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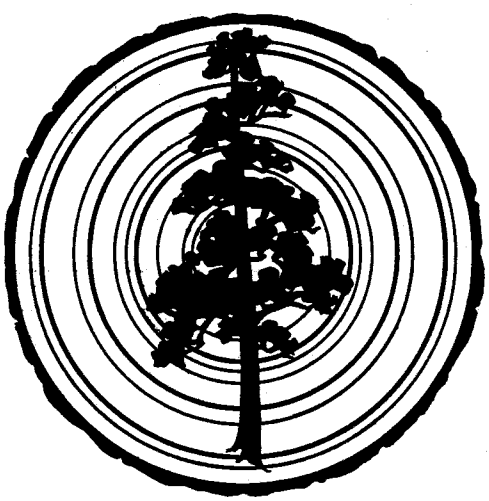

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Tree-Ring Laboratory
University of Arizona
Tucson, Arizona

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All correspondence regarding subscriptions should be addressed to Mr. Edmund Schulman, Tree-Ring Laboratory, University of Arizona, Tucson, Arizona.

NOTES ON THE TECHNIQUE OF TREE-RING ANALYSIS, I[1]

A. E. DOUGLASS

Introduction

The techniques here described have developed through the handling of thousands of specimens both for visual study and photographic representation. These methods are built around certain basic principles and facts whose neglect has led some experienced investigators into serious errors. While much of the following applies specifically to material from the Southwest, it can with minor modifications apply also in general. These notes are not intended as a complete discussion, but will supplement much material on this subject already published.[2]

SOME POINTS OF GENERAL PROCEDURE

Modern specimens

Modern specimens consist chiefly of increment cores about four mm in diameter usually obtained with the Swedish increment borer, V-cuts or cuttings across the tops of stumps or the ends of logs, part sections or cross-sections, and very rarely cores one inch in diameter obtained with a tubuler borer. All or most of these specimens have a known outside date and their ring record may be carried back into the past by crossdating. The relation of this record to climate is of primary importance. Hence the first step in work with such specimens is to have a look, if possible, at the last few dozen rings right on the spot where the tree grew in order to interpret the ring growth in terms of local topography. This is facilitated by a gentle shaving of the surface, not in a haphazard fashion but in such a way as to reveal the complete series of rings to best advantage. The necessary method is described in the details of technique given below.

Prehistoric specimens

Prehistoric material from Southwestern ruins consists characteristically of good log sections, sections with the sapwood all or partly worn off, fragments of sections, great numbers of tubuler-borer cores, charcoal beams and sections or parts of sections, and vast numbers of charcoal fragments whose place in the beam is commonly unknown.

In undertaking work on a group of specimens of unknown cutting dates the first need is to find the most promising pieces; it is far easier to recognize ring identities in the poor pieces after getting acquainted with the good ones, than to do the reverse. Hence one wishes to pick out the desirable

[1] It is planned to publish in the April, 1941 issue of this Bulletin a continuation of these notes, accompanied by a set of illustrations which apply in part to the material of the present issue.

[2] See especially Douglass, Climatic Cycles and Tree Growth, Carnegie Inst. of Washington Pub. 289, *I*, 1919, 54-64; *ibid.*, *II*, 1928, 34-50.

kinds of wood, pine and Douglas fir preferred, and then in these to choose the longer sequences with rather thin and sensitive rings.

Use some sort of tree-ring knife or sharp razor blade and make a diagonal cut along a radius at a slant of 30° to 40° from the grain wherever possible. With proper direction of the light such a cut gives in most cases an immediate and very clear view of the rings (illumination is discussed at greater length below).

If actual dated identities are not recognized at once, look for some parts of a good specimen that seem datable in terms of ring patterns and, generally holding central rings toward the left, build and record a "floating" chronology.

Mark every tenth ring with a really sharp, small needle; this is more convenient if mounted. In the Pueblo area a pine or fir ring almost always has a sharp outside boundary. A suspicious "lens" ring outside this is apt to represent another year, while a suspicious ring just inside a larger one is apt to be a part of the larger ring. This was found to be the case in the work on the Flagstaff-Prescott material in 1911-1913 and has been almost the universal occurrence in the Pueblo area. It was described to some extent in 1919 (Climatic Cycles and Tree Growth, *I*).

About 1920, when attempts were made to date the Arizona and New Mexico ruins by comparisons of their prehistoric ring patterns with those of the giant sequoias of California, many tree records were plotted in the ordinary manner with abscissae representing time and ordinates representing ring width. Then, to draw attention to certain features, marks were placed on the plots where minima were conspicuous. These marks were found to be easy points of reference and thus the skeleton plot began. We have found that two mm makes an excellent unit of time, well adapted to the eye and suitable for use in our analyzing instrument, the cycloscope. Accurate coordinate paper, with 2 mm as the smallest dimension, can be purchased. A strip 4.5 cm wide has been found very convenient. We commonly put dates near the upper part of the coordinate strip, marking the dates at two cm intervals. These dates may, of course, be actual dates or merely numbers from a central zero or any other initial number that is used. We then note at every date represented by a thin ring a vertical line at the base of the strip, the length of this line being roughly an indicator of the thinness of the ring. If the ring differs from its neighbors only a little in thickness, the line representing it is very short, perhaps two to four mm, but if the ring is absent or locally absent, then the line may be two cm long. A skelton plot is also marked for a series of thin rings by a zigzag line over the dates during which the series continues. Especially thick rings are noted on the plot by the letter B. In our experience with sequences from the Southwest, there are some cases in which crossdating is indicated by thick rings, but generally speaking the crossdating by thin rings in this region is far more satisfactory.

Our standard or master plot, carrying known dates, is usually made on the upper edge of a long strip so that the undated series under examination can be brought in contact with it and the indicator marks on each will be adjacent. With this arrangement we can not only test very quickly any given pattern as to whether it matches the master plot in any one region, but we can also move the unknown pattern along the entire length of the master chart in order to test any possibility of its dating at some other perhaps quite unexpected time. In doing that, for instance, we once found that a certain log outside a ruin in eastern Arizona was cut in 1804 instead of at an expected much earlier date, and it therefore associated that ruin with the troubles between the Spaniards and Indians at that time.

The skeleton plot was used extensively in the early 1920's to preserve important ring records for our files. Its first general application to dating

was in 1927 in applying crossdating to many prehistoric specimens. It gave great help in the detection of corresponding patterns. The first important specimens so dated were WPT-25 and BE-67 which showed the exact positions of Wupatki and Mesa Verde in the Pueblo Bonito chronology.

SOME DETAILS OF LABORATORY TECHNIQUE

Specimen form

The pencil form of specimen is preferred, about ½ to 1 inch in diameter or square. A watchmaker's eye lens, which frees the hand, is highly serviceable for dating and expressing other notation on the wood; a pin or needle specially sharpened is very satisfactory for this purpose.

Surface

To prepare a surface on a square-cut or V-cut, hold the specimen so that the time sequence of rings runs from left to right—thus the bark or outer end of the specimen will be on the right. Turn the specimen until the cells are vertical; the alignment of the cells (grain) may be observed readily with a hand lens. Cut at an angle of approximately 35° to the grain, on the farther side of the upper surface of the specimen. Surface a narrow strip, preferably ½ inch to 1 inch wide, although ¼ inch will do if necessary; make the first dating attempts just on the edge of this strip. If a photograph is desired, flatten the cut surface by rubbing it with a large file. Finish the surface with a very thin and very sharp razor blade; this is usually held bare in the fingers and worked in long sliding strokes under a low-power lens. The flatness of surface should be preserved as far as possible.

SI Core mounting position

Mount Swedish increment (SI) cores with the cells inclined at an angle of 50° or so, and upward to the left when viewed from the bark end (the cells incline toward the operator when the flat side of the half-round is downward and the late end of the specimen is toward the right). If the core has been twisted in extraction, this applies especially at and near the late end. For photography, the surface should be prepared as in the preceding paragraph; for ordinary visual work the use of the file is unnecessary.

Lighting

If the surface is cut and oriented as in the preceding paragraphs and illuminated by light coming towards the observer from in front, the visibility of the rings will be near a maximum. All visual and photographic work on the wood specimen should then be done if possible in this position and lighting. This arrangement is especially necessary in the case of twisted increment cores, when the rings are faint or in groups of microscopic size, and when working with sapwood which in pine often lacks deep coloring in the latewood. The student will find that in visual work certain other positions of grain, surface, and illumination are equally good, but certainly at first it is better to follow the preceding directions with some care.

Surface reflection

In certain conditions of decayed or burnt wood, there is another kind of reflection that is often useful. The "pencil" is held as usual in a left-to-right position and is twisted until the razor-cut surface itself reflects the light as if it were a mirror. But the different parts of the ring, early and late wood, reflect very different amounts of light, and so the ring becomes very conspicuous and the microscopic details show nicely. This resembles the work on charcoal to be described below. In order to get this particular form of reflection the surface is inclined to the line of sight. That is of little consequence when a magnification of X10 or so is used, but it is a complete obstacle to photographic work.

Sliding coincidence

Two different trees can be compared minutely with each other, ring by ring, by the "sliding coincidence" method. This requires practical contact of corresponding rings in different specimens so that the eye can estimate their resemblance. For this purpose prepare suitable surfaces on square cuts, V-cuts, or mounted SI cores as indicated above; use a watchmaker's lens; hold two "pencils" in contact in one hand with the late ends to the right; with the other hand, put in pinholes for provisional dating in a marginal position to show they are not final; start at some identified feature in

each in contact; then work forward or backward while keeping corresponding rings and patterns together by a little slipping of one "pencil" along the other. A record of the striking coincidences is easily made and is often a great aid in judging results. It was this method of comparison that, in the early tree-ring work, wrested important results out of many specimens of medium to poor quality.

SUPPLEMENTARY NOTES ON HANDLING OF SPECIMENS

Use X 10 magnifying glass, triple aplanat if possible, taking care to adjust it straight every time. Have a higher power available if possible. Be careful of *eye* focus. In using any magnifying glass or microscope, be sure to hold specimen as far away as distinct vision permits; change view quickly to distant vision, on trees or mountains, every once in a while to keep the eye from strain.

A ¾ inch wooden half-round a foot or so in length, grooved to a proper size to fit the Sl cores closely, is very convenient as a mount. Attach the core carefully to the mount with good glue, and tie with a string for 24 hours until glue is hard. Cores are usually dry enough to mount within 24 hours after collection. If the core is broken the pieces should be matched together and marked before gluing and then mounted in proper contact.

If the photography of the specimen is important, one should consider mounting the cores on the top of a strip about ⅜″ thick, ⅝″ high, and 12″ long or more; this narrow form allows the photography of several specimens at once in certain kinds of enlargement.

AN APPLICATION OF WOOD-CELL STRUCTURE

In certain tests of the dissected tree OL-12 (Tree-Ring Bulletin, *4*, No. 4, 6-8, 1938; *6*, 13-16, 1939) it seemed worthwhile to check carefully certain sections as to which surface was above and which below in the original tree. This occurred because the north point had been marked on the sections, but not the east or west point. Wherever a knot appeared in either surface of a section, this identification could be done at once by throwing a beam of light upon the surface at a low angle and then rotating the section while watching the "brightness" of the knot. This brightening of course occurred when the slanting cells in the knot reflected the light up to the eye. To do that they must point downward to some point below the light. Thus one could tell immediately whether the direction of the branch forming the knot was upward toward the center, showing a lower surface in the original tree, or downward toward the center showing an upper surface of the section.

ANALYSIS OF CHARCOAL SPECIMENS

The thought of ring patterns in charcoal did not attract our serious attention in the earlier years of tree-ring work. In 1921 I told Mr. Neil M. Judd, who was beginning work on Pueblo Bonito for the National Geographic Society, that we would like to have good beam sections, sound, and if possible six inches in diameter. Specimen no. 5 which he sent was a burnt log end. The charcoal side showed a very distinct but complacent set of rings. His nos. 15 and 17 were severely charred wood but more readable, and were dated readily. They still show the latest dates yet found in Pueblo Bonito.

The large BE collections were practically all of wood. But in September and October, 1928, Mr. Hargrave and I stayed several weeks at Mr. Earl Morris' camp on the Juddito Mesa, and there we spent all our time on charcoal that Morris was collecting. The collection of charcoal was not new to Mr. Morris. In the previous year he had sent me several cartons and boxes of charcoal specimens, including one immense section, M-200, from a kiva in the Johnson-La Plata area. This splendid section with nearly 360 rings,

cut as we learned later near 830 A.D., became the basis of chronologies preceding 700 A.D. under the name of JCD, Johnson Canyon Dating.

First charcoal dating

These specimens now appearing from Kawaika climaxed in a superb piece of Douglas fir charcoal[3] that completely verified the tentative dating of small pine wood fragments, and thus confirmed the first prehistoric dating by the tree-ring method and established the value of charcoal ring records. Its ring series dated from 1396 to 1467. Early the following spring a group of charcoal fragments from Showlow ruin, obtained through the courtesy of Mr. H. S. Gladwin, of Gila Pueblo, helped to direct our attention to Showlow as a promising place for beam material to close the "Gap."

Handling charcoal in quantity

In May and June, 1929, thousands of fragments of charcoal were collected there and brought to our temporary laboratory in the Woman's Club Building at Flagstaff, which Dr. Colton was using at that time for the Museum of Northern Arizona. This brought us directly against the problem of handling great quantities of charcoal. Fortunately we had a large amount of table space in the building above mentioned. The bags of charcoal were spread out on cotton nests so that with a hundred of these nest groups, nearly a thousand fragments, in sight at one time, the eye could pass over the individual pieces quickly and crudely select the more promising ones. The pieces so picked out were given a rapid examination, a record of their ring sequence was made, each was tagged with a number which was simply the current date and its serial number for that day, and the specimen, unless extra good, was returned to its nest. Finally, Dr. Haury reviewed the entire collection and added a large number of dates.

Dates from charcoal fragments

Of course the problem in that charcoal was how to get tangible results out of such a multitude of pieces coming from every part of many charcoal logs. Only a very small percentage could possibly be from the original bark-covered surface of the logs, nor could we know how far each fragment had been from the outside of the log. But the one thing they would have in common was overlapping dates with a probable approach to some obvious limiting date for each construction period. So the solution was easier than expected; the specimens were arranged in order of their last dated rings and plotted on long coordinate paper one by one in continuous lines on a horizontal time scale. Thus they obviously divided themselves into groups of lines which as a group approached some date and then stopped. The number of dated specimens from one ruin was so great (461 from Showlow) that no doubt remained that these converging dates represented real construction times.

The value of charcoal being thus insistently demonstrated, the best methods of handling it had to be considered, both to make the pieces safely usable at once and to preserve them for future use.

PRESERVATION OF CHARCOAL SPECIMENS

Charcoal preservation

In this dry country charcoal usually comes out of the ground relatively moist. Soft masses often go to pieces in a half hour as they dry. The practice we found good in 1929 was to dip them briefly in a can holding a weak solution of paraffin in gasoline as soon as they came out of the ground. If that was not convenient at the moment, then a little earth over the specimens would hold them intact for a time. In all our specimens of that year this gasoline-paraffin treatment was followed by a wrapping in cheesecloth if the specimen was large and seemed to be falling apart; cotton and string were then used. The paraffin may penetrate ⅛ inch to ¼ inch; melted paraffin is apt not to soak in at all. When a surface is cut or broken

[3] Photograph in Douglass, Dating Pueblo Bonito and other Ruins of the Southwest, National Geographic Society Pueblo Bonito Series No. 1, 1935, p. 30.

on one of these pieces the new surface is often devoid of paraffin and should be treated anew. It is probably a bad policy to make the solution too strong or saturated or to leave the charcoal too long in the solution, for after a surface is prepared in that way it is apt to cloud over with paraffin working to the surface. This however can be removed by washing with gasoline. Our special specimens so treated have hardly changed with time; for example number HH-10, collected and photographed in 1929, shows today a marvelous record through the great drought in the late 1200's. On the other hand I have seen valuable specimens collected not that long ago now rapidly going to pieces for lack of some binding material like paraffin to hold them together.

There are of course other substances like flexible collodian, solutions of cellulose in acetone, and preparations of bakelite. But for practical usage out in the field, the paraffin treatment seems to be one that the collector should have always ready for use.

Earl Morris did a very fine piece of preservation work on several very large and important specimens in 1927 and 1931 in his Site 33 near Johnson Canyon, in the La Plata River district of the San Juan area. In his great kiva he found vertical roof supports made of immense logs some 24 inches in diameter. They had been burned off above an ancient ground level and had decayed below, but at the ground level a charred section was still intact averaging about 2 inches in thickness, in certain parts reaching 3 inches and in a square inch or two completely burned through. His general method was to cover the exposed surface with one thickness of newspaper, then with melted paraffin in thick layers, finally with burlap bags wrung out in wet plaster of paris and allowed to harden. This top cover had its lower paper layer extend 2 to 4 inches beyond the edge. Loops were fixed in the plaster so that in unpacking it could be lifted off. Then he burrowed carefully under one edge and introduced supporting ridges of the same covering, paper, paraffin, paper and burlaps in plaster of paris. Three or four ropes of burlaps in plaster of paris were passed around the edge from the top to the supports beneath (these were cut through in unpacking). The process was repeated until there was sufficient support below to overturn the specimen, clean out the loose earth and construct a complete supporting layer for the under side. The whole was then packed in a strong wooded box and shipped.

That packing was so good that the first of these specimens, M-200, stood in my laboratory without deterioration for several years until I had a chance to begin work on it in 1931; it has been well worth the effort made to preserve it.

SURFACING OF CHARCOAL SPECIMENS

Keep in mind that the value of a piece of charcoal depends on the number and sensitivity of the rings in the series and not on the size of the specimen. Do not disdain a small piece if it has some good-looking small rings or a small number of highly sensitive rings. A fragment 6 mm radially, about 15 mm along the rings and perhaps 12 mm vertically, gave a record from 1275 (in part) to 1308 complete at Kinnikinic and was my first dated piece from there, found in June, 1940, in an hour's visit by poking in a room that overlooked the canyon. The record was exceedingly good and was the first one of the great drouth in the late 1200's that I had seen from the Flagstaff area. In a Basket Maker site at Mesa Verde the workmen were saving only those pieces of charcoal (of course there was no wood) that were as large as one's fist. But I picked up datable pieces that were only an inch long. All must be saved for expert inspection.

In the vast majority of cases one begins laboratory work on each attractive piece by breaking off a corner, at some point where it can be spared, to see

whether the rings look sensitive and thus favorable, or whether the ring series is complacent and thus bad, or whether the rings show thready late wood as in some junipers that are practically impossible to date. Then if the rings are numerous in the specimen, if they have high sensitivity, and if they belong to a favorable species, further work on the piece will be worthwhile and it must be carefully wrapped.

Place charcoal ring series on record at once

The next important thing is to date the specimen or at least place its ring series on record by a "skeleton count". This can be done on very irregular surfaces but it is vastly easier and more reliable if done on one continuous surface. This does not have to be flat or straight or strictly radial, but the continuity of rings needs to be traceable. There are two ways of getting something workable: (a) by a transverse break, often giving a slightly irregular surface of the highest brilliance on which high magnification may be used to see the complete cell structure, and (b) by a razor blade cut, which is slower and more easily made flat and more difficult to do successfully, there being always some gamble about the quality of surface that will be reached. In practice I use the fracture method first, if necessary chipping the surface with a bare razor blade held in the fingers. In this chipping the pressure should always be put along the rings transversely and very rarely across the rings radially. The fracture process however done leaves the specimen less changed than the razor cut and hence is to be recommended for first application.

Many pieces can be broken in two by taking advantage of some slight transverse crack. In very valuable pieces of course the chipping or breaking has to be reduced to a minimum.

Paraffin for razor cutting on charcoal

In preparing to make a razor blade cut, one recalls that soft and non-paraffined charcoal is very liable to crumble, as are certain kinds of very hard charcoal that give the impression of having stony deposits in them. It is much safer to dip the charcoal in a weak paraffin-gasoline solution. Often a long flat surface is obtained by sawing through the charcoal block with a fine hack-saw blade held in the bare fingers. Do not use a handle, for the touch is much more delicate without it. The cut must extend radially but with respect to the grain of the wood it is believed better to make it at a 35° angle and to dip the proposed surface in a weak paraffin-gasoline solution before applying the razor blade if it has not already been done. This surface may be cut directly with a sharp razor blade, always with the grain, as in surfacing the 35° cuts in wood. The skeleton count is then made with a X10 lens (or even a weaker one), preferably close to a large window that has no sunlight coming in. If there is sunlight, interpose a piece of tissue paper to diffuse the light. That simple arrangement is one of the very good ways of studying these rings. Similar use of tissue paper is made whenever this visual work is done with an electric light. Direct light from a concentrated source such as the sun or a strong electric desk light produces intense sparkles in irregular spots on the specimen and thus disturbs the view. The correct viewing of charcoal has to be done in diffused light.

Use diffused light on charcoal

Change of details in technique may be useful

In considering this review of some tree-ring techniques that have served well in the Southwest, mention should be made of the careful work of some of our students in other regions, work that depends more on the extensive use of the skeleton plot than does ours here. It may be that nature has greatly favored us here by climatic and topographic conditions that sometimes make almost supersensitive ring systems. Very probably other places will be found of similar type and fully successful work is being done in different climates, but we are not to infer from that that such work may not receive great assistance from some change of emphasis in the details of the techniques here described.