Crossdating in Dendrochronology

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This paper defines and illustrates crossdating, an initial process in dendrochronology or tree-ring work by which accurate ring chronologies may be built for dating purposes, for climatic information, or for certain ecological problems. Here are briefly explained its operation by an efficient method, its principles of interpretation and application, its character as differentiated from correlation, its procedures for reaching assurance in results, its significance as a guide to special sites where certain climatic effects on tree rings can be distinguished, and finally references are given to some of its published discussions. The purpose of this paper is to call the attention of ecologists and others to this fruitful process that carries conviction by tests on well-located trees but whose reality in certain well-assured regions cannot be judged by misinterpretation of material or untechnical treatment of specimens.

THE article called "The Dendrochronology Enigma" by A. W. Sampson in the December 1940 JOURNAL OF FORESTRY is based on a serious misunderstanding of the principle on which dendrochronology or tree-ring work is founded. Our criterion of climatic character in the ring records in our trees is not sensitivity (the amount of fluctuation in thickness from ring to ring) as he states and criticises, but crossdating quality which is of an altogether different nature. Crossdating is the recognition of the same ring pattern in different trees, so that the actual growth date of any one ring of the pattern is the same in the different trees and one may carry a chronology across from tree to tree. Sensitivity is a secondary feature which is important only in the presence of crossdating. If there is no sensitivity there can be no patterns and therefore no crossdating by patterns, and no assurance that the specimen came from a site in which the trees can show a climatic variation year by year.

Inattention to the initial crossdating by patterns was the error in the study of 21 increment cores by W. E. Davis[1] some years ago, cores that came from the Southwestern Forest and Range Experiment Station at Flagstaff, Arizona, and which I later examined very carefully together with his report made available through that station. He discarded about half of those specimens because he was not sure of the identity of the rings. While this was apparently a worthy reason, the fact was that the specimens he discarded were the only ones that had what we consider sensitivity, even though to a very small degree; and from that peculiarity he became uncertain of ring identity obtained by counting in from the outside and omitted them. Those Davis did use had practically no sensitivity and, therefore, had no patterns to crossdate, and thus no evident climatic value so that negative results were to be expected.

In localities new to us our standard procedure is to secure a series of ring sequences from increment cores or stump-cuts taken out in the field by someone who understands the effects of topography, in order to see what climatic effects the trees of the region are showing normally when growing in an environment capable of producing climatic effects in the rings. In the Southwest we seek steep slopes and shallow soils and a rainfall about as small as the trees can stand. These are of course not the characters a lumberman prefers; in fact he avoids them. In the study of large numbers of such specimens, we had become familiar with the normal Flagstaff patterns and could recognize at sight that even the better specimens discarded by Davis were still not good enough to be used in his test. These errors would have been avoided by his adherence to the requirement of initial crossdating in real ring patterns.

It is surprising to most people to see crossdating in the form in which we can show it. Our success is believed to be due to favorable sites in a dry region. Advantageous conditions reveal themselves in certain superb locations in Mesa Verde and near Durango, Colorado and many other places. Figure 1 shows a very distinctive topographic environment in the Mesa Verde National Park, one of the best sites seen in forty years of field work. The available moisture for the fir trees on the slope is restricted to the precipitation that falls on or near the trees them-

[1]Co-author with A. W. Sampson of "Experiment in Correlation of Tree Growth Rings and Precipitation Cycles," published in Trans. Amer. Geoph. Union, 493-496, 1936. This paper is referred to in "The Dendrochronology Enigma." Mr. Edmund Schulman of this laboratory in March 1939 examined substantially all of the collections and analysis on which that article was based and found fundamental errors that showed the necessity of a complete revision of that paper. In the text above I am giving my personal experience with an earlier Davis test.

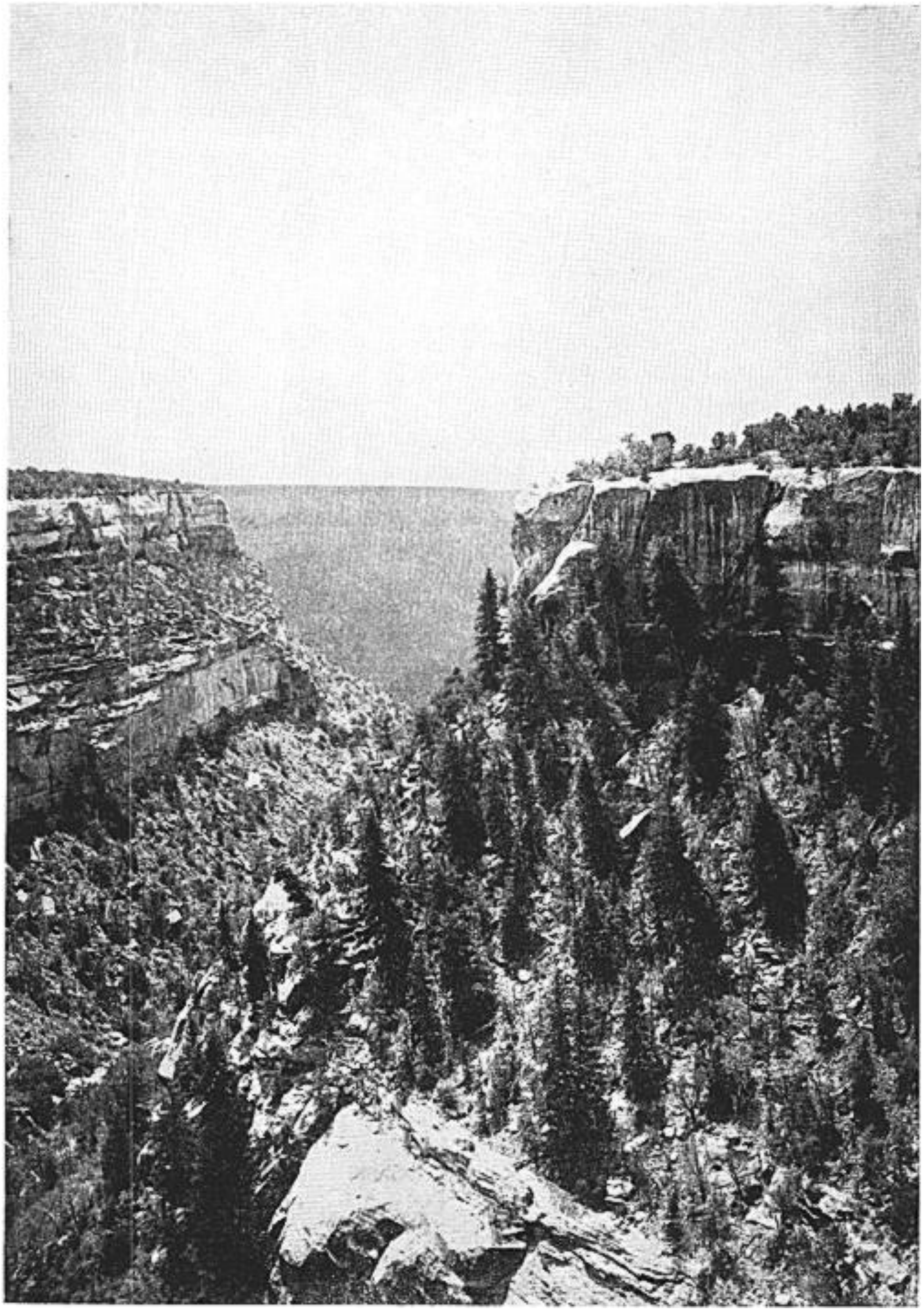

Fig. 1.---Mesa Verde site in Fewkes' Canyon, highly favorable to crossdating; the mesa top at the right slopes generally away from this canyon.

selves, chiefly in the winter rainy season; the steep slope reduces local conservation of moisture to a minimum; an elevation of 6,700 feet above the sea and a mean annual rainfall of perhaps twenty inches keep these trees under a stress of moisture deficiency. Our increment borings in five of these trees, well distributed both as to location and age of tree, show a very high quality of crossdating in the ring patterns and a sensitivity that we have called class AA.

People who live in moist climates have great difficulty in judging these topographic characters as such sites are rare and experience is often needed in evaluating them. The chief requisites here are: first, the near impossibility of the trees getting "imported" water that has fallen on, or been stored in, other localities and then moved to the area whose trees are under test; second, a shallow soil or one with small water storage capacity; and third, a low mean precipitation so that the trees rarely or never get all the moisture they can use.

Illustrations of Crossdating

Our crossdating is done directly in the ring patterns on the wood (often aided by what we call "skeleton" plots), hence in spite of their unfamiliarity direct photographs of ring sequences constitute our first exhibit. Figure 2 represents patterns in four different trees of a sequence of years in the middle 1200's. We have called this pattern the "Gap" signature because these rings were involved in the successful 1929 dating across the gap between the earliest historic dates and the most recent prehistoric ones. In examining this illustration one should start with the three large rings near the left end of each photo, the rings dated 1248, 1249, and 1250, and note in each tree the small rings at 1251, 1254, 1258, 1263, 1270, and 1276 (this last in two only). The illustration would be more appealing if rings and dates were not marked and one had to "dig" out this similarity for himself. Thus he would take the small ring 1251 and then make a list of the dates of succeeding very small rings for each tree and find the agreement between the trees.

Figure 3 represents sequences from four trees that grew in the 1500's.[2] We have called this the "Hopi" signature as it is common in the beams of the Hopi villages. One can start here with the two large rings in the left center of each, 1530-1531, and especially the small ring of 1532; then list the small rings both backward and forward and observe the agreements between these trees. That is the sort of crossdating we have found in thousands of cases.

But most people are familiar with plotted curves and so Figures 4 and 5 have been arranged to give plots of measures of the thickness of these same rings shown in Figures 2 and 3. The similarity between these curves is evident. In a region where moisture is the critical factor, the years of minimum growth seems to be more individualized and to afford more ready points of correspondence between different trees. To these examples of crossdating in plots is added Figure 6 showing the agreement between two groups of trees about 70 miles apart. The upper shows the average growth in seven trees in the Chuska Mountains between Fort Defiance and Chinle. The lower curve is from a group of three logs that came from near the store at Pinyon in the middle of the Black Mesa, about 70 miles west of the other group.

Finally Figure 7 gives a general curve from 55 trees in the northern parts of Arizona compared to the winter precipitation records from three widely separated points in the same area that are highly representative of the area. The winter record is here modified by introducing a lag of 2½ years in the smoothed values, which means that annual changes are retained but that a conservation is introduced in the smoothed values. This is a slight variant of the author's usage in testing Prescott trees, published in 1919.[3]

Crossdating Memory

The most efficient and at the same time the most convincing method of crossdating is by that memory which develops on examining scores of specimens of approximately the same age in which similar patterns are identified in the great majority of cases. Usually the process begins in the selection of some feature such as a little combination of rings that is found to be common to two or three specimens; then some number, a real date or a hypothetical date is applied to one

[2]Figures 2 and 3 are photographs of specimens collected under the auspices of the National Geographic Society. My sincere thanks go to that society, to the Carnegie Institution of Washington, to the University of Arizona and other institutions and persons without whose aid the development of the subject would have been impossible.

[3]See also F. P. Keen, "Climatic Cycles in Eastern Oregon as indicated by Tree Rings," in Mon. Wea. Rev. 65, 175, May 1937.

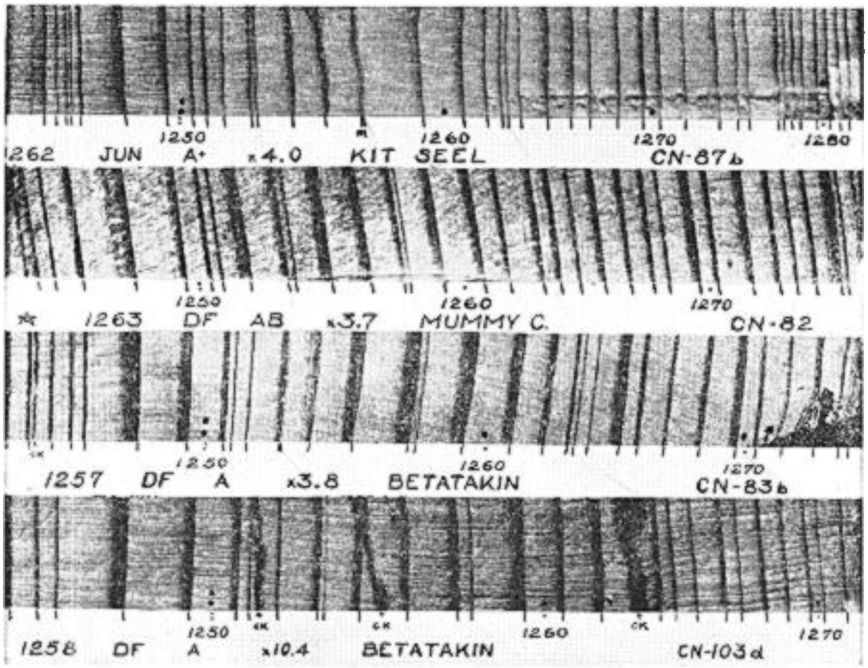

Fig. 2.—Crossdating in the "Gap" signature.

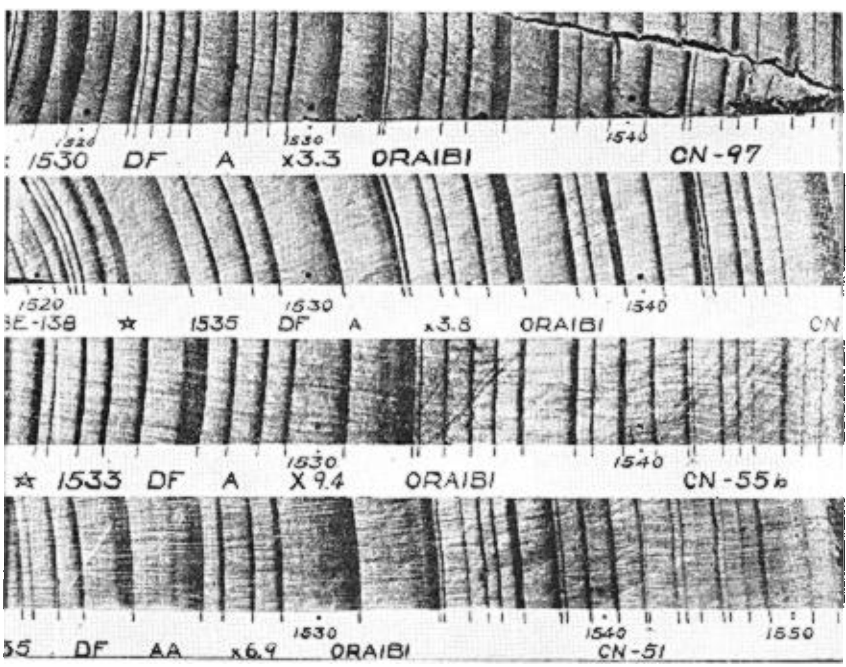

Fig. 3.—Crossdating in the "Hopi" signature.

of the rings and a "skeleton" count is made, often in memory only, giving the related chronological position of the various small rings. This is applied to each specimen in turn. If one has a flair for numbers (such as many persons have in remembering telephone numbers) one soon finds that one has in his mind a picture of ring patterns in which each ring is identified by a number. In the writer's experience that first picture came in 1911 after about twenty Prescott specimens had been carefully examined. In larger and larger groups of specimens the original small numbered pattern grows and grows to greater size and interest just like a picture puzzle whose small fragments join until one begins to see what the picture really is.

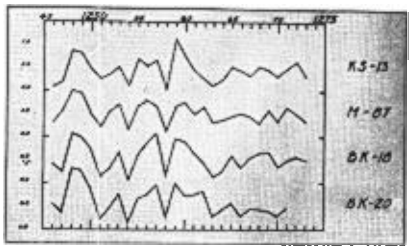

Fig. 4.—Crossdating in growth curves of four trees shown in Figure 2.

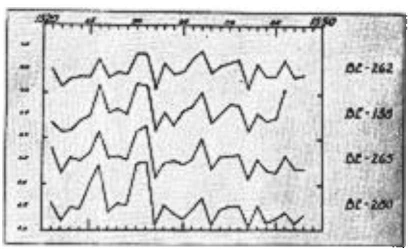

Fig. 5.—Crossdating in growth curves of four trees shown in Figure 3.

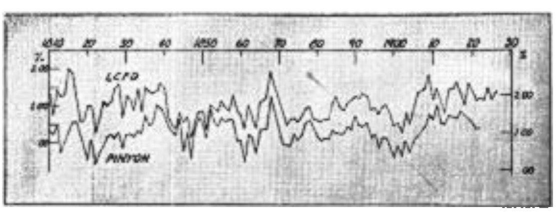

Fig. 6.--Crossdating across 70 miles.

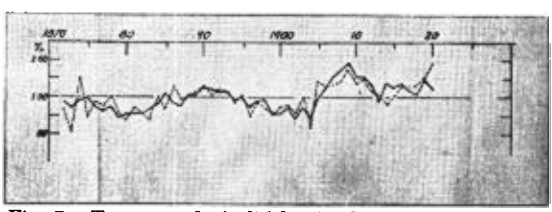

Fig. 7.—Tree growth (solid line) of 55 trees and winter precipitation (dotted line) with 2½ years conservation in the smoothed values.

Principles of Interpretation and Application

Looking back after almost thirty years of constant use and tests of crossdating on some twenty thousand specimens, after dating probably a million rings and measuring perhaps half of that number we find no evidence that leads us to doubt the general accuracy of the chronology in this Pueblo area and in the big sequoias and in other carefully tested areas. We have developed many very stringent rules of technique which, if ignored, cast doubt on the results. Certain principles of interpretation and application have been developed. The principles of interpretation are as follows:

1. If many independent trees in a forest over a wide area and for a long interval of time show similar ring variations in identical years, the cause of such variation is climatic because climate is the common continuous factor in their surroundings.[4]

2. A forest border dependent on general topographic features such as altitude or latitude or coast line becomes an important guide in the search for the climatic element influencing the trees because that element's importance to the tree is emphasized at the forest border.[4]

3. General areas like forest borders are commonly invaded by localities controlled by exterior conditions such as dryer upland ridges, shallow soils and so forth (in critically dry regions) or locally extended by areas showing forest interior conditions such as streams, moist valley bottoms and so forth (in dry regions); these surroundings have strong influence upon the ring record of the individual tree.

The principles of application are as follows:

1. Crossdating procedures have changed fundamentally the method of getting information from tree rings by introducing as the unit of information not the individual tree but a group of trees whose ring patterns crossdate.[5]

2. Crossdating should not be accepted in any new locality until it is proved by test to be there. So also its absence in one locality carries no inference with respect to its genuineness in another locality that differs in climatic and topographic features.[5]

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[4]Carnegie Institution of Washington, Year Book 1932, page 217.

[5]Tree Ring Bulletin, 6. 26, April, 1940.

Crossdating and Correlation

Crossdating is not to be confused with correlation. It is not a correlation coefficient between the records of different trees; it is not identity of thickness of a given ring in many trees, exact thickness of a ring is not highly important. In our Southwestern work crossdating is finding in many different trees the same relative chronological placement of years of deficient growth.

The writer feels that no correlation formula should be used to decide whether sequences from two different trees are showing the same dates. In doubtful crossdating cases there are several procedures that carry one toward final assurance. First, review the rings very carefully under absolutely rigorous conditions of microscopic power and of standard surface and illumination and see if any change or uncertainty is indicated in them. Second, withhold any decision in the matter till the length of the sequences susceptible of comparison is sufficiently extended to give a definite decision. This usually means waiting for new specimens. On the average, datable Arizona pine trees need crossdating patterns about fifty years in length; Mesa Verde firs often work well in patterns of twenty-five years; giant sequoias commonly need one hundred years and in northerly groves they require several hundred. Third, strengthen the local chronology by crossdating between all available specimens. Fourth, secure datable ring records farther and farther away for proper checking purposes.

Significance of Crossdating

Crossdating is not a magic formula which only the elect can use; on the contrary it is a valuable guide to those topographic laboratories where nature has isolated certain climatic elements in their effects on growth rings. It points the way by which we ourselves can find these laboratories and study the effects under measurable conditions. This process was first used by the writer for dating purposes in 1904 but it has taken years of unending tests in the field on living trees and a minute acquaintance with their individual sites, to reach the more evident phases of the relation of ring character to the surroundings of the tree in which it grew. In a general way it is realized that higher elevations (with more rainfall), running streams and deep moist soils decrease crossdating, while lower elevations (near the forest's lower border where the rainfall is less), sandstone and limestone bed rock under shallow soils, steep slopes, high ridges, and the dryer east or "shadow" sides of the mountains (away from the moist westerly winds) are favorable to crossdating.

In conclusion we are quite aware that these emphasized climatic effects in tree rings are not a general character of all trees about the world; on the contrary they are the result of specialized conditions but when finally found in relative purity they offer rare opportunities for important studies in climatics and prehistory as well as in dynamic ecology.

Some Published Discussion of Crossdating

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Philadelphia Industrial Union Council Adopts Resolution Supporting Federal Regulation of Private Forest Lands

Whereas, For more than 50 years foresters and farsighted people have fought against the cut-out and get-out policy pursued by many lumbermen on private lands. This policy of selfish devastation has turned millions of acres of productive land into barren waste. Instead of a national and community asset, it has become a fire and flood menace and an economic burden to state and nation. Prosperous communities dependent on the timber for livelihood have become ghost towns. Workers and local businessmen and their families have been thrown into dire poverty and the few remaining local taxpayers have had to meet an ever-increasing and unbearable tax load, and

Whereas, Under proper management these wasted lands would have continued to produce timber and provide work in forest, mill and construction. Tourists, sportsmen and vacationists would secure recreation and contribute income to local residents. Water would be conserved for fishing, bathing, industry and home. Rapid runoff and erosion with resultant flood damage would be reduced and both the local worker, the landowner, the community and the nation at large would have the benefits and security resulting from a stable and assured income, and

Whereas, Because of these facts and because organized labor is vitally interested in all measures which promote stable and fruitful use of and conservation of our natural resources whether these be privately or publicly owned, therefore be it

Resolved, That the Philadelphia Industrial Union Council go on record as supporting the federal regulation of private forest lands and endorsing H. R. 3849, known as the Pierce Bill, and be it further

Resolved, That Locals affiliated with this Council be urged to take similar action, and be it further

Resolved, That copies of this resolution shall be sent to both Pennsylvania United States Senators and to all Congressmen from this area, and to Congressman Pierce and to the Speaker of the House of Representatives.