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ADVANCES IN DENDROCHRONOLGY. 1943

By A. E. DOUGLASS

The last general survey of Dendrochronolgy or Tree-Ring Work in these pages was in 1937 (July).* That year 1937 was the concluding year of the generous aid from the Carnegie Institution of Washington and its last month saw the beginning of the continuing organization, the Laboratory of Tree-Ring Research of the University of Arizona (Jan., 1938). Offices, storage and work rooms for this Laboratory were assigned in the Stadium. The purpose of this Laboratory was to safeguard the collections and equipment, and to continue the activities connected with tree-ring work which have been carried on during the past 35 years chiefly on the University of Arizona campus.

In the issues of this Bulletin since the formation of the Laboratory just referred to, several papers of special interest have appeared. A bibliography of tree-ring analysis with more than 400 titles was prepared by Edmund Schulman (April, 1940). An insert in that same number brought together the complete set of diagrams published under the name "Estimated Ring Chronology 150 to 1934 A.D." by the writer.

In the succeeding numbers general techniques were presented. The first (July, 1940) suggested procedures in handling specimens, the beginnings of laboratory techniques in preparing them for use, the treatment of charcoal. The second installment of technique (April, 1941) presented methods of illuminating and photographing specimens, including what was called "cell illumination," a great aid in the study of wood or charcoal. The third part (Oct., 1941) gave further treatment of charcoal with discussion of its photography and certain identification characters of different species. All of these techniques emerged from multitudes of cases which have been handled and thus gave the results of long experience.

Certain techniques in dating specimens and reporting results under conditions of great rarity of desired specimens were described in a paper on "Checkng the Date of Bluff Ruin, Forestdale" (Oct., 1942). This particular study was an extension into the past of the early ring chronology in a relatively new area. That is one of the advances which has been reported recently; the present references to it give an opportunity of considering some of its more general aspects by comparison with other locations. An issue has

*Dates in parentheses give the issue of the Tree-Ring Bulletin referred to.

been devoted to chronology variations in the Colorado drainage area (April, 1942) and another to chronologies in northern Alaska (July, 1942).

I. THEORIES AND METHODS

The advances made recently have dealt primarily with the problem of finding sites in which the best climatic records could be secured from the rings of trees, expecially in arid areas such as the southwestern part of the United States.

Assured many years ago that crossdating by patterns (that is, finding the same chronological placement of deficient rings in different trees) is, in most of our cases, entirely correct and reliable, we undertook to find why it is less satisfactory in some instances. An examination of successes and failures and some tests in the Spring of 1936 pointed clearly to the immediate environment of the individual tree. Long before that the policy had been adopted that every case of crossdating found in prehistoric trees, by which ruins were to be dated, should be accompanied by proof that crossdating is now taking place in the modern trees of that region. This had led to a close acquaintance with modern trees all over the Pueblo area and aided greatly in understanding where crossdating could occur. This policy involved: first, acquaintance with the modern ring chronology of the region as shown in the best sequences previously known; and second, a study of the surroundings of each tree immediately after boring it and comparisons of its ring record in the core with the common record of the area and with the topography about this particular tree. Soil proved to be the important factor to watch, its depth and composition and slope and its present or potential water supply. Thus we found the dependence of each ring record on its environment and the influence of local factors that make some trees give better climatic records than others.

In the writer's earlier work the available tree had been the western yellow pine of which there are very large forests in northern Arizona. Schulman noticed that the Douglas firs gave more pronounced rings, less trouble from absences and less doubling from the secondary rainy season. Accordinly in 1939 he began extensive collections of Douglas fir cores to try out their ring record in relation to precipitation. This proved to be satisfactory. He and I visited the type site Mesa Verde (Oct., 1939) in July, 1941. His collections there across two miles of mesa and canyon with high selection of tree sites were amazing even to me in their superb crossdating.

So when, in 1941, the Boulder Dam Management asked for a history of the runoff of the Colorado River, we already had a large assortment of material from the southerly part of its drainage area and needed collections in its northerly parts, Colorado, Utah, and Wyoming. So under the combined sponsorship of the Los Angeles Bureau of Power and Light and the University of Arizona Schulman made the collections and reductions with very satisfactory results.

This careful selection of sites has provided us with the best crossdating yet seen and thus given us the best climatic records 500 years long that we possess. He searched far to find trees in actual spots that are completely isolated from "imported" water; i.e., no brooks, no drainage areas, no deep soils. The oldest trees proved not necessarily the big ones; they sometimes grow in such difficult locations they cannot produce large rings. He found pinyon and fir 850 years old. The cycle characters in these records will prove of importance in climatological studies.

Schulman has made a number of reports on his collections in different parts of the country, for example, "Centuries-Long Tree Indices of Precipi-

tation in the Southwest," Bulletin of the American Meteorolgical Society, April and May, 1942; "Dendrochronology in Pines of Arkansas," Ecology, July, 1942. He is preparing a report on the tree-ring records in the Colorado River drainage area.

II. EXTENSION IN PREHISTORY

In the pictures of crossdating curves such as the seven Douglas firs at Mesa Verde shown in the accompanying cut, we can see at once that if one of those trees in any set had been so badly burned that only a fragment remained showing say 50 rings in succession, we would have no trouble at all in dating the rings in that fragment by comparisons with the other trees. By the use of the skeleton plot this process can be done in the field without other tools than a magnifying glass and coordinate paper and a master plot, all of which can easily be carried along. In a similar way, and by comparisons between thousands of specimens, many centuries of tree-ring chronology have been built.

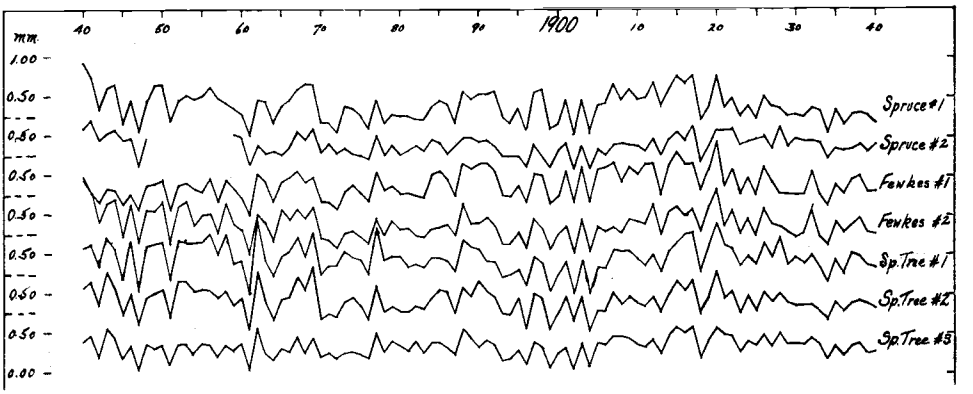

Fig. 1. The last hundred years of ring growth in seven different Douglas firs, in type sites, Mesa Verde National Park. After Schulman in "Bulletin American Meteorological Society."

The development of these chronologies has taken place in this area because large number of specimens have been secured by the archaeologists for our examination. In return they secure the dating of important ruins and various cultures. By this exchange our ring chronology has been developed until it easily covers a continuous interval from the present time back into the fourth century. Excellent ring records extend to a little before 250 A.D. From there backward, the number of specimens very rapidly decreases and contributions to them are of the greatest importance. The specimens, as they come to us, may be either wood in perfect condition from enclosing caves fully protected from rain, or they may be charcoal or charred wood, or wood heavily filled with pitch, which are the forms that permit the wood structure and the rings to last through nearly 2000 years.

For years the earliest building date which we were able to recognize was 348 A.D. with the center near 260 in M-106 from Mummy cave in the Chinlee area, northern Arizona. Obelisk Cave in the Red Rock Valley, 40 miles to the north, for some years was the oldest known single-culture cave; it had its major building in the 400's, but had also a few dates near 350 A.D. In this cave a Douglas fir log was found which was cut in the middle 400's, but whose very compressed though rather complacent rings gave an immensely long series extending back to 11 A.D. This gave the earliest dated ring in the Pueblo area, but its climatic record is poor. Broken

Flute Cave nearby was occupied chiefly in the 600's and to some extent in the 400's and possibly in the 300's. The few beams of that age could have come from other older locations. In the last 3 or 4 years, through the aid of Earl Morris and I. F. Flora, specimens from a third site, Ignacio 7:101 near Durango, southwestern Colorado, have given superb Douglas fir records

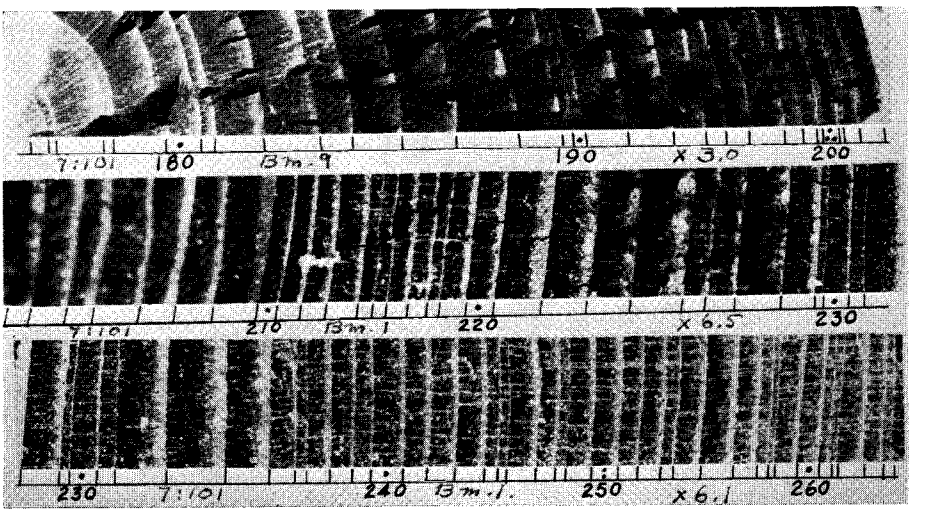

Fig. 2. Douglas fir ring record from Durango, Colorado; site Ing. 7:101—; MFD-34 Beams 1 and 9.

through the 200's and to 175 A.D. This sequence is shown in the accompanying cut. Their building dates were probably somewhat after 320 A.D.

Some of Flora's records from Durango in scopulorum juniper will give important additions, back to the 130's A.D. if certain double rings can be solved satisfactorily. A good pinyon log from a fourth site at Du Pont Cave near Kanab, Utah, found some years ago by Jesse Nusbaum of the National Park Service, was dated recently by W. S. Stallings, who was then at the Laboratory of Anthropology, Santa Fe. It was cut in 217 A.D. with center going back to about 90 A.D. This stands almost alone as an important record between 105 and 175 A.D.

Now, just yesterday as it were, a fifth early site has been found at Forestdale, Arizona, in Bluff Ruin excavated under the direction of E. W. Haury in work sponsored by the Arizona State Museum and the American Philosophical Society. The study of the specimens from Bluff Ruin was begun by Ralph L. Patton, a graduate student in the Department of Anthropology and doing research work in the Laboratory of Tree-Ring Research. Patton picked out—with our approval—a couple of dozen specimens that looked promising, examined them skillfully, and derived a date near 310 A.D. He was then obliged to leave Arizona for some work in Alaska, and after some months Haury asked me to review this dating since it had importance in the prehistory of the State. This has been done and the dating by Patton is sustained. Most of the outside of the specimens has been lost, but a date at 330±10 seems near (Oct., 1942).

Thus there are now five early sites. Of these, Forestdale and Durango in the 300's are the only open ruins, that is, not in protecting caves. Nearly all specimens from these sites are in the form of charcoal, some of them having part wood remaining. The Kanab site, mentioned above, is in a

cave as are also those at Broken Flute and Obelisk caves in Red Rock Valley, north of the Lukachukai Mountains and Mummy Cave on the south side of the same. The largest collection are those from Mummy Cave in the Chinlee area, the Red Rock Caves in northeastern Arizona, and Durango in southwestern Colorado. These have given us our best dated material going back into the 200's. The Du Pont cave near Kanab in southern Utah has given us an excellent pinyon log, but since other specimens are largely juniper, its number of datable specimens is very limited.

III. EXTENSION ABOUT THE WORLD

Increase in the number of centuries covered by our ring records suggests possibilities of a similar increase in our space extension. This refers to new geographical areas such as those which have already contributed to the early prehistory of the Alaskan Eskimo. Or this sort of extension may sometime help to solve a weak place in Egyptian chronology; so also it may solve one in Mayan chronology. But more especially the study of the world climate will be advanced by an extensions of genuine ring-climate work into new regions, and this is because they will help to build up a world picture of historic climate. And when that is somewhat well along and when some idea of the cause of various climate changes is worked out, then we can really attack that great economic problem—the long-range forecasting of water supply for the southwest and for great hydro-electric projects and other enterprises.

The Sequoias and California. We have an excellent collection of 50 or more radial cuttings of the Giant Sequoia of California. These have been dated, measured, plotted, and analyzed for growth cyclics. This kind of record was specially developed 20 years ago or so when an attempt was made to date our prehistoric ruins by crossdating the pines of northern Arizona with the sequoias or the Sierra Nevada Mountains of California, but the attempt failed. Yet we have thus secured superb and extensive records of climatic changes that have a unique value. These appear to agree with the ring records of the pine trees that grow in their vicinity as checked in 1935 by the writer and more recently carefully studied by Schulman. These statements apply only to pines and sequoias whose sites have been most carefully selected.

Also we have pine ring collections from California and the west coast made by the writer, and recently further large collections made there by Schulman using improved methods. He has applied these good methods to the Colorado drainage area and to various areas just east of the Continental Divide from Pikes Peak to west Texas. He has also made a preliminary survey across the South to the Atlantic coast.

Two especially strong pieces of extension work have been done by other men who have worked with us, who have in the last year been appointed Research Associates of our Laboratory of Tree-Ring Research.

Rio Grande. One was by W. S. Stallings, Jr., at the Laboratory of Anthropology, Santa Fe (later in the Taylor Museum, Colorado Springs, and now in Military Service). He built a full Rio Grande ring chronology with the utmost care and accuracy, extending from modern trees back a thousand years, and dated large numbers of the prehistoric ruins in New Mexico. This Rio Grande chronology, built independently, was then found to match closely the Pueblo Chronology.

Alaska. The other work referred to is by James Louis Giddings, Jr., of the University of Alaska, who brought back here the results of some two or three years's field work and a large group of specimens personally collected in practically untrodden area. He spent a year in preparing a report

which has recently been published jointly by the Universities of Alaska and Arizona under the title *Dendrochronology in Northern Alaska.**

In this report he shows that crossdating qualities (climatic in origin) in Northern Alaskan spruce rings are at their best near timberline and depend on temperature stresses. He finds very satisfactory crossdating in the Yukon Flats, in trees near the river. Their ring records also differ a little from those in timberline trees, as might be expected. He also found the distribution of crossdating in latitude as the forests fade out to the north. This work of Giddings is a fundamental advance in dendrochronology and has enlarged our world picture. Besides this fundamental work he has dated many ruins and artifacts in Alaska and on the islands in Bering Straits and has developed a thousand year chronology. All this involved close examination of drift wood and he has thus secured important information regarding ocean currents in that region.

During the winter from September 1942 to June 1943 he has worked with us at the Laboratory of Tree-Ring Research in a cooperative arrangement between the Universities of Alaska and Arizona. His work is sponsored through the University of Alaska. The objective of this joint work has been the development of the climatic picture both historical and causal by using our thousand-year near-climate tree-ring records both here and in Alaska combined with our special facilities for timing cyclic changes such as can be done very rapidly in our cycloscope.

This work has been undertaken very earnestly because of the special request of a great hydro-electric power plant that we do all we can to improve the forecasting picture because of the great demand for power at this time. The same urge comes to us strongly from the water users of this Southwest on account of the marked decline in our water reserves underground. All this is very closely related to War conditions and we have undertaken it as a vital matter in this region.

IV. EXTENSION IN CYCLICS AND CLIMATOLOGY

Thirty years ago, April 1913, there was completed the first accurately dated 500-year tree-ring chronology. The original purpose in building a climatic record like that was to see if the sunspot cycle or any other solar effect was visible in the rings of trees. Obviously such a test must be accomplished by some form of cycle analysis and so a new method was worked out. The method is too technical to be presented at this moment,† but its main character is that it makes no assumption that cycles are permanent —an assumption which is the drawback in harmonic analysis because it has made that method always unsuccessful in the study of climatic changes. Since our method assumes that cycles may be unstable, I have been compelled, in writing papers on this subject, to change the word cycle to the word "cyclic" to avoid the misunderstandings that were aroused. The word cycle has generally come to be regarded as referring to something permanent if existing at all.

The results of the application of this new method were at first bewildering—there were great numbers of cyclic lengths. This was observed near 1920 in extensive analyses of the long sequoia records. In 1925 we collected some hundreds of pine tree borings in the western states and thus secured quantities of climatic records from different but yet from adjacent areas.

*This report constitued his thesis for a Master's degree in the Department of Anthropology here.

†This "cycloscope" and its work has received little more than mere mention in these pages; perhaps an issue can be given to it in the near future; the chief operating parts of the instrument are shown in the accompanying cut.

All these were promptly analyzed because it could be done rapidly and at little cost. In December 1926 a general feature emerged from this mass of cyclics, namely, all showed a preference for values which were simple fractions of 1, 2, or 3 times the length of the sunspot cycle, taking it as near

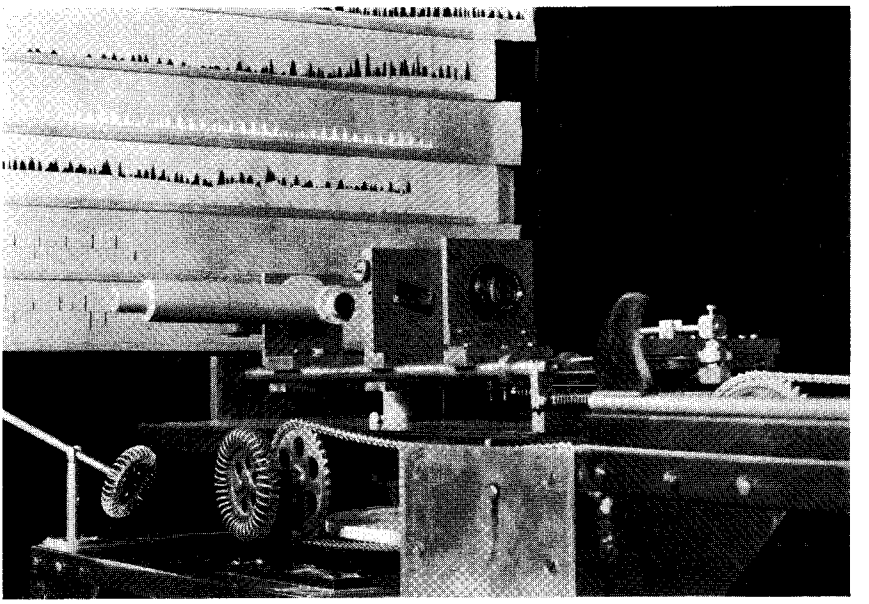

Fig. 3. Central parts of cycloscope: paper strips with curve cut through (above-left) are the cycleplots in the "comparator"; viewing eyepiece left-center; main lens near center; central wheel in front below moves the mirrors (outside to the right) to give long range of cyclic lengths that can be brought into position for testing.

11.3 years. That is, they were harmonics of the sunspot cycle length. After repeated checking to make sure it was not an accident, this was published in 1928 (Climatic Cycles and Tree Growth: Vol. II, Carnegie Institution of Washington, page 124). Since then general lists of these cycles lengths have been made with these approximate values in years: 5.7, 7.0, 8.4, 10.1, 11.3, 13 to 14, 17, 19-20, 23, 34 and others longer. Considering the facts in the case we regard these cyclics as climatic cyclics and not biological life cycles.

The other chief line of study directed toward improvement in forecasting is in the detection of cyclics active at the present time. For recognizing such cyclics our analyzing instrument, the cycloscope, is peculiarly adapted both on account of its exceptional speed and because of its easy and immediate display of the various details of these cyclics. It has made it possible for us to secure without outside aid a series of preliminary tests on forecasting from Arizona and Alaska ring records with promising results.

In addition to instrumental equipment we now have the advantage of the superb ring records produced by Schulman in the Colorado drainage area, the unique ring-temperature records produced by Giddings from Alaskan trees, and our own long time data in the southwest. In looking toward the future we feel that this is not enough. The problem of forecasting water-supply changes is a world problem, and we urgently need ring data from all possible parts of the world, and especially records from the southern hemisphere, particularly from South America.