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CONTENTS

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THE TREE RING SOCIETY

DR. A. E. DOUGLASS, President

H. T. GETTY, Secretary and Treasurer

Main office, University of Arizona, Tucson, Arizona.
Editorial office Museum of Northern Arizona,
Flagstaff, Arizona

BY-LAWS

Article 1—The name of this association shall be the Tree Ring Society.

Article 2—There shall be two classes of active members,
(a) those who are contributing to basic research in dendrochronology
(b) honorary members who have contributed in special ways to tree-ring studies.

Article 3—Prospective members must be proposed by two members of the society and elected by a two-thirds majority of the members present at a meeting duly called by the president.

Article 4—The officers of the society shall be a president and secretary to serve for a term of one year.

Article 5—The Tree Ring Bulletin shall be the official organ of the society, the board of editors of which shall be appointed by the president.

Article 6—These by-laws can be amended at any duly announced meeting of the society.

INFORMATION

AUTHORS

The **Tree-Ring Bulletin** will appear four times a year and will publish papers which are the results of original research on tree rings in their relation to climatology, and to other subjects. No paper which has already appeared will be accepted.

Manuscripts should be typewritten in double spacing. The Editor reserves the privilege of returning to the author for revision approved manuscripts and illustrations which are not in the proper form for the printer.

In reporting tree-ring data authors are requested to submit their data in a table such as appears on the back page of Vol. I, No. 1. This will cut the cost of publication very greatly.

Until funds are available authors will be requested to pay the cost of illustration which may be line cuts or half-tones, but must be drawn or printed on white paper, and mounted with paste, not glue.

Each author will be given, free of charge, twenty-five copies of the Bulletin in which his article appears. Reprints may be procured at cost with or without covers if ordered at the time the galley proof is submitted.

Manuscripts and illustrations should be sent express prepaid or by registered mail to the Editor, Dr. A. E. Douglass, Tree Ring Laboratories, University of Arizona, Tucson, Arizona.

SUBSCRIBERS

All correspondence having to do with subscriptions must be addressed to the Managing Editor, Dr. Harold S. Colton, Museum of Northern Arizona, Flagstaff, Ariz.

TREE-RINGS AND CYCLE ANALYSIS

BY EDMUND SCHULMAN

I. THE PROBLEM

When Dr. A. E. Douglass first turned his attention to the study of the annual growth-rings of trees in 1901, it was with the hope of finding a general variation in growth that might be traced back through the medium of climate to variations in solar radiation, and thus greatly extend the known history of the latter. Early work consisted largely in the acquisition of data; at the same time the best methods of collection, preparation and reduction of specimens were established. It soon became evident that trees undergo not only a general variation in growth, but that time leaves an indelible signature on the individual rings. Through the medium of cross-dating part of an undated specimen with part of a dated one, an exact date could be assigned to any rings in a sequence. A precise and ever-lengthening chronology for Northern Arizona and analogous ones for other regions began to emerge.

As it developed, the investigation began to make increasingly insistent calls on neighboring sciences; botany, geology, meteorology, and astronomy are only some of these. In particular, the precision in dating found a fertile domain in archaeology. The dating of prehistoric Southwest Indian ruins through their building timbers offered inviting prospects, and proved enormously fruitful.

From the standpoint of climatology, the archaeological activity in dating rings was of great value in furnishing a continuous, accurate, and highly sensitive record of variation in tree-growth over a period of some nineteen hundred years in Arizona. Together with the records of growth of the California Sequoias extending back over three thousand years, and the tree-growth data from other parts of the world, it forms a most promising subject for an investigation of the climatological problem.

The fundamental problem of tree-ring analysis may be formulated as follows, in three phases: (1) Are these recurrence phenomena in past climate? (2) What are the elements of such recurrence phenomena? and (3) Is there sufficient law and order in these elements to enable the accurate long-range prediction of future climate?

Climatically speaking, the primary source of activation of the atmosphere is the sun. And one evidence of at least an approach to law and order in recurrence phenomena is found in the number of sun-spots, in the familiar sun-spot cycle of about eleven years. At minimum sun-spots appear infrequently; soon they grow more numerous and some four or five years after minimum the mean number of spots reaches a maximum; activity then declines, at a slower rate, to a minimum again in six or seven years, when the next wave of the cycle begins. Since the phenomena of sun-spot variation are probably intimately connected with variation in solar radiation, it is evident that some effect of this cycle may well exist in climate. But meteorological records are on the whole much shorter than even sun-spot records; perhaps much too short to give any real insight into what is happening in climate. On the other hand, the long records in trees offer a proper study of the problem.

Dr. Douglass discovered in the early years of the investigation that the faithfulness with which tree-rings in Northern Arizona recorded in the more favorable cases the annual fluctuations in rainfall were truly remarkable. The extension to other areas, in some cases with different dominating climatic factors than rainfall, was no simple task and is yet far from complete.

But regardless of the climatic **interpretation** of the cycles found in tree growth, we are confronted with the problem of determining the **nature** of the cycles that may exist in climatic data or tree-growth variation. Consideration of a plot of the annual tree-growth in, let us say, Arizona or California, or even of the short meteorological records, shows that if cycles are operating they are probably quite complex. There is furthermore no particular *a priori* reason why the cycles should be regular in form or period, like the sine-curve. The comparatively simple sun-spot curve is an example. Ordinary mathematical methods for the analysis of data containing periodic variations become extremely cumbersome, or fail completely, when the factor of unknown variability is present in the length, strength, duration and other elements of those variations.

It is for this season that Dr. Douglass developed (1) in 1914-1915 an instrument which, after undergoing considerable evolution, is now called the Cyclograph.

II. THE CYCLOGRAPH AND CYCLES

The cyclograph has been in use for twenty years, and has yielded information (2) about the nature of recurrence phenomena in tree-ring and other data almost unobtainable by present day mathematical analysis.

For purposes of cycle analysis with the instrument, tree-ring material must be processed to a much greater degree than is necessary when the objective is the date of the specimen. The width of each ring of a sequence is measured quite exactly. A plot then made with time as usual along the horizontal axis and corresponding ring width as the vertical coordinate yields the specimen growth curve. To remove very short period variations the curve is next smoothed. It is then transferred to a strip of opaque paper and the maxima isolated and cut out; the result is called a cycleplot, and the curve is ready for cycle analysis. However, mean growth curves of cross-dated groups are usually analyzed. To derive these, each individual reserve must have its non-climatic variations, such as age trend, eliminated and must be reduced to an average ring size of approximate unity. This may be accomplished in a single step. The sequences of reduced ring-widths are then averaged together, and a cycleplot made of the mean smoothed curve.

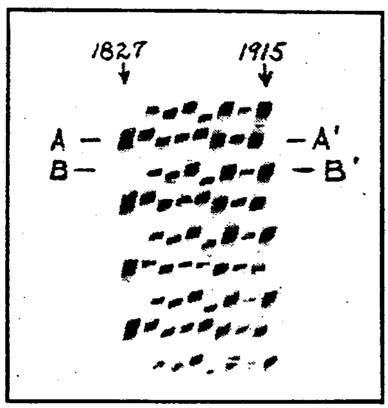
When placed in the illuminated window of the cyclograph, the cycle-

1. Douglass, A. E. 1914. A photographic periodogram of the sunt-spot numbers. Astroph. Jour., Vol. XL, No. 3, 326-331, Oct. 1914.
   1915. An Optical periodograph. Astroph. Jour., Vol. XLI, No. 3, 173-186, April 1915.
   1919. Climatic cycles and tree-growth. Carn. Inst. Wash. Pub. 289. 1919, Vol. I, 85-97. 1928, Vol. II, 42-50.
   1929. Cycles in tree-growth. Reports of the conference on cycles. Carn. Inst. Wash. pp. 34-41.

Stumpff, K. Analyse periodischer Vorgange. Berlin, 1927.

2. Douglass, A. E.
   1919. C C & TG. Vol. I, 98-110.
   1928. C C & TG. Vol. II, 68-96 and 113-135.
   1923. Conclusions from tree-ring data. Report of a conference on cycles. Geog. Rev., Vol. 13, No. 4, Suppl., Oct. 1923, 659-661.
   1933. Evidences of cycles in tree-ring records. Proc. Nat. Acad. Sci., Vol. 19, No. 3, 350-360 March 1933.
   1933. Tree growth and climatic cycles. Scientific Monthly, Vol. XXXVII, 481-495, Dec. 1933.

plot permits light to pass only through the maxima. By means of an optical train of lenses, including a cylindrical one, and a grating, the curve is transformed into a pattern (as seen in the eye-piece) of patches of light, each representing a maximum. Every maximum in the curve has corresponding images in the pattern. Cycles are indicated by alignments of these patches; because of five-fold duplication of every maximum, these alignments are multiple and symmetric, and strikingly catch the eye. One of the distinctive features of the instrument is that alignments in different directions are visible at once; thus, for instance, the mutual relationship of several neighboring cycles shows up immediately. By moving a set of mirrors along a calibrated track an alignment may be brought to a horizontal position and the length of the cycle for normal scale curves read off directly from the mirror setting. Thus is any curve all the cycles between the scale limits of 5 to 42 units may be discovered and their elements approximately determined in a few minutes of analysis. Longer or shorter cycles may be found by replotting the curve on a different horizontal scale. The cyclograph admits a determination of the elements of cycles having a duration which does not cover the entire data, with a length not necessarily constant, with changes of phase at any point, and with variable amplitude.



The accompanying cyclogram is one of the cyclograph patterns of the Grand Canyon modern tree-growth curve. Every spot in the pattern represents the center of mass of a maximum in the growth curve. The photograph was taken with the cyclograph mirrors set so than at 11.6-year cycle would show a horizontal alignment of spots. It is evident that a strong cycle of this length is present in the last eighty years. This is approximately the length of the sun-spot cycle in the interval.

The row AA', repeated four times, represents growth maxima very nearly as follows, from left to right: 1827, 1839, 1850, 1862, 1875, 1885, 1898, 1909. If there are maxima which fall between the recurrent crests of the main cycle there will be spots in the pattern between the main rows. The cyclogram shows alignment of these spots into intermediate rows BB', indicating that the 11.6-year cycle is two-crested. The maxima are approximately: 1844, 1855, 1868, 1878, 1891, 1903, 1915. —E.S.

Hundreds of tree-growth curves have now been analyzed by Dr. Douglass and the results published. Of several hundred analyses by the writer, a considerable portion represented a check on previous work, the results of which were completely verified. While a complete discussion of the complex character of the cycles in tree growth is beyond the scope of this paper (3), two features apparently characteristic of tree-growth phenomena, and possibly of meteorological phenomena, may be mentioned.

First, there is in general no one cycle that dominates in tree-growth. In fact, if a number of groups in a geographically homogeneous area are analyzed, cycles of many different lengths will usually be found to occur. These cycles at first sight seem quite irregular, differ decidedly from each other in relative strength, and may start and stop at any point in the curve.

The second characteristic is that in spite of this apparent chaos, in-

3. An extensive treatment of cycle analysis, by Dr. Douglass, is expected to appear shortly.

vestigation of the frequency and strength of the cycles in any area has invariably shown that there are some half-a-dozen cycles that dominate. What is more, these dominating cycles are approximately the **same** in all areas, and thus form a characteristic cycle family. And more striking still is the fact that these cycles are almost exactly those which are associated with the major sun-spot cycle of 11 plus years.

It is probable that cycles not belonging to this dominating family are due to random effects operating in the trees or local effects of a non-climatic nature. It is noteworthy that some tree-ring groups, in particular the Yellowstone Fossil Trees, are governed almost exclusively by the characteristic cycle family, given below. The various controlling factors, principally climatic and geologic, are perhaps less complex in these cases than is usually true.

The tree-ring cycle family centers about the sun-spot cycle of 11 plus years. This cycle, frequently split into two maxima, is often found in trees but does not usually dominate. Associated with it are cycle lengths near 8+, 10, 14, 17, 19-20, and 23-24 years. These cycles are not equally strong and in general vary in strength in different areas. A short cycle of about two years is not uncommon. Dr. Douglass remarks: "Dating of specimens is largely done by the effects of the two year cycle." Of the long cycles, one very close to 100 years is of importance in tree-growth in the Southwest; associated with it is a strong cycle somewhat less than 300 years in length. A very strong 37 year cycle has operated for much of the last thousand years. Cycles near 55-60 years have been prominent in Ariona tree-growth for at least the last two millenia.

Much ground has been won, and a vantage point gained from which a commanding view of the field of cyclic variation is possible. To be sure, there remains much that is unexplained. Cycles suddenly appear in natural prenomena, perhaps suffer changes of phase, amplitude and length, and as suddenly disappear in a manner in many cases not yet completely understood. Again, where there is no single dominating climatic factor, such as rainfall, in our dry Southwest, tree-rings are less straight-forward "climatic indicators." These and similar problems have been receiving much attention in late years.

The cycles operating in different areas, and in different centuries, represent a study with which the Tree-Ring Laboratories is at present intensively concerned. The remarkable consistency thus far found in the cycle pattern over hundreds of miles and across millions of years points to a dependable and consistent framework in the "vagaries" of climate, and a promising basis for the long-range prediction of climatic phenomena.

THE FIELD COLLECTOR OF BEAM MATERIAL

BY LYNDON L. HARGRAVE

The rapid progress made in the field of dendro-chronology during the past few years and the dual application of the results of dating by this method, to the studies of climate and archaeology is tending to develop two classes of students of dendro-chronology: those interested mainly in the study of climatic cycles, and those interested in archaeology. Closely associated with members of each class is the field collector of beam material from historic and prehistoric sites, with whose qualifications and responsibilitities this brief paper deals.

Dating results have become so important that new responsibilities rest upon the collector. During the earlier days of this work, before archaeologists did the dating, they were content with the actual date of a site, while recognizing the possibilities of correlating more accurately cross finds and of interpreting more correctly various situations found in the field. The entrance of archaeologists as daters into the realm of tree-ring studies is advancing the study of archaeology and increasing the accuracy of field interpretation. When dates are correlated by one not familiar with field conditions much information may be lost. Obviously, the ideal situation would be for the collector to date his own material as he has available all of the facts concerning the specimens. This, however, is not always possible and the field collector and dendro-chronologist then both become responsible in part for the correct interpretation of the data.

Heretofore, greater stress has been placed on the interpretation of material objects of human handiwork than on the interpretation of the factors which made possible an object or a situation. Field interpretations of the latter type are often intangible and require a large background of the broader subject: a specialized knowledge of the particular period or stage being studied, and at least a general, but better still, a thorough understanding of the natural factors at work in a locality today and the ecological conditions at the time a given site was occupied. With these the collector should be deeply concerned. These form an intangible sort of correlative data that may conceivably be of greater value in the understanding of human relationships in times past than may be correlations made through the use of material data.

The qualifications of a field collector of beams should, therefore, not only include a thorough knowledge of collecting methods and the care of specimens in the field, but he should possess a knowledge of the geography and geology of the region studied and the fauna and flora. This is because manifestations of their effect upon the human ecology of a locality are seldom material in nature and must be seen in the field in their various relations to each other in order to be understood.

In the collecting of such material, biotic surveys are more than helpful. Their necessity is indicated by situations encountered while excavating and studying at Wupatki Pueblo. Pueblo II sites in the Wupatki district were found to have been roofed with timbers from trees characteristic of the Upper Sonoran Zone, the zone in which Wupatpi lies. But the timbers from Wupatki Pueblo, a Pueblo III site, represent trees of the Transition Zone, of higher altitude, whose nearest (lower) edge today is several miles removed. Apparently ecological factors and possibly the climate of the locality differed during Pueblo III from ecological factors as seen today. Thus we infer an "intrusion" of a special climatic condition during Wupatki occupation between more moist climates before and after.* It is safe to believe that the full story of the occupation of that pueblo will become well known only when all the ecological factors are well joined to the dates of the beams.

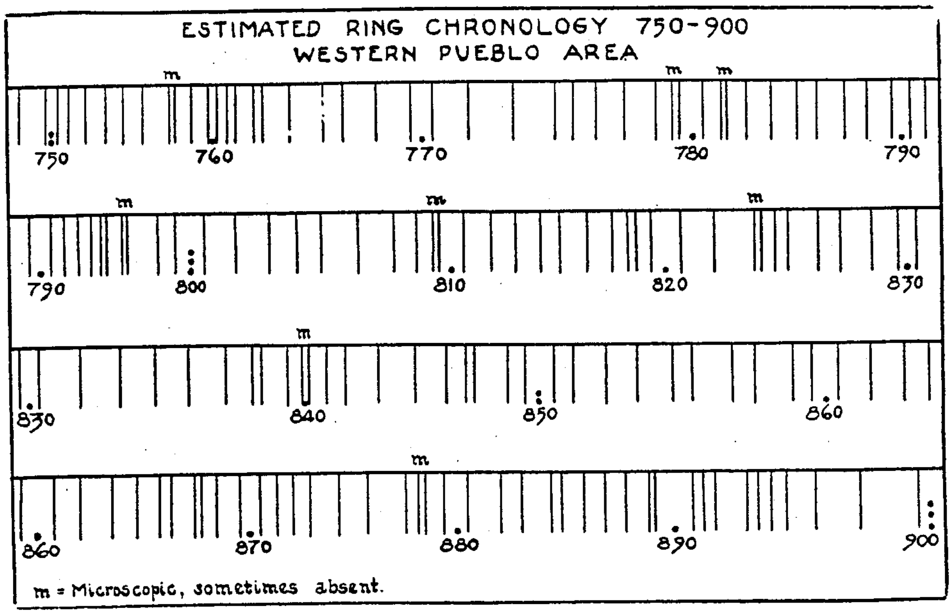
Data on general ecology thus are essential to a correct interpretation of the facts found in a house timber, a story that cannot be read from a date alone. The collecting of beam specimens from prehistoric ruins, therefore, should be done not by one trained only in the mechanics of collecting, but by one versed in these requirements enumerated above.

*H. S. Colton: Sunset Crater: The Effect of a Volcanic Eruption on an Ancient Pueblo people, Geographic Review, XXII, No. 4, October 1932, p. 582.

It therefore seems well to stress more heavily the qualifications of the field collector of timbers from prehistoric ruins; when possible, the dater should do the collecting in the field, provided he has the required archaeological and ecological background; and the worker most familiar with all these factors should have an important part in the interpretation of results.

ESTIMATED RING CHRONOLOGY VIII (750-900)

A. E. DOUGLASS



Special Ring Characters

A.D.
751 Very small, occasionally absent
757-64 Group of small rings, often classed as signature
757 Microscopic
764 Microscopic
767 Smallish; 765-77 large
770 Smallish; 769 is rarely small
774 Smallish
778-9 Small to very small, especially 779; 778 usually larger
782 Very small
787 Large
791 Very small
794-7 Very small
799 Smallish in series of large rings
806 Very large
808 Sometimes small
809 Very small to microscopic and very often absent
812 Sometimes smallish
814 Sometimes smallish
817)
818) All smallish and one or two of
819) them sometimes absent
820-2 Very large, increasing series
823 Microscopic and frequently absent

A.D.
824 Very small, rarely absent
825 Very small
830 Small
837 Very small
840 Microscopic and sometimes absent
842 Smallish
843-6 Large
847 Very small often microscopic; rarely absent
849 Smallish
855 Smallish
857 Small, amidst large rings
859 Small
865 Very small
867 Small to microscopic
868 Usually very small but sometimes normal with faint red
870 Small
876 Usually normal to large
878 Very small to microscopic or absent
884 Very small
889 Small
891-2 Small and often with heavy reds
893 Large
894-5 Small and often with heavy reds
897-89 Large; increasing series