 17; Stallings 1937; Studhalter 1955: 57-58</td>
</tr>
<tr>
<td>/onhausen 1859</td>
<td>found the ring for 1858 to be small in six species; based on measurements of ring thickness</td>
<td>Studhalter 1955: 58</td>
</tr>
<tr>
<td>Pokorny 1865-1866, 1867, 1869</td>
<td>&quot;proposes a comparative study of the annual rings of the same given year in different trees&quot;; noted a thick ring for 1861 in numerous eastern European firs</td>
<td>Studhalter 1955: 58, 1956:35</td>
</tr>
<tr>
<td>Ratzburg 1866</td>
<td>&quot;compared the ring of a certain year, the result of caterpillar injury, in different trees, thus dating these rings absolutely&quot;</td>
<td>Studhalter 1955: 59</td>
</tr>
<tr>
<td>Hartig 1897</td>
<td>used crossdating within a tree to determine which rings were present higher in the tree but missing at the base</td>
<td>Studhalter 1955: 59</td>
</tr>
</tbody>
</table>
### IV. Chronology building.

Fritts defines chronology building as "The dating and processing of ring widths in many trees from a given region or site to produce long homogeneous ring-width chronologies used for crossdating and for deducing past climate" (1976:353). There are two reasons why it is advantageous to use numerous cross-dated samples to build a chronology. First, if the samples come from trees that lived during overlapping but non-identical periods, then the chronology will be longer than the sequences provided by individual samples. Second, for the periods when the samples overlap, the averaging of yearly values from numerous sequences maximized the chronology's climatic signal. In many instances, the individual sequences need to be standardized before they are averaged.

#### Name, Date | Remarks | References
---|---|---
Kapteyn | in 1880 he crossdated 50 oak sections from Germany and Holland; "made extensive comparisons between specimens to make sure of dates" | Schulman 1937: 28; Studhalter 1955:59-60

### V. Dendroclimatology

The goal of dendrochronology is to extract climatic information from tree-ring chronologies. Some early tree-ring analysts realized more fully than others the potential of tree-ring chronologies as sources of proxy climatic data.

#### Name, Date | Remarks | References
---|---|---
Twining | saw tree-ring analysis as "'the means of carrying back our knowledge of the seasons, through a period coeval with the age of the oldest forest trees, and in regions of the country where scientific observation has never yet penetrated'" | Studhalter 1955: 57
<table>
<thead>
<tr>
<th>Name, Date</th>
<th>Remarks</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babbage 1838</td>
<td>given a pattern of wide and narrow rings, &quot;The nature of the season...</td>
<td>Heizer 1956:187</td>
</tr>
<tr>
<td></td>
<td>might be conjectured... from the class of tree&quot;; &quot;the succession of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>seasons might be ... ascertained at remote geological periods.&quot;</td>
<td></td>
</tr>
<tr>
<td>Kuechler 1859</td>
<td>used tree-rings to determine the past frequency of wet and dry years</td>
<td>Campbell 1949</td>
</tr>
<tr>
<td>Vonhausen 1859</td>
<td>in several species &quot;he found the ring of 1858 to be thin because the</td>
<td>Studhalter 1955:58</td>
</tr>
<tr>
<td></td>
<td>preceding late summer, winter and spring had been very dry&quot;</td>
<td></td>
</tr>
<tr>
<td>Pokorny 1865-1866, 1867</td>
<td>spoke of tree-rings as &quot;meteorological yearbooks, going back hundreds and even thousands of years&quot;</td>
<td>Studhalter 1955:58</td>
</tr>
<tr>
<td>Kapteyn 1914</td>
<td>concluded that &quot;fluctuations in growth are due largely to meteorolo-</td>
<td>Schulman 1937:28</td>
</tr>
<tr>
<td></td>
<td>gical factors&quot;</td>
<td></td>
</tr>
<tr>
<td>American Philo-</td>
<td>Circular letter. Transactions of the American Philosophical Society 4:</td>
<td>Kraus Reprint Corporation:</td>
</tr>
<tr>
<td>sophical Society, Committee of</td>
<td>xxxvii-xxxix</td>
<td>1966</td>
</tr>
<tr>
<td>the 1799</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REFERENCES

Campbell, T. N.

Heizer, Robert F.

Mills, Enos A.

Sarten, G.
1954 When was tree-ring analysis discovered? Isis 45(142) part 4:383-84.

Schulman, E.
Stallings, W. S.


Studhalter, R. A.


MAXIMUM RECORDED AGES FOR SOUTHWEST SPECIES

Bristlecone Pine; *Pinus aristata*: 4900 years (WPN-114); Snake Range, Nevada; Ecology 46 (4):564-566.

Sequoia; *Sequoia gigantea*: 3200 years (D-21, 1918); General Grant National Park, California; Climatic Cycles, Vol. 1, p. 51.

Western Juniper; *Juniperus utahensis*: 1620 years; Idaho Falls, Idaho; U.S. Geol. Survey Water Supply Paper 774 (1938).

Limber Pine; *Pinus flexilis*: 2000 years; Kingston Canyon, Toiyabe Range, Nevada; Dendroclimatic Changes, p. 137.

Rocky Mountain Juniper; *Juniperus scopulorum*: 950 years (BRY-2104); Dendroclimatic Changes, p. 32, 33. Jardine Juniper: Slightly over 1500 years (estimate); Dendroclimatic Changes, p. 34.

Single-leaf Pinyon; *Pinus monophylla*: 1500 years (ring count) Panamint Mountains, California; C. W. Ferguson (unpub.).

Pinyon Pine; *Pinus edulis*: 980 years (SUN-2522); Sunnyside, Utah, Dendroclimatic Changes, p. 33.

Douglas-fir; *Pseudotsuga menziesii*: 890 years (NNM 3084, 1950); Nine Mile Canyon, Utah; Dendroclimatic Changes, pp. 32-33.

Ponderosa Pine; *Pinus ponderosa*: 860 years (BRY 4002, 1952); Tropic Canyon, Bryce National Park, Utah, Dendroclimatic Changes, pp. 32-33.
Dendrochronology, the study of tree rings, is a coined word, from the Greek "dendron," tree; "chronos," time; and "ology," the study of. By common usage, the terms have been extended to cover the study of growth rings in general. But, technically, it should be applied only to trees. Hence, I have taken the Greek "thamnos," shrub, and coined the word thamnochronology to describe the study of growth rings in shrubs.

The basic concepts and techniques of dendrochronology, as practiced with the conifers, apply equally well to shrubs and nonconiferous trees. Conifers are valuable because of their clearcut annual ring and its uniformity in width around the circuit; relatively great age; widespread geographical distribution; and their common occurrence in archaeological sites. Shrubs and nonconifers, in contrast, lack many of all of these characteristics. The following points may be used to partially compensate for this: (1) Anatomical studies to determine what delimits annual growth; (2) Use of multiple radii; noting that the center of a single lobe is an equivalent to a radius in a stem with uniform growth; (3) Local application; (4) Limited archaeological occurrence.

Special techniques may be used to accentuate ring structure; angle cut, stains, ultra-violet light, and macro- vs. micro-inspection. Staining, as used in histology, is used to accentuate certain structures; in shrub studies, it is used to mask certain features, such as meaningless color differences.

In a new situation or an unexplored area, a survey should be made of the range of species possibilities and the results evaluated in relation to the problems at hand. A survey of the growth-ring potential in shrubs and nonconifers has turned up a wealth of negative information. From a survey of roughly 300 species, mostly in the Southwestern deserts and adjoining mountain ranges, only a few have been truly usable (Ferguson 1959). Initial work in the Southwest gave the following general results by species: negative, 80%; personal positive, 10%; and positive, 10%. With more intense work and personal familiarity, the percentage figures should shift toward the positive. Of the species with a positive potential, only big sagebrush has been fully reported (Ferguson 1964). Others have been sparsely reported and lightly applied.


SITE: SPECIMEN CRITERIA

Features, indicative of stress conditions, which serve as criteria in the selection of sites producing old trees:

1. Thin soil or rock outcrop, as opposed to a thick soil with optimum nutrient and water-holding capacities.

2. Southern exposure, as opposed to the generally moister north-facing slopes.

3. Lower elevation, either for the forest or for the particular species, because of the increased moisture stress.

4. Southern latitude (in the U.S.), because of increased moisture stress.

5. Parent material: limestone rather than sandstone, for example, because of temperature and nutrient differences.

Features, indicative of age and relatively slow growth, which serve as criteria for the selection of trees with maximum age and sensitivity:

1. Spike top resulting from a natural dieback rather than from injury as by lightning or porcupines, or disease.

2. Foreshortened form of the trunk, resulting in a short cone rather than in a tall cylinder.

3. Large-diameter branches.

4. Downward trending branches.

5. High percentage of dead wood, especially of large branches, in the crown.

6. Recession of the stem cambium at one or more places on the main trunk.

7. Spiral twist, as evidenced by the alignment of fissures in the bark, of lightning scars, or in exposed dead wood.

8. Exposed roots, due to long-term erosion of the soil or of the bedrock.
SITE-SPECIMEN CRITERIA

"Good" Site
Complacent Specimen

- Conical, regular
tall, cylindrical

"Hard" Site
Sensitive Specimen

- Irregular
foreshortened cone

- Small diameter,
ascending or horizontal

- Large, heavy
downward trending

- Full bark

- Partial dieback

- Vertical or nonevident

- Spiral twist
DATA PROCESSING SECTION

The Data Processing Section of the Laboratory of Tree-Ring Research was established in 1965 under the management of Linda Drew. Personnel have changed in the ensuing 17 years but the functions have remained. The three principal functions of the Section are: the storage and maintenance of ring-width measurement files and the chronologies developed from these and other measurements; the storage and maintenance of climatic data records including temperature, precipitation and atmospheric pressure; the development and maintenance of standard computer programs used in the development and analysis of tree-ring chronologies.

Holdings of the Tree-Ring Laboratory Data Base number approximately 1100 final chronologies and approximately 1000 temperature and precipitation station records from the United States and southwestern Canada. Numerous other station records (hundreds) from throughout the world are stored and are available for use but are not updated locally.

While making the measurements of tree rings is not a task of this section, we are responsible for the transmission of measurements to the University Computer Center and their storage on magnetic tape. Detailed site information sheets are required before measurements are transmitted enabling accurate information on each site to be entered and stored on magnetic tape and made available for future use.

A catalog entitled "Data Sets for Tree-Ring Related Research" which will include maps and sorted lists of the holdings of the Laboratory Data Base is in preparation and should be available for interested researchers about March 1983.
Laboratory of Tree-Ring Research
TEST FOR ACCURACY OF RING-WIDTH MEASUREMENTS

1. Measure 20 successive rings twice in hundredths of a millimeter using the same measuring machine.

2. Subtract each ring width from the corresponding ring width in the other measured series.

3. Square the differences between each of the 2 measurements (expressed in hundredths of a millimeter, i.e., decimal point to the right, xxx.) and sum the squared differences over a 20-year period.

If the sum of the squares of the 20 differences is less than 1000, accept the measurements as accurate.

If the sum of the squares exceeds 1000, reject the measurements as inaccurate.

The degree of accuracy is greater the smaller the sum of the squares.

You can compare your results with those obtained by the experts by referring to the histogram below.

Revised by H. C. Fritts
September, 1973
A SELECTED BIBLIOGRAPHY
for
Workshop on Methods for Dendroclimatic Research
June 6 - 11, 1966

ARCHAEOLOGY


BIBLIOGRAPHIES


DENDROCLIMATOLOGY AND CYCLES


GENERAL WORKS IN DENDROCHRONOLOGY


PHYSIOLOGY, TREE GROWTH, AND ECOLOGY


STATISTICS


TECHNIQUES


TREE-RING BULLETIN


TREE-RING STUDIES


X-RAY DENSITOMETRY


MILSOM, S. J., and HUGHES, M. K., no date indicated. X-ray densitometry as a dendrochronological technique.


PHILLIPS, E. W., 1965. Methods and equipment for determining the specific gravity of wood. IUFRO Meeting, October, Section 41.


METHODS FOR RECONSTRUCTING FIRE HISTORY:
A SELECTED AND ANNOTATED BIBLIOGRAPHY

Pioneering work in Estes Park, Colorado, using scarred trees to reconstruct fire year chronology, stand origin dates, and historical records to work out fire history.

Marked three trees with varying degrees of defoliation after a June 1924 fire and documented with photographs the resulting ring pattern revealed in cores taken two years later.

Comprehensive study of 32,054 acre Itasca State Park using Clements methods to construct fire year maps. From 1650 to 1922, 32 fires giving an average of a fire every 8.8 years and any specific location in the park was affected by fire every 22 years.

Comprehensive study of about one million-acres of virgin forests for the 377 year period from A.D. 1555-1972. Used 235 fire scars on 178 trees to reconstruct fire year chronology, stand origin dates, historical records, map of all major stands according to origin dates, and then constructed fire year maps.

Some 40 scarred trees used to reconstruct frequency and size of fires for past 300-400 years, with about 9 major fires.

Several figures showing great forest fires in the U.S. since 1800, fires in the western U.S. in 1910, and location of fires in northern Minnesota and Wisconsin for 1910. Contains a table that lists forest fires for the U.S., Canada, and Newfoundland by state for each year showing the number of fires, causes, total fires, and area burned.


Using dates from fire scars determined fire dates from 1530. Average between fires was 8 yrs, shortest time was 3 yrs, and the longest 11 years.


The 12,000,000 acres of virgin forest affected by fires. Average interval is 8 years for period 1685-1889. "...careful study of the scars on thousands of trees enable us to piece together a fire history.... (p. 1)."


Uses methods of Clements (1910) including section and increment borings to obtain a fire chronology, age classes of stands, and records of early observers.


A detailed pollen record for the last 1000 years showing charcoal curves based on close-interval sampling of the upper layers of laminated sediments in Lake of the Clouds. There were more fires from 1000 A.D. to 1420 A.D., with peaks at 1300 and 1400 A.D. Reduced fire from 1400 A.D. to 1670 A.D. Then 1670 to 1750 show a strong charcoal peak, then a decline to low levels in the upper sediments. This record extends that of Heinselman (1973) back to 1000 A.D.

Working with plots in the Coville Indian Reservation, north-central Washington, made a study of age-size relationships comparison between a stagnated unburned stand to that which had been thinned accidently by fire. Used cores to establish age and stand origin.


Used scars and stand origin data to support contention that bark-like stands of ponderosa occur when downed trees are consumed by light intensity surface fires once every seven to fifteen years.


Use tree-ring and fire-scar record to reconstruct fire on the San Carlos Indian Reservation. Fires occurred on the average every seven years. Outlines use of cat-faces and some of the problems with dating.
DENDROGEOMORPHOLOGY


SELECTED REFERENCES IN GREAT BASIN DENDROCHRONOLOGY

Antevs, Ernst

Damon, P.E., Ferguson, C.W., Long, A. and E.I. Wallick

Ferguson, C.W.
1964 Annual Rings in Big Sagebrush, Artemisia tridentata. Papers of the Laboratory of Tree-Ring Research 1. The University of Arizona Press, Tucson.


Ferguson, C.W. and R.A. Wright

Fritts, H.C.


LaMarche, Valmore C., Jr.


1973 Holocene Climatic Variations Inferred from Treeline Fluctuations in the White Mountains, California. Quaternary Research 3(4)632-60.

LaMarche, V.C., Jr. and H.A. Mooney


LaMarche, V.C., Jr. and C.W. Stockton

Schulman, Edmund

SELECTED REFERENCES FOR DENDROCLIMATOLOGICAL WORK
IN THE ALASKA/YUKON REGION


Giddings, J. L., Jr., 1941. Dendrochronology in Northern Alaska. U. of Arizona Bulletin XII, No. 4/ Laboratory of Tree-Ring Research Bulletin No. 1. Published jointly by the University of Arizona and University of Alaska, 107 pp.


BIBLIOGRAPHY OF DENDROCHRONOLOGY AND RELATED TOPICS
IN NEW ZEALAND

Anon. The Deputation to the Commissioner of State Forests. Royal Forest and

Anon. Traditional Government Policy. Royal Forest and Bird Protection Society

Anon. Wanted: The Truth about Waipoua! A "Tree Cemetery" or a Live Forest?
Royal Forest and Bird Protection Society of New Zealand, November 1946, pp.
3-4.

Barker, C. S. 1928. Wood Technological notes. Te kura Ngahere. New Zealand

Zealand Journal of Botany, v. 10(1), March.

Bately, R. A. L. 1956. Some practical aspects of dendrochronology in New

Bell, R. E. 1958. Dendrochronology. From Proceedings of New Zealand Archaeo-

Bell, Virginia and R. E. Bell. 1958 or 1959. Dendrochronological studies in

Bieleski, R.L. 1959. Factors affecting Growth and Distribution of kauri (Agathis
Australis Salisb.), May 26, 1959.

Blair, W. N. 19___. The building materials of Otago. Transactions, New
Zealand Institute (9). (Direct ring counts.)

No. 34, 551-577-38 (931). N. Z. Journal of Science and Technology, Section
B, v. 32, no. 2, September, pp. 3-10.

conditions. New Zealand Journal of Botany 6(1):63-75. (related to
phenology.)

Butterfield, B. G. 1972. Developmental changes in the vascular cambium of
Aeschynomene hispida Willd. New Zealand Journal of Botany, v. 10, no. 3,
pp. 373-386, September.

Cameron, R. J. 1957. Lake shore forest as an indicator of post rainfall.
New Zealand Journal of Forestry 4:104.

_________. 1959. The management potential of the native forests of North
Auckland. New Zealand Journal of Forestry 8(1):46-56. (Growth ring data
on rimu.)

Cameron, R. J. 1960b. Natural regeneration of podocarps in the Whirinaki River Valley. New Zealand Journal of Forestry 8(2):337-54. (Growth ring data on rimu.)


BIBLIOGRAPHY OF DENDROCHRONOLOGY

IN AUSTRALIA

C. W. Ferguson

June 1974

Brown, A. G.  
1958  
The extraction of large wood samples from living trees. Journal of Forestry, 56(10).

Byrnes, N.  
Preliminary investigation of growth rings in some Australian woods of known ages. N.S.W. Forestry Commission, Division of Wood Technology. Project A-8, Instruction sheet, typed 2p.

Costin, A. B.  
1954  
A study of the Ecosystems of the Monaro region. Soil Conserv. Serv. of N.S.W. (pp. 370-1, Comparison between growth rings in snow gum, Eucalyptus niphophila, in the upper subalpine tract in Mt. Kosciusko and sunspot activity. The study specimen had an age of 155 years and a maximum life span of 200 years was estimated).

Francis, W. D.  
1928  

Green, J. W.  
1969  

Griffith, Lynette R.  
1973  

Lange, R. T.  
1965  
Maconochie, J. R. and R. T. Lange  
1970 Canopy dynamics of trees and shrubs with particular reference to mid-zone topfeed species. Trans. R. Soc. S. Aust. 94:243-248. (No use of tree rings, but is relevant in that foliage gain and loss is related to time of year and rainfalls during that period).

Madden, J. L.  

Mazanec, Z.  

Mazanec, Z.  

Pearman, G. I.  

Pook, E. W.; A. B. Costin & C. W. E. Moore  

Readshaw, J. L. & Z. Mazanec  

Warren, J. F.  

Woolfenden, Wallace B.  

Addendum:  
Churchill, D.M.  
1961 The Tertiary and Quaternary vegetation and climate in relation to the living flora in South Western Australia. Ph.D thesis, Dept. of Botany, Univ. of W. Australia. (one chapter on dendrochronology; trees in range of 150-200 years).
ADDENDUM:


Bibliography

Bauch, J., and D. Eckstein


Dobbs, C. G.


Ferguson, C. W., B. Hüber, and H. E. Suess


Høeg, O. A.


Holmsgaard, Erik


Mariopoulos, E. G.

1962 Fluctuation of rainfall in Attica during the years of the erection of the Parthenon. Geofisica Para E Applicata 51:243-250.

Miller, A. K.


Mitchell, A. F.

Peitsa, Mikola
1956 Tree ring research in Finland. Tree Ring Bulletin 21:1-4:16-20

Schwere, H. J.

Schulman, E.

Vins, B.

Abstracts Available

Bauch, T. Liesew and D. Eckstein

Calistrisi, I.

Corona, E.
EUROPE

Fürst, O.

Huber, B.

Koliskuk, V. G.

Kostin, S. I.

Munaut, A. V.

Mitchell, A. F.

O'Nuirgheasa, N.

Pausch, E.

Schove, D. J.
EUROPE

Schove, D. J. (Cont’d.)


Serre, P.


Sirén, G.

1961 Pine at the tree line as an indicator of climatic fluctuations in Fennoscandia in historic times. Commun Inst. for Finn. 54:2166.

Tharandt


Vins, B.

DENDROCHRONOLOGY IN AFRICA

Dendrochronological Age Determination of Podocarpus falcatus
South African J. of Sci., v. 74, p. 92-95

Guy, G. L., 1969
Adansonia digitata and its rate of growth in relation to rainfall in South Central Africa.

Hall, M., 1976
Dendroclimatology, rainfall and human adaptation in the Later Iron Age of Natal and Zululand.

Lilly, M. A., 1977
An assessment of the dendrochronological potential of indigenous species of trees in South Africa
Environmental Studies. Occ. Pap. No. 18, Department of Geography and Environmental Studies, University of the Witwatersrand, Johannesburg.

Stewart, Philip, 1969
Cupressus dupreziana, Threatened Conifer of the Sahara
Biological Conservation, v. 2, no. 1, pp. 10-12

Storry, J. G., 1975
Preliminary dendrochronology study in Rhodesia

Walter, H., 1970
Die Jahresrige der Bäume als Mittel zur Festellung der Niederschlagsverhältnisse in der Vergangenheit, insbesondere in Deutsch - Sudwest-Afrika
Naturwiss 38, 607-612.

Addendun:

Dendroclimatological Studies on Cedars in Morocco
Laboratoire de Palynologie et Phytosociologie, Université Catholique de Louvain-la-Neuve, Belgium
LABORATORY OF TREE-RING RESEARCH

An Introduction

College of Earth Sciences
University of Arizona
Tucson, Arizona 85721

The unique research program of the Laboratory of Tree-Ring Research is designed to explore the complex relationships between tree growth and environment and to utilize tree-ring chronologies as a basis for dating ancient structures and events and to derive climatic and hydrologic reconstructions. The science of dendrochronology, developed at the University of Arizona by Andrew Ellicott Douglass, has resulted in the establishment of long term tree-ring chronologies which serve as an index to past climatic conditions and in the dating of wood and charcoal samples from archaeological sites in western North America and the Near East. The present collections are the largest in the world and contain 20-25,000 dated archaeological tree-ring specimens and about 25,000 cores and sections from living or recently dead trees including millennia-old bristlecone pines. Current emphasis is on modern codification of ring data, better understanding of growth phenomena, extension of ring chronologies into the past, discovery of new datable species, and expansion of tree-ring dating techniques into new areas of the world. Laboratory facilities and study collections are available for research in all aspects of dendrochronology and dendroclimatology.

The staff, presently exceeding 50 people, is divided into informal, but interrelated sections: administration, modern studies, archaeological dating, dendroclimatic studies, dendrohydrologic studies, data processing, and a newly established densitometric group.

Publications by the staff occur in a wide variety of journals, as papers in proceedings of scientific meetings, as contributed chapters in books, and as edited or authored books. The Tree-Ring Bulletin has been published by the Tree-Ring Society since 1934.

The Laboratory offers graduate-level courses and research in dendrochronology that can be applied to graduate degree programs in other departments of the College of Earth Sciences, as well as in other colleges of the University.

Suggested Reading:

National Science Foundation, 1977.
Tales the Tree Rings Tell. Mosaic 8(5)2-9.
DENDROCHRONOLOGY

Dendrochronology may be defined as the study of the chronological sequence of annual growth rings in trees. Development of the science of dendrochronology - as opposed to the simple counting of tree rings in a stump - began in 1901 with an observation on aridity in relation to elevation by Andrew Ellicott Douglass, an astronomer interested in sunspots, and continues up to our computer-oriented age. In the southwestern United States most of the tree-ring studies have been conducted on four major species: Douglas-fir, ponderosa pine, pinyon, and Rocky Mountain juniper. Sampling may be done by taking a cross section or, more conveniently, by using a Swedish increment borer, a precision tool designed to remove a small core without causing the living tree any harm. The dating of a sample is guided by two basic concepts: sensitivity and crossdating. Sensitivity is the variation in width from year to year, as, for example, in response to annual changes in precipitation. Crossdating is the systematic comparison of ring patterns, permitting the establishment of absolute dating for each growth ring as the calendar year in which it was formed, between radii of a single tree, between trees, between species, between age classes within a species, and between sites, and major geographical areas in relation to one another and to climatic and historic data. Given the fact that each consecutive annual growth can be dated, it is possible to extend the chronology back into the past by dating and incorporating older and older pieces of wood. With this extended chronology, it is possible to date archaeological tree-ring material, either wood or charcoal, from earlier periods.

Suggested Reading:

Ferguson, C. W., 1970.

Fritts, Harold C., 1976.

Schulman, Edmund, 1956.

An Introduction to Tree-Ring Dating. The University of Chicago Press, Chicago.
Larrea References Associated with Age of the Plant


TAMARISK BIBLIOGRAPHY


Foresters have observed the prominent fire scars or "cat faces" on old growth trees, usually considering them to be a loss of potential lumber and as evidence of the destructive nature of widespread wildfire prior to the days of effective fire control. Researchers have now found that fire scarred trees can also be a source of detailed records of past fire occurrence and fire frequency.

A close examination of some "cat faces" will reveal that they are actually a series of overlapping scars and that each scar is a record of a fire that burned around the base of the tree. By taking cross sections through the fire scars of many trees from an area and then crossdating the growth rings and fire scars as they occur within the rings, researchers can reconstruct a fire history extending back many years before white settlement, livestock grazing and fire control.

The development of fire histories or fire chronologies can help us to better understand the ecological role of natural fire and its influence on the forests that we see today. Fire histories may be useful in establishing guidelines for hazard reduction rotational burning and for establishing objectives for natural fire programs in National Parks and Wilderness Areas. As a data base of long term fire occurrence, fire histories may also be useful in future studies of the relationship of climate, growth and land use to forest fire.

The application of techniques developed at the Laboratory of Tree-Ring Research to the dating of fire scars ensures a level of accuracy and precision that is desirable in the development of fire histories. In order to provide a forum for the discussion of methods, terminology and current studies in fire history, the Tree-Ring Lab co-hosted with the Rocky Mountain Forest and Range Experiment Station, a workshop which was held in Tucson in October 1980. References to the proceedings of this meeting and other useful publications are listed below:


FORENSIC DENDROCHRONOLOGY

The following paragraph, and the associated references, are from Studhalter (1955, p. 53): "Numerous legal cases involving property rights have been settled in court from the blazes left by surveyors on the trunks of trees along boundary lines (P. C. Smith, 1883; Child, 1883; Hotchkiss, 1894; Fernow, 1888, 1897). In nearly all cases the court accepted the dictum that tree rings are annual; however, at least one case is on record (Child, 1883) in which the court ruled that growth layers are not infallible indicators of age. A case was recently brought to court in Alsace in which tree rings were used as evidence of ownership (Senn, 1933). Tree rings were used also by Tharp (Sellards, Tharp, and Hill, 1923) in a boundary dispute between the States of Texas and Oklahoma, and by Cowles (1915) in an extensive Federal lawsuit in Arkansas involving riparian boundaries."

Primary reference:

Secondary references:
FORENSIC DENDROCHRONOLOGY

For many years, I have known of a reference to the Hauptman ladder (Koehler, 1952) and recently had a librarian try to locate it. She found that it was more of an in-house report of a category not distributed to libraries. I then wrote to the Forest Products Laboratory and was promptly sent a photocopy of the technical report. A few weeks later, I received from the FPL librarian a copy of a recent journal that had a four-page article (Christensen, 1977) based upon this report and incorporating some broader aspects of the case.


FORENSIC DENDROCHRONOLOGY

Since the 1800's, numerous legal cases involving property rights have been settled in court by determining the age of blaze marks left by surveyors on the trunks of trees along boundary lines.

The age of trees in the floodplains of the Colorado River, near Blythe, California, and of the Snake River, near Jackson, Wyoming, have been used as evidence in court cases regarding riparian boundary litigation.

Perhaps the most famous use of tree rings in a legal case was that of the Hauptmann trial in the kidnapping of the Lindbergh baby. Hauptmann used a homemade ladder to reach the second-story bedroom window -- and he left the ladder leaning against the house. Through an amazing bit of detective work, the commercial lumber in the ladder was traced to Hauptmann. The real cincher, however, came from one rung that was not made from the same wood as the rest. Apparently, he ran short of wood and made the final rung from a piece of floorboard in his attic. The piece was matched by a combination of saw marks, nail holes, and the pattern of the annual growth rings in the sawn ends. Thus, the ladder found at the scene was identified with the Hauptmann residence.

In 1979, plant thieves stole an estimated $600,000 worth of rare plants in Arizona. A booming worldwide market in rare cactus species, combined with a protection force that can't cover the whole state, makes plant theft a lucrative business. However, the courts are accepting the matching of plant parts, usually the roots, to tie the suspected thief to the site of the crime.

Suggested Reading:


DENDROCHRONOLOGY OF BRISTLECONE PINE

Dendrochronological studies of bristlecone pine, Pinus longaeva, in the White Mountains of east-central California have resulted in the establishment of a continuous tree-ring sequence back to 6700 B.C., a total of 8681 years. A second long-term chronology, going back to 3200 B.C., has been established for a site in east-central Nevada. Other sites are being studied. The millennia-old pines have emerged as a unique source of chronological data and the precisely dated wood is essential to certain paleoenvironmental and geophysical investigations. Over 1000 dendrochronologically dated decade samples of bristlecone pine, supplied to four C-14 laboratories, have been used to calibrate the radiocarbon time scale for the past seven millennia, 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, such as techniques involving stable isotope ratios have increased the demand for wood of known age and, hence, for chronology development.

Suggested Reading:


DENDROCHRONOLOGY OF BRISTLECONE PINE: A PROGRESS REPORT

C. W. Ferguson and D. A. Graybill
Laboratory of Tree-Ring Research
University of Arizona
Tucson, Arizona 85721

Dendrochronological studies of bristlecone pine, Pinus longaeva, in the White Mountains of California have resulted in the establishment of a continuous tree-ring sequence back to 6700 B.C., a total of 8681 years. Recent collections at a site in the White Pine Range, east-central Nevada, have provided excellent material for a chronology back to 3240 B.C., a total of 5221 years. This site will ultimately provide the second longest continuous record of isotopic and paleoclimatic variation at the lower, rainfall dependent range of the bristlecone pine.

The project has provided dendrochronologically dated samples for an interlaboratory calibration of the radiocarbon time scale, and continues to do so as material for selected time periods becomes available.

From the standpoint of paleoclimatic research the long tree-ring series from California and Nevada provide a unique data set for investigating Holocene-modern climatic variation. The primary climatic signal that can be isolated in each series is annual moisture variability. Current efforts are directed at calibration of the tree-ring series with instrumented climatic series. Climatic reconstructions can be attempted if the statistical models that are developed survive verification testing.
ECOLOGY OF BRISTLEcone PINE

Billings, W. D. and Thompson, J. H.

Beasley, Roy Scott

Beasley, R. S. and J. O. Klemmedson

Beasley, R. S. and J. O. Klemmedson

LaMarche, Valmore C., Jr.

Loope, Lloyd L.

Went, F. W.
1964 Growing Conditions of Alpine Plants. Israel Journal of Botany Volume 13, 1964, pp. 82-92. The alpine plants of Charleston Peak in Southern Nevada have been studied both under the controlled conditions of the Earhart Plant Research Laboratory and by comparison with other alpine plants. It was found that the restriction of their occurrence to the alpine zone depends either on a long chilling requirement or on low optimal temperatures during the short growing season. The remarkable degree of endemism among these alpine plants cannot be explained by a variable environment, since growth of very old Pinus aristata shows that during the last 2500, and probably more than 5000 years, essentially no climatic changes have occurred.

Wright, R. D.

Wright, R. D. and Mooney, H. A.
BRISTLECONE PINE AND RADIOCARBON DATING


When neutrons from cosmic radiation are captured by nitrogen nuclei in the earth's atmosphere, the long-lived radioisotope $^{14}$C is produced. The $^{14}$C nuclei so produced combine with oxygen to form $^{14}$CO$_2$, and become part of the carbon cycle. All living things achieve an equilibrium concentration of $^{14}$C, and when they die, their $^{14}$C nuclei decay with a half-life of 5,730 years.

Willard Libby demonstrated in 1946 that the time since the death of an object which had participated in the carbon cycle could be determined by measuring, in a nuclear counter, the radioactivity of $^{14}$C remaining in that object and comparing it with the equilibrium radioactivity of $^{14}$C characteristic of living objects. This original discovery by Libby has been exploited by researchers in disciplines from anthropology to zoology. Among these researchers are members of the University of Arizona, Department of Geosciences, who for years have studied the $^{14}$C content of various anthropological and geophysical specimens.

Among the programs of the local geoscientists is a joint project with scientists from the University of Arizona Laboratory for Tree-ring Research. The $^{14}$C content of tree rings of known age, from the present back to about 6,000 B.C., has been measured and recorded. With this information, scientists are able to check theoretical models of equilibrium $^{14}$C concentrations for the last 8,000 years, and to study in some detail the temporal fluctuations of cosmic rays which produced the atmospheric $^{14}$C.
A serious limitation of Libby's technique (mentioned in the discussion of $^{14}$C dating) is the fact that large quantities of a sample are needed to determine the $^{14}$C radioactivity of that sample. Many artifacts which scientists would like to date are too small to allow radioactivity measurements. A new technique has recently been developed for determining the $^{14}$C content of a sample. This technique employs a particle accelerator as part of a high energy mass spectrometer.

As a joint project between the Department's of Physics and Geosciences, sponsored by the National Science Foundation, an instrument of this type is being installed and tested in the Van de Graaff Laboratory of the Department of Physics. It is expected that with this instrument, scientists will be able to determine the $^{14}$C of samples one ten thousandth the size of those necessary for more conventional measurements. The ability to make measurements on such small samples will allow many experiments to be performed which were previously not feasible. The new facility will be used by researchers from many departments of the University as well as from laboratories around the world.