MAP OF TREE-RING AREAS KNOWN IN AMERICA

Tree-Ring Analysis and Dating in the Mississippi Drainage

By

FLORENCE HAWLEY 1906

Director of Laboratory of Dendrochronology, Department of Anthropology
University of Chicago

WITH APPENDED PAPERS

Reflection of Precipitation and Temperature in Tree Growth

MILDRED MOTT WEDEL *and* FLORENCE HAWLEY

A New Dendrochronograph

E. J. WORKMAN *and* FLORENCE HAWLEY

THE UNIVERSITY OF CHICAGO PRESS
CHICAGO · ILLINOIS

ACKNOWLEDGMENTS

In relating the story of tree-ring work in the Mississippi Drainage, the first acknowledgments must be to Dr. Fay-Cooper Cole, of the Department of Anthropology at the University of Chicago, and to Mr. Eli Lilly, of the Indiana Historical Society, whose vision of the possibility of obtaining exact dates for mound archaeology led to sponsoring and financing the large project. There could have been no success without the efforts of Donovan Senter, who explained dendrochronology and its needs to scientists, to business executives, to farmers, and to mountain men in the process of locating and collecting old wood and interesting possible contributors of wood. The names of some of the men whose aid has been of prime importance to the Chicago laboratory appear in this manuscript. Our gratitude belongs equally to many others who made their interest tangible by offering information, advice, and time.

The archaeologists and their field assistants who so carefully saved and shipped in fragile wood and charcoal specimens from their mound excavations have provided the actual material to be dated. Some of these men co-operated, as well, in obtaining log cabin specimens and sections of modern trees. Of the Chicago students who have put in patient hours of laboratory work, Mrs. Mildred Mott Wedel, whose work on the correlations of weather fluctuations and tree growth appears in this volume, and Messrs. Andrew Whiteford and William Mulloy especially have been an integral part of this project.

In describing instruments, techniques, and previous work of this kind, extensive use has been made of the various reports and of methods long employed at the Laboratory of Tree-Ring Research at the University of Arizona. Dr. A. E. Douglass, founder of the science of dendrochronology, and Mr. Edmund Schulman, both of the Arizona Laboratory; Mr. Harry T. Getty, of the Department of Anthropology, University of Arizona; and Mr. W. S. Stallings, of the Laboratory of Anthropology, Santa Fe, have generously co-operated in checking specimens, in advice of the project, and in criticism of this manuscript. Our deep appreciation of their long interest and aid is more than can be expressed in words.

The publication of this study has been made possible through funds provided by the Marian and Adolph Lichstern Foundation for Anthropology.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF ILLUSTRATIONS

CHAPTER I [1]

HISTORY OF STUDY

The study of tree-rings as a means of establishing exact chronologies in the mound-builder area of the Mississippi Drainage was begun in 1934, under the auspices of the University of Chicago, primarily as a development in archaeological method. Since that time, tree-ring analysis, which has revolutionized old concepts of prehistoric chronologies in the Southwest, has been carried on as a research project for application to similar dating problems and to movements of prehistoric Indians in the mound-builder area. A secondary interest has been such modern problems as the occurrence of past droughts and floods.

Before discussing in detail the work in the Mississippi area it is desirable that we trace the development of dendrochronology in general. Leonardo da Vinci,[2] four hundred years ago, seems to have been first to state that ring widths vary according to wet and dry years. In 1859 Mr. J. Keuchler measured oak rings and found that they varied in width according to annual variation in precipitation.[3] Others left records from time to time of their knowledge of counting the rings of a tree to discover its age, but no one of these visioned the concept of tree-ring analysis.

---

[1] This paper has been divided into sections so that the reader may readily refer to subjects in which he is interested. This scheme entails some repetition of data in various sections, but places related material together for use of students, busy professionals, and laymen.

[2] Dmitri Merejknowski, *The Romance of Leonardo da Vinci*, (Herbert Trench) trans., first printing, 2 vols.; London and New York; G. P. Putnam Son, 1902), chap. x.

[3] Cleveland Abbe, "Notes by the Editor," *Monthly Weather Review*, XXI (November, 1893), 331-32.

It was Keuchler's work in Gillespie County, Texas, that first developed the idea that the rings of a tree gave a record of weather changes, especially of water available for the roots. He measured and made charts of the rings of three post oaks growing upon high ground, identified the record of each in that of the others, and concluded that moisture was the main cause of variation in ring width. His investigations were not carried far and their interest is more historical than scientific.[4] In 1880 J. C. Kapteyn made a similar but more extensive study of the rings of oaks from a number of regions in Holland and Germany.[5]

Tree-ring work - dendrochronology - was begun in the Southwest in 1904 by Dr. A. E. Douglass, an astronomer interested at the time primarily in solar activity. According to theory, the activity of the sun increased periodically and affected the weather upon the earth by increase and decrease of storms. Working upon the hypothesis that this variation in weather should be reflected in the growth of trees, Douglass collected hundreds of specimens of pines from the Coconino National Forest near Flagstaff, Arizona. Cross-dating, matching the growth patterns of the modern trees upon themselves year by year, was accomplished experimentally in 1904,[6] but the full significance of cross-dating as a fundamental part of tree-ring work was not recognized until between 1911 and 1913.[7] Beams from Bonito and Aztec pueblos were collected by Wissler and Morris as experimental material for Douglass and perhaps with the idea that eventual dating might be possible. The chronology was carried back from modern times to A.D. 1400 on the records of living trees, but there was no suspicion that the records of prehistoric pueblo beams would match the records of the modern trees, for at this time the age of these ruins was variously estimated at from several hundred to several thousand years.

By matching the interior ring records of one group of trees on to the exterior ring record of earlier trees, and so extending the

---

[4] W. S. Stallings and Edmund Schulman, "Some Early Papers on Tree Rings," *Tree Ring Bulletin,* III, No. 4 (1937), 27-29.

[5] *Ibid.*

[6] A. E. Douglass, "Dating Pueblo Bonito and Other Ruins of the Southwest," *National Geographic Society Technical Papers* ("Pueblo Bonito Series," No. 1 (1935).

[7] A. E. Douglass, *Climatic Cycles and Tree Growth* (Carnegie Institute of Washington ("Carnegie Inst. Wash. Pub.," No. 289), Vol. I (1935).

total chart into the past for the number of years covered by the two groups of trees, Douglass extended the chart into the past far enough so that it actually picked up the records of the prehistoric specimens; but the great drought between A. D. 1276 and 1299 was drastic enough in its effect upon southwestern trees so that many of them missed rings and made the sequence insecure.[8] Douglass suspected that he actually had an overlap between the prehistoric specimens and his main chronology. Without the certainty of many good records covering this period of overlap, however, he preferred to speak of a "gap" which separated the two groups, for he himself could not be sure that his cross-identification was accurate. It was not until 1929, after some excellent charcoal beam material had been collected by E. W. Haury from an ancient pueblo underlying a yard in the town of Showlow, Arizona, that Douglass was sure that the gap actually was closed and that, as a matter of fact, it had never existed. Thirty pueblos were given actual dates, the first ever obtained on ruins for which no written records of any sort were available, and southwestern archaeologists took up the idea of tree-rings as a more specific aid to chronology than anything hitherto developed. These prehistoric dates came seventeen years after Douglass began to cross-date trees although they were not certified and published until twenty-five years after the initial work. Since that time archaeological interest and tree-ring analysis have constantly increased.

Later this period of the great drought, A.D. 1276 to 1299, was crossed by a large number of other specimens so that there was no question concerning the validity of the period represented by the Showlow beam.

When the central pueblo pine chart had been carried back to A.D. 700, necessity arose of filling another gap between that period and a period represented by a number of cross-dated archaeological specimens collected by Earl Morris in the Chinle region. Actual dates on those archaeological specimens were held up until August, 1934. The first intimation of the true dating appeared when a log from a kiva at Chetro Ketl in Chaco Canyon, New Mexico, was recovered by Florence Hawley in 1931 and was taken to the laboratory for study. This fine specimen was dated by her, and the

---

[8] A. E. Douglass, "The Central Pueblo Chronology," *Tree Ring Bulletin,* II, No. 5 (1936), 29-33.

interior was found to extend back to A. D. 643. In January, 1932, Douglass suspected that this bridged the gap which tied in the other previously floating chronology of the archaeologic specimens of unknown date. But this dating was not announced until confirmed by several specimens from Allentown, Arizona, examined in August, 1934. After one other gap near A. D. 500 was crossed, the total record was taken back to A. D. 11. At present another series of southwestern archaeological specimens has been cross-dated but cannot be matched onto the master-chart, indicating that there is the possibility of yet another gap to be crossed. All that can be said about the actual date of any set of specimens which cannot be matched into a master-chart is that they must antedate the earliest period represented by that chart. Whether they antedate the chart by a few years or by some centuries it is impossible to say until the gap has been crossed.

Working out the Rio Grande chronology was a distinctive part of the picture both because separate attack was required and because the chronology was carried back from living trees within the area independently.[8] Similarities and differences between the Rio Grande chronology and that of the Pueblo area, as well as transitional ring features, were determined after this independent development of the Rio Grande sequence.

After southwestern ruins previously estimated as from a few hundred to several thousand years old had been placed in definite chronologies, and their actual building dates obtained, the effects of drought and of soil denudation as a cause of abandonment were studied.

Studying climatic chronology from the trees of a humid zone is a different matter from studying it in trees of forests that border the western deserts. Extension of tree-ring dating to archaeological problems in areas outside the Southwest was contemplated periodically, but it seemed that the abundance of rain and the temperate climate in such places as the Mississippi Drainage would provide constantly excellent growing conditions, and that a tree's growth year by year would be approximately equal except for other effective growth factors, such as age. Although most species grow

---

[8] W. S. Stallings, "A Tree-Ring Chronology for the Rio Grande Drainage in Northern New Mexico," *Proceedings of the National Academy of Sciences*, Vol. X, No. 9 (Washington, 1933).

faster when young than when old, some pass their youth shadowed by other trees which restrict the amount of sunlight needed for photosynthesis, and this limits the annual growth increment. These variations must be considered by dendrochronologists, but it is the difference between widths of individual rings caused by some determinate factor of weather variation which gives the patterns necessary for tree-ring dating.

From 1923 Keen had been working on the study of droughts as indicated by pine rings in the dry area of Klamath Falls in eastern Oregon with the object of discovering whether the present "trend toward dryness and retreat of the forest was to continue over any long period of time or was merely a short cycle in a variable climate which would soon reverse the trend and give some hope for forest perpetuation in threatened sites." Tree insect pests are particularly troublesome in dry periods, and the Bureau of Entymology of the United States Department of Agriculture hoped that it could find indications of past recurrent droughts so that they might anticipate future droughts, which would aid man in the control of the pests. The outcome of this study from a district which, like that of the southwestern tree-ring studies, bordered on desert country, indicated that the drought of the modern period represented a major fluctuation in a broad climatic cycle, but that the exact prediction as to the time of reversal in trend could not be made. From a series of 1,240 modern pines, of which the oldest good specimen was 710 years of age, Keen drew up a chart of ring widths and climatic cycles carrying back to A.D. 1268. In 1936 Hardman and Reil, working in the same general area, published the record of 685 growth rings in a ponderosa pine from the Truckee River Basin.

Trees have been tested and cross-dating has been done in moist areas, but difficulties were anticipated not because the trees were insensitive to weather changes but because the interaction of the diverse growth factors was anticipated to be more complicated than in a dry climate.

Keen[9] had experimented with Douglas firs in the moist zone west of the Cascades with no satisfactory results and was inclined to think that work in the Mississippi or in other moist areas would be too hampered by excess precipitation and by lack of very old

---

[9]F. P. Keen, "Climatic Cycles in Eastern Oregon as Indicated by Tree Rings," *Monthly Weather Review*, LXV (May, 1937), 175-88.

trees to produce information useful for archaeology or for weather studies. "Radial growth of trees," as Keen says, "is so dependent upon local conditions, tree dominance, age of tree, position in stand, occurrence of fires, or insect defoliations, that, until these influences are eliminated through comparing large numbers of samples over a wide area, the effect of climate, principally precipitation, does not appear."

The ring patterns upon which southwestern dendrochronological study depends are the result primarily of the trees' reactions to wet and to dry years or to annual average temperature changes which are relatively consistent over a large area. In the Southwest, and in other relatively dry areas, precipitation provides a limiting and apparently the most decisive factor in tree growth; in the North and in high altitudes, temperature is a limiting factor. In areas with considerable rainfall and with a temperate climate, the combination of the two affects the trees. Contrary to the situation in the Southwest, in the Mississippi Drainage the deviation from the norm of actual precipitation appears to be more important to plant growth than the actual amount of precipitation in inches, and the effect of the precipitation is limited and varied, especially by winds and by heat, which cause evaporation.

Dr. Douglass already had tried cross-dating in trees of England, of the Scandanavian Peninsula, of northern Germany, of Bohemia, of Pennsylvania, of California, Colorado, Idaho, Oregon, New Mexico, of New England, and of the Ozark Mountains of Missouri. He found that in these areas certain species, at least, did reflect weather changes because the pattern made by the annual ring record of one tree could be identified in the records of other individuals of the same species growing at the same time. This situation, requisite to tree-ring analysis, indicated that tree-ring studies need not be confined merely to dry areas.

Lyon,[10] using hemlock in New England studies, supplemented Douglass's experiments there and drew up a master-chart of ring growth which he compared in its unusually large and in its very narrow rings to old records of bountiful crops and of crop failures in early centuries of Vermont farm life. His work indicated a very

---

[10]Charles Lyon, Jr., "Objectives and Methods in New England Tree Ring Studies," *Tree Ring Bulletin*, V. No. 4 (1939), 27–30.
"Tree Ring Width as an Index of Physiological Dryness in New England," *Ecology*, XVII (1936), 457–58.

close relationship between crop growth and tree growth in that area which, considering that both are dependent upon the same factors of weather variations, is what one reasonably should expect.

Robbins[11] made successful tests of cross-dating on sixteen oak stumps which had grown on rolling land near Columbia, Missouri, and found that the relative ring widths reflected precipitation variations. A number of short articles on the pros and cons of reactions of various species to weather fluctuations had been published for other parts of the Mississippi Drainage, of the eastern stages, and of Florida. Correlation of tree growth with precipitation and temperature for parts of a year were made by Rogue, Stewart, Brown, Pearson, and Lodewick.[12] Their results were suggestive; but most of the deductions had been made on the basis of too little data or of too unusual circumstances to offer definite conclusions of the practicability of using those species for tree-ring analysis in these areas. O. D. Diller, of the Central States Forestry Division, reviewed these many brief publications, indicated their legitimate points and their fallacies, and published the results of his own studies of the rings of seventy beech trees growing in seven woodlands in the northern half of Indiana.

It was not until 1934, when farmers were complaining of a drought throughout the central states and crops were drying in the fields, that tree-ring dating in that part of the United States was seriously contemplated. It was apparent that in spite of what seemed, by southwestern standards, to be a considerable annual precipitation even during this drought period, the leaves of trees were drying, and many trees were actually dying just as the crops were dying for lack of water.

This observation led to examination of farmers' woodpiles around Chicago. The logs showed small rings for 1930 and 1932 and for preceding years, such as 1913 and 1914, when that area had previously suffered from lack of rainfall. This left no question but what trees even in a moist climate suffer from a drop in annual precipitation and runoff.

With these observations as a basis, Dr. Fay-Cooper Cole, of the Department of Anthropology at the University of Chicago, de-

---

[11] William J. Robbins, "Precipitation and Growth of Oaks at Columbus, Missouri," *Univ. Mo. Agric. Exp. Sta. Res. Bull. 44*, (1921).

[12] Oliver D. Diller, "The Relation of Temperature and Precipitation to the Growth of Beech in Northern Indiana, *Ecology*, XVI (1935), 72-81.

cided to sponsor some preliminary field work in dendrochronology, to determine whether it seemed possible to construct charts of midwestern trees extending into the past far enough to match the ring records of charcoal and of semi-decayed beams found in ancient Indian mounds. A number of major problems, different from those in the Southwest, had to be met *(see p. 74)*.

If solving these problems appeared to be practical after general reconnaissance, Dr. Cole proposed obtaining sponsorship for a tree-ring project, primarily to date the mounds and secondarily to study ancient weather conditions throughout the Mississippi Drainage and wherever else the tree-ring trail might lead. The plan called for co-operation of the various institutions excavating in the area so that their wood material could be saved and sent to the laboratory in Chicago to be dated as soon as charts of the various species were worked out. Hampered by the lack of stratigraphy in most of the mound sites and with little data from which to place cultures even in a relative chronology, archaeologists of other parts of the United States had been looking enviously at the increasing number of exact dates which covered many of the southwestern pueblos and which sometimes indicated even the season of the year at which the trees had been cut to be made into building material.

The plan was presented to the assembled archaeologists of the central and southern states at the joint meeting of the Central Section of the American Anthropological Association and of Section H of the American Association for the Advancement of Science. General interest was shown, and co-operation was offered by many institutions represented. Arrangements were made for Florence Hawley to go into the field with Roy Lassetter as assistant for the first summer session. Many suggestions were made for locating wood in various parts of the area, and collections of existent mound wood were offered. A few weeks later, Dr. Carl Guthe, of the University of Michigan, sent out a bulletin announcing the project to archaeologists all over the United States and asking for aid in the location of virgin timber tracts and in preservation of wood specimens taken from any mounds being excavated in the Central States, in the East, and in the Southeast. In answer many workers offered their co-operation. Major William Webb, director of the anthropology department at the University of Kentucky and in charge of the archaeological excavations carried on for the T.V.A. in the Norris Basin, wrote to suggest that the work be initiated in the area to be covered by Norris Lake, as all standing timber was being cut. This permitted the collection of specimens from a number of different species of trees. Moreover, settlements in that district were known to have been made earlier than in most other regions of the South and of the Middle West, and the log cabins of the pioneers still stood, for the most part inhabited. From these it was hoped to obtain cross-sections of timbers which might extend the modern chronology into the past.

First Season: 1934-35

As the T.V.A.'s program of land clearing offered unusual opportunity for opening our program, Major Webb's invitation was accepted and the party left for La Follette, Tennessee. Ten days were spent there in the collection and examination of specimens. Cross-dating, the basis of dendrochronology, was at once apparent, and arrangements were made for Mr. Clarence Prosise to act as field man in the collection of several hundred specimens of modern wood. Instructions were given regarding preservation of the partially decayed wood being taken from postholes, from the steps of ancient mound structures, and from grave coverings.

The remaining four weeks of the season were spent in collecting and studying oaks around Wicliffe and Paducah in Kentucky and Cairo in Illinois, an area where the University of Chicago was interested in dating the mounds being excavated.

Several hundred specimens of oaks were taken, principally V-cuts from stumps. In this area oak stumps remain sound on an average of about five years after cutting before heart rot eats away the center. The ring record of these oaks from western Kentucky was found to match those from eastern Tennessee with but minor regional variations, so that at once it was known that a single tree-ring area encompassed both districts. Visual comparison of weather records obtained from the station of the United States Weather Bureau located at Cairo indicated that the ring record of the trees was related to the precipitation record, which meant that an approximation of the precipitation for the past could be computed from a correlation between tree growth and precipitation records of the present.

Becoming interested in the possibility of obtaining information on floods and droughts in the distant past, the T.V.A. agreed to sponsor a project of studying modern cedar and pine rings in the Norris Basin on a part-time basis during the remainder of 1934 and during the summer of 1935. The project was to be directed by Hawley, working at the University of New Mexico (where she was under contract), and the cedar and oak specimens were to be studied there. Lassetter went to Knoxville to work on pine studies and to oversee field collections.

While a number of different species of trees - pines, oaks, junipers, hickory, elm, maple, and cucumber - were found to carry records of some sensitivity, the best records were located in those trees which likewise carried the longest sequences. The white oak *(Quercus alba)*, the eastern red cedar *(J. virgiana)*, and the southern white cedar *(Chamaecyparis thyoides)* produce records sensitive to annual precipitation changes and yet grow slowly enough to provide long ring sequences. The best of the pines show sensitive records sometimes extending back two hundred years or slightly more. Moreover, oaks, red cedars, and pines are the three species of wood most commonly found as charcoal or as partially decayed posts, grave coverings, and step facings in the mounds. During 1934 and 1935 the study concentrated chiefly upon junipers and pines.

Junipers, especially the *pachyphloeas*, have been found useful only occasionally for southwestern dating, as their habitat of poor soil and relatively low altitude, about 4,000 feet, gives their records a tendency to be erratic and confused with frequent false rings. Moreover, lobed growth of the trunk, so common in this tree, causes irregularity in circuit uniformity of many specimens. As the yellow pine *(P. ponderosa)* and Douglas fir *(Pseudotsuga taxifolia)* growing in a higher altitude and providing records much better for tree ring analysis, were primarily used for beams of the ancient pueblos, pine and Douglas fir were taken as the foundation of the tree-ring studies for the southwestern pueblo area. The pinon, a close relative of the pine, was also largely used. Jessup[13], however, found a high degree of cross-dating in four junipers of the Harney Basin in Oregon and a high correlation of its mean growth curve with the curve of precipitation.

In the southeastern part of the United States, the junipers

---

[13] L. T. Jessup, "Precipitation and Tree Growth in the Harney Basin, Oregon," *Geographic Review*, XXV, No. 2 (1935), 310-12.

grow at lower altitudes and in a climate much more humid than in the Southwest. The most common species is the *J. Virginiana*, but some of the northern white cedar *(Thuya occidentalis)* is found in the damper locations. Ring records of both are sensitive to annual precipitation fluctuations but much less erratic than those of western specimens. Nevertheless, the rings of southern cedars are considerably more difficult and slower to read than are those of the southern pines and oaks.

Approximately five hundred specimens of various woods were collected from modern trees and from mounds of Eastern Tennessee during this first period of work for the University of Chicago and for the T.V.A. Of these, five modern cedar specimens carried records old enough to extend the tentative master-chart back to A.D. 1321. But it was apparent that more specimens of old cedars must be collected to certify cross-dating beyond question before this chart could be used. During this first season pine and oak records were taken back approximately to A.D. 1700.

Specifically for the interests of the T.V.A. in finding the dependence of tree growth upon precipitation in this humid area, and in computing approximate precipitation and runoff for the past from tree-rings of that period, modern pine and cedar growth were correlated with modern precipitation and runoff records of the Clinch and Powell rivers.[14]

The cedars of eastern Tennessee are dependent upon precipitation only to a slightly lesser extent than the pines in Arizona. The opportunity of studying past weather fluctuations through tree-rings of the past was apparent. In a letter regarding the Norris Basin data, Dr. Douglass states: "Let me add that you have another very important line started, namely, the climatic chronology. . . . If those curves in which you obtain a relation between cedar trees and the precipitation are good, then you have available in your long ring records some very important material on climate."

SECOND SEASON: 1937-38

In 1937, supported by the Indiana Historical Society, the University of Chicago laboratory resumed sponsorship of the study of tree-rings in the Mississippi Drainage on the basis of a three-

---

[14]Florence Hawley, "Relationship of Southern Cedar Growth to Precipitation and Run-Off," *Ecology*, XVIII, No. 3 (1937), 403.

year project. The first year's work was to cover twelve months, from June 1937, to June 1938; during the second and the third years, the work was to cover the periods between February and July, two six-month periods. The field party of 1937, consisting of Florence Hawley (Senter) and Donovan Senter, planned a wide survey of cross-dating in Wisconsin, western Minnesota, Illinois, Indiana, Ohio, Kentucky, Tennessee, and Missouri.

On this first quick circuit of Wisconsin, foresters, lumbermen, Indian agents, ecologists, officials of paper mills, men of the Forest Products Laboratory and of the Milwaukee Public Museum, and chance acquaintances were questioned for information on the location of stands of old timber and even of individual large logs. Increment borings were collected wherever possible and crates of cross-sections were shipped back to the laboratory. A few cores were taken from pines in eastern Minnesota north of Duluth on the Canadian border. Mr. Gordon Eckholm, of St. Paul, Minnesota, offered a group of twenty-eight increment borings of pines he had taken in western Wisconsin and on the Minnesota border. Mr. Mead and other officials of the Consolidated Power and Paper Company of Wisconsin Rapids arranged to have forty-five cross-sections of the largest hemlock logs from the mill-yard sent to the Chicago laboratory for study. These averaged between two and three feet in diameter. The hemlock, a tree with soft wood, grows slowly in youth, and good specimens give considerably longer ring records than those of any of the pines found through this northern area.

The Milwaukee Public Museum, through Dr. Frank Fuller and Mr. W. C. McKern, co-operated in suggesting possibilities of locating old trees, in locating old building and bridge timbers, and in preserving and collecting wood taken from mound sites in past excavations. Mr. George Lidburg, at the request of Dr. Ralph Linton, then of the department of anthropology at the University of Wisconsin, made a survey of historical records giving locations of buildings and bridges which should provide old beams. Old mill dams from which logs might be obtained when the dams were demolished were located. Unfortunately, in this first field work in Wisconsin there was no time to collect most of the historical material - a task which must be a part of future dendrochronological exploration.

The rest of this three-and-a-half month field season was spent in locating sites of old timber and in investigating structures which promised old logs in the Central area: Illinois, Kentucky, Tennessee, southeastern Missouri, Indiana, and to a small extent Ohio and Michigan. Where timber has been cut and recut for several hundred years, it is almost impossible to find virgin stands or even old trees of second growth. The best finds of the season came after Mr. Henry Hamilton of Marshall, Missouri, called attention to a tree cut for exhibit at the Missouri State Fair. It was one of the largest logs seen in the central states and contained three hundred rings showing a good record of weather variations. This tree had been taken from Shannon County in the southeastern part of the state - rough, mountainous country sparsely inhabited and only recently being cut over by lumber companies. It was not until the end of the season that the field party had the opportunity of getting into this limestone area with its steep slopes, poor roads, and few towns, but there it found by far the best stand of virgin timber located during the season of 1937 or since. The local lumbermen were interested in the project, especially in eventually obtaining information on past weather and growth conditions in that section. They offered every opportunity to collect the finest oak and pine specimens available at the time. During the fall, Mr. Ed Johnson, of Brushy, Missouri, sent the laboratory at Chicago a large collection of excellent pine and oak sections, including several with records of over two centuries, some of the oldest yet obtained in the Central area.

In Fulton County, Illinois, Dr. Don Dickson and Mr. Ernest Dickson aided in the location and collection of oak wood from stumps and barns. Mr. Rube Mitchell and Mr. Harry Rudy helped in taking V-cuts from oak stumps on their land just south of the tip of Illinois in Tennessee. In Indiana, Mr. Charles H. Barnaby, Mr. Eli Lilly, Mr. J. S. Wright, and Mr. Glenn Black made a number of collections of wood which were sent to the laboratory. The summer's field work included a scattered sampling of specimens from southern and central Indiana.

In Kentucky, sections of logs from old slave quarters of the historical Cross Keys Tavern were donated, and elsewhere through Kentucky and Tennessee arrangements were made for end cuts of logs in old barns and cabins.

Mr. H. S. Shetrone and Mr. Richard Morgan of Columbus, Ohio, offered suggestions on location of log cabins in their state and sent in sections after the close of the field season.

Mr. Ralph K. Day, director of the Central States Forestry Station, provided us with notes on the location of a number of old timber tracts in the area over which he is in charge and which fortunately chanced to coincide with the area in which the University of Chicago is interested. Mr. Day sent notices to his field men to supply us with data regarding all old individual trees or small groups of old trees concerning which they might have information.

By the end of this field season, it was apparent that the Central tree-ring area extended from the Appalachian Mountains of eastern Tennessee as far west as eastern Missouri and from Northern Illinois south to northern Arkansas.

Field work was concluded in September, and on October 1, 1937, a permanent laboratory was set up at the University of Chicago.

The wood specimens were separated in boxes so that the best, the second best, and the poor groups were kept together. The best specimens were studied first, the second best next, and the poor ones were used only if specially needed. When study of specimens in a box had been completed, the box was so marked. After all the specimens from an area had been studied, the finest were selected and were put aside as giving representative records for that area. Later, type specimens to be measured were taken from this group.

Students interested in the study of dendrochronology came to the laboratory twice a week to be given lectures on the subject and to work on the simpler of the specimens. During this first season, student work was concentrated especially on large cross-sections of Wisconsin hemlock which had been donated by the Consolidated Power and Paper Company. All of these were cross-dated and charted. The charts were compared and an average of the group, year by year, was taken as material for a master-chart representing Wisconsin hemlocks. This chart extended back to the middle of the sixteenth century.

All the pines and oaks, modern and from log cabins in the Central area, were studied by Hawley and individual skeleton plots made. A master-chart for oaks was drawn up from 1600 to the present and one for pines from 1725 to the present.

In the latter part of November, 1937, an invitation came from the Indianapolis Historical Society to talk to the members on the subject of tree-ring work. Material presented for this discussion was later worked up for publication in the *Proceedings of the Nine-*

teenth Annual Indiana History Conference.[15]

The bulletin was widely distributed to professionals and to interested laymen, many of whom sent in small wood collections and suggestions of the location of individual big trees and of isolated patches of old trees hitherto unknown to the laboratory.

The work was discussed with anthropologists at the New Haven meeting of the American Association for the Advancement of Science, and a second detailed talk on the subject was given at the Indianapolis meeting of the Central Division of the American Association for the Advancement of Science, December 30, 1937.

A new use for dendrochronology was suggested by Commander E. F. McDonald, who for some years had been trying to trace the remains of LaSalle's ship, the "Griffin," thought to have been built near Niagara Falls in New York in 1667. Analysis of the metal of the bolts holding some of the timbers together in a wreck found on the beach of Manitoulin Island in Lake Huron proved them to be of old European make. If the timbers could be dated and found to fall into the approximate period preceding 1667, the supposition that this was the wreck would be further substantiated. The timbers submitted to the Chicago laboratory were of oak. Commander McDonald sent Mr. George Fox to Niagara Falls to collect wood from modern oaks and from historic sites. Unfortunately, oaks are scarce in that district at present, and the master-chart has not been extended beyond A. D. 1700.

In the spring, it was decided to attempt the first actual dating of cabins by use of oak wood, and cross-sections taken from a Kentucky cabin of unknown building date were cross-dated between themselves and then laid against the master-chart in an attempt to find their actual cutting date. The two best specimens contained approximately one hundred rings apiece. Matched against these was a cross-section from an ash log taken from the same cabin. After a couple of days of work, the three specimens were slipped into place in the central oak master-chart, and the date 1880 ascertained. This, as far as is known, is the first actual oak dating done anywhere, and certainly the first in the Mississippi Drainage. It proved that dating by oak wood was an accomplished fact rather than

---

[15]Florence Hawley Senter, "Dendrochronology: Can We Fix Prehistoric Dates in the Middle West by Tree Rings?" *Indiana History Bulletin*, Vol. XVI, No. 2 (1938).

a mere hope. If log cabins could be dated by use of oak logs, mounds could equally well be dated by use of oak wood as soon as the master-chart is carried back sufficiently to pick up their record. The discovery that ash carries a sensitive clear record and cross-dates with oak was as gratifying as it had hitherto been unexpected.

In the latter part of May, Dr. Douglass, founder of the science of tree-ring analysis, visited the Chicago laboratory and examined the best specimens from both North and Central areas. He checked the cross-dating and the master-charts which had been constructed and verified the actual dating of the log cabin specimens mentioned above.

THIRD SEASON: 1938-39

Field work for 1938 covered two months of travel in the Central area. Immediately upon leaving Chicago, the Hawley-Senter field party went to Oregon in northern Illinois, where pine cores were collected in the White Pines State Park. The next stop was the Starved Rock State Park near La Salle, Illinois, and in this second park more cores were collected. From here the party turned southward. After two weeks concentration upon collection of cabin specimens around Charleston, Tennessee, a reconnaissance was made of northern Georgia, northern South Carolina, and from northern Illinois south through central Missouri west across Arkansas into the Ouachita Mountains and westward through Oklahoma. On all the latter part of this trip, increment borings, V-cuts, and pencil rubbings of trees, stumps, and fence posts were taken every fifty miles. Approximately one hundred of the pencil rubbings were made; they were found to be very useful for regional studies when there was no time to make actual wood collections.

Mr. Clarence Prosise was employed for one month as field man, especially to make borings and V-cuts from old cedars of eastern Tennessee for use in substantiating the master-chart made in 1934-35. Besides the cedars, Mr. Prosise sent in fourteen hemlock cores from the Smoky Mountains; these borings later became the basis of a southern hemlock chart.

The laboratory work for the second season covered the period from February to June, 1939, supplemented by extra work on the best specimens while the author was teaching at the University of New

Mexico during the fall semester of 1938. Cross-dating of the pine and oak material collected during the summer of 1938 extended the Central area as far west as Oklahoma City and as far south as northern Georgia and South Carolina, but during the period of laboratory work in the spring of 1939, Mr. Gordon Willey had lent pine borings from near Macon, Georgia, and Mr. William Mulloy had collected pine V-cuts from near Jena, Louisiana, the cross-dating of which indicated that the Central area extended even farther southward than hitherto had been supposed. The Central area as known by the spring of 1939 covered the territory from north to south between northern Illinois and Indiana and central Georgia and Louisiana, and extended from east to west between the Appalachian Mountains and Oklahoma City *(see Frontispiece)*. It is probable that later field work beyond these present-known limits will extend the area at least a little to the east and to the south. The one master-chart for each type of tree studied in this large area is representative of the entire area, with the exception of small local variations covered by local charts.

From the pine material sent in by Mr. Delaney from the Menomenee Indian Reservation, Wisconsin, a northern pine chart was constructed extending from 1668 to 1939. This chart, as had been expected previously, did not check the hemlock chart for the same area. A southern hemlock chart was constructed by the students of dendrochronological work in 1939, the material having been collected from the Smoky Mountains during the preceding summer's field work. In this district, as well as in the North, the hemlock record does not match that of the pines.

During this season the southern pine chart was carried a few years further into the past, reaching 1700, and the oak chart was extended to A. D. 1536.

With the pine and oak charts carried back far enough for archaeologists to suspect that the latest mound material might possibly fall into their period, the first detailed work on mound charcoal was begun. Several hundred specimens were examined. They comprised all the material sent in by T. M. N. Lewis from the Charleston district of Tennessee and by Jesse Jennings and Charles Fairbanks from the Okmulgee National Monument of Macon, Georgia, and by W. C. McKern from Aztlan and from the Rice Lake Mounds of Wisconsin. The useless, the fairly good, and the fine specimens were separated into groups for each species represented, and the best specimens were cross-dated with each other and charted. It was necessary to treat much of the best charcoal with bakelite-acetone solution before the surface could be cut for study *(see "Method and Technique")*.

The first work was concentrated on the coniferous species. The results were cross-dating of a group of fine sensitive prehistoric pine specimens from Macon, Georgia, cross-dating of a group of pine specimens from the mounds near Charleston, Tennessee, and charting of two good tamarack specimens from southern Wisconsin.

Dr. Duncan Strong, of Columbia University, sent in a group of mound specimens of popular wood from his Nebraska site. Lacking any records of modern poplar growth for that district, it was impossible to attempt dating them at present, but their sensitivity offered promise for the future.

The cross-dating of mound specimens 4 MN 3, DS 1 and 4 MN 3, DS 2 was checked by Dr. Douglass. The problem of actual dating of the historic and of mound specimens from near Charleston was found to be more difficult than first anticipated because of the tendency toward individual variation in trees growing in the lower forest border of the foothills and the lack of old living pine trees in this area. It was interesting to see that while the young modern trees showed too little consistenty of record to allow cross-dating, the older specimens taken from log cabins and from mounds in the area showed a great deal more consistency. This suggested less local variation in weather conditions in the past or that considerable modern cutting had varied the conditions of tree growth in the district to such an extent that the reactions of the trees to given weather conditions is now highly individual.

During 1938, a tree-ring machine was designed and constructed by Dr. Jack Workman, director of the physics department of the University of New Mexico, for use in the Chicago laboratory. This machine differs from measuring machines being used in other tree-ring laboratories at present in that the carriage is moved by a lever rather than by a screw and that it is equipped with a self-plotting device which produces a curve representing the actual measurements of the ring widths. This device reduces the time required for making up master-charts of tree growth by at least 25 per cent. A detailed description of the machine will be found in a supplement to this paper.

For the publication of representative ring growth of pines and oaks in the Central area, in connection with publication of the master-charts, Mrs. Mildred Mott Wedel measured fifteen oak and twenty-three pine specimens, standardized the curves, and computed averages representative of indices of ring growth year by year for the two species during the period covered. The specimens measured were selected for their long sensitive and nonerratic records, representing healthy trees. They had been previously cross-dated with hundreds of other specimens from the same area and hence could be considered as type examples for this area. Photographs were taken of the best specimens measured and are here published.

From these ring charts and measurements, studies of droughts of the past, as indicated by groups of small rings, were made. Long series of years dryer than the average in southeastern Missouri from 1793 back to 1780, and from 1745 back to 1725. Near Charleston, Tennessee, droughts were found in the period from 1894 to 1899, from 1822 to 1828, from 1810 to 1813, from 1763 to 1774, from 1747 to 1756, and from 1718 to 1740. The period from 1720 to 1748 was the most erratic and the longest dry period of the series, different groups of years within this series showing the worst effects in different districts. These droughts do not show up with equal intensity for each district in each year, but those which seem to have been the most exaggerated near Charleston are the two earliest. It is this record of prehistoric droughts which may provide archaeologists working within the area with leads on old Indian migrations and possible tribal contacts.

Fourth Season: 1939-40.

The two months of field work in 1939, the last field season under the original contract. was divided between a brief investigation on the eastern periphery of the Central area and further concentrated work in Central Tennessee, where the mound specimens appeared to offer the best opportunity for dates in the near future.

From Chicago the field party started eastward to collect increment borings of pines, hemlocks, and maples from the provinces of Ontario and Quebec in southern Canada, where that country dips southward between Lakes Huron, Erie, and Ontario. Maple and oak specimens were taken from near Niagara, New York, and pine borings were taken from that point eastward through New York and northward through Massachusetts and Vermont to Dartmouth. There Mr. Charles

Lyon, who had done considerable previous work on New England forest growth and its comparison to former farm-crop yields, was studying trees blown down in the great tornado of 1938. Increment borings were made in the Harvard Forest near Petersham, Massachusetts.

Turning southward on the eastern edge of the Appalachians, the field party took samples on Highway 1 between Washington and Knoxville, Tennessee. From this point, Mr. Senter worked out to make collections near Charleston and farther west in the Black Mountain region, Tennessee, from which Mr. Andy Elmore agreed to send collections of oak and pine during the fall and winter. Mr. Jack Carlander drove southward from Knoxville through Athens to Macon, Georgia, to collection borings and to arrange for collections of mound and log cabin specimens.

Laboratory work for this season is planned to cover study of the modern and log cabin collections and to proceed with further work on mound specimens.

CHAPTER II

METHOD AND TECHNIQUE

Field Collection

In traveling over the country in search of old stands of timber or of old structures which might contain useful logs, the prime requisite for making the most of one's time and field funds is getting the interest of the local people. The initial work was begun with the idea that one could go into an area and make collections from forests, wood lots, and stump land by merely locating the material, taking cores, and hiring one or more laborers to assist with taking V-cuts. The difficulty with this procedure was that it was necessarily very slow, and that the money required in salaries, hotel bills, and car expenses while one searched for the right locations and worked with the laborers in taking specimens quickly amounted to a considerable sum. After the first field season, the situation became even more difficult because good locations for work were increasingly elusive.

In 1937 a new system was tried. Local people encountered in restaurants, hotels, drugstores, and on farms were asked about the locations of old timber and log cabins in their districts. Data were collected on the location of small sawmills and of larger lumber companies and of the stands being cut by them. Owners and workmen were visited. The aims and general procedure of tree-ring work in the Mississippi Drainage were explained. Most of these men were very willing to cooperate in obtaining material which would further science and wanted to know as much as possible about tree-ring analysis. The men were usually more interested in the climatic side of the study than in the archaeological side, the lumbermen being concerned about the rate of growth of their trees, about the age of their oldest trees, and about the relationship of growth, precipitation, and runoff. The farmers were particularly interested in the confirmation of small rings which indicated dry years during the period when they could remember droughts and crop failures. Many of the men previously had counted rings to discover the age of stumps, but the association of small rings and droughts had not occurred to them. Men who owned or lived in log structures or even in houses with old beams were invariably interested in the exact age of these places. After their interest had been gained, most of them were glad to help in cutting specimens from the ends of logs or of beams in the old buildings.

The quickest and some of the best collections of oak specimens have come from the waste piles of small stave mills which do not burn slabs in their engines. The logs brought into these mills are put into an equalizer which cuts a slice off one end to bring the log to a specified size. The cross-sections thus removed are ideal for tree-ring work and can be purchased at a few cents per hundred pounds. The pieces with the longest records are selected by the field worker and arrangements are made with the foremen and with the block boys, who tend the equalizer, to save and ship to the Chicago laboratory cross-sections from large logs which may be brought to the mill in future shipments. When full cross-sections are not necessary or desired, radial wedges may be chopped out with a blow or two of a small hatchet. This minimizes weight. The specimens are put into gunny sacks or, when more fragile, into boxes, and are shipped by freight c.o.d. to the Chicago laboratory. The only disadvantage of this procedure is that the exact location from which a specimen comes cannot be ascertained, but the mill men always know at least the approximate area being cut over at the time, a section usually within a fifty mile radius of the mill. The tree-ring areas have been found to be so large that this approximation of location is close enough for all the work except that of special botanical and ecological interest in giving the exact reaction of a tree to its surroundings. Such studies have to be limited to specimens individually collected, but since the major interest of the laboratory so far has been cross-dating trees and extending charts, the data regarding geography and location within the fifty mile radius has been sufficient.

Unfortunately for tree-ring interests, larger mills have their logs brought to them already cut in an exact length and these logs, not being intended for barrel staves, are cut into boards with no opportunity for the dendrochronologist to obtain cross-sections or even borings from them. Under these conditions, the mill men can sometimes be interested in arranging for some of their cutters to take V-cuts from freshly cut stumps.

Many of the log cabins and barns in the South are being torn down and rebuilt. Cross-sections from ends of the logs are easy to obtain and most of the owners have been found willing to take a small sum for their labor in cutting such sections and shipping them. Where the cabins are inhabited, it is often possible, if the owners can be interested, to cut half-sections or V-cuts from the ends of logs at the corners of the structures or even where a door or a window casing may be removed temporarily. Such casings, of course, are put back into place before the workers leave. The prices asked by the men for their labor in this work have always been those of the local labor rate and not exorbitant.

Implements: saws and borers.-- In studying the growth rate of modern conifers and even of hardwoods, the Forestry Service uses the Swedish Increment Borer, an instrument devised for taking cores from living trees without injuring them, (see Pl. 1). This instrument consists of a hollow tube with a screw end, a crossbar handle by which the tube is screwed into the tree, and an extractor by which the core is removed from the interior of the tube before the borer is screwed out of the tree. These implements are made in several sizes of which two are commonly used by dendrochronologists, one twelve and one fifteen inches long. They may be had in two diameters, one-eighth and three-sixteenth inches, respectively. The Chicago laboratory uses the latter. The foresters usually take cores only an inch or so long, including the outer growth of the tree, but for dendrochronology one should have a core extending from the outermost rings to those at the center. Douglass and those he has trained have used the Swedish Increment Borer extensively in collecting wood from conifers, but the tip of the borer is likely to be chipped in going into the tough heart wood of oaks and of other hardwood trees.

The Chicago laboratory has used the increment borer for all their softwood collections from modern trees. For use on living oaks, Mr. Ernest Dickson devised a heavier tubular bore made out of a piece of steel pipe. This was redesigned and improved upon by engineers in the laboratory of Commander E. F. MacDonald of the Zenith Radio Corporation. The new borer consists of a long tube with a screw at the narrower distal end and an arrangement for attaching a crossbar handle at the wider proximal end. In these respects it is like the Swedish Increment Borer except in size and strength but it varies from the increment borer in being equiped with a block and an encircling canvas belt to hold it to the tree. The tip of the borer passes through a hole in this block, which holds it from slipping when it first penetrates the exterior of the wood. The core is removed from the borer by being forced out with a ramrod. This borer is constructed to operate on a tree five feet in diameter. Experiments with it indicate the need of a few new adjustments to be made in its design, which Mr. MacDonald's laboratory has offered to undertake.

In taking samples from dry wood, southwestern dendrochronologists use a tubular borer devised by Dr. Douglass. This borer is made from a piece of pipe with saw teeth cut into one end and a piece of metal welded into the other end so that it can be clamped into a carpenter's brace. This borer works through a hole in the center of an iron starting plate made about four inches long, two inches wide, and three-eights of an inch thick. By a nail driven through a small hole at each end, this plate is held to the wood. The plate prevents the borer from slipping and so from knocking off the outside rings of the core.

The borer is removed from the wood every few minutes and the worker puffs the sawdust away by blowing through a short length of rubber tubing inserted into the cut. When the borer has reached the center of the log, it is removed and a thin screwdriver is inserted and pushed forcibly to one side to break the core from the center wood. Cores which come out in several pieces are marked and the parts put together with glue or with waterproof cement.

After the core has been removed from the beam, a plug of wood cut for the purpose is hammered into the hole and cut off even with the exterior of the beam. By means of this borer, a core may be taken from timbers built into a structure without the structure being appreciably despoiled.

For V-cuts in stumps, the best implement is a two-man cross-cut saw such as lumbermen use and which usually can be borrowed from local farmers. If there is a chance that only one man would be available for handling the saw, a smaller cross-cut saw intended for one-man use may be carried in the car. A keyhole saw and a ripsaw are valuable in taking slabs from the end of log cabins beams. Files for sharpening the saws and oil for preventing rust on saws and borers are carried.

Transportation of specimens.-- Heavy, solid specimens such as cross-cuts, V-cuts, and slabs of wood from stave mills are shipped by freight in gunny sacks or in boxes, or, if they are more fragile, by express. Before they are shipped, they are marked singly or as a group with a catalogue designation indicating state, county, and number of the specimen or specimens, and a card giving all available information on location, date of collection, date of cutting, and collector's initials is made out. If the specimens come from log structures, the approximate date of the building of the structure is obtained if available. Such information often facilitates actual dating of the specimen.

Increment borings are something of a problem to carry without breaking. Long envelopes may be used for individual specimens, but the chances are that such a specimen will be in many pieces before it reaches the laboratory. One convenient carrier is that devised by T.M.N. Lewis. A stem of bamboo is cut close to the node, which forms the end of a tube. The other one or two nodes occurring in a fifteen-inch length are punched through, the core is put into the tube, and a piece of cotton is used to plug the open end. The cord of a tag giving the catalogue designation and any pertinent information on the specimen is tucked into the tube below the cotton. Individual or group catalogue cards are made out in the field. The best core carrier yet used is a thermometer box, which may be purchased from the Brooklyn Thermometer Company for ten cents. The thermometer box, which is just the right size for carrying the core, has a self-cap at the end, and the tag label may be tied around the case and later removed in the laboratory so that the case may be reused a number of times.

Rubbings of ring-records.-- When all the actual specimens desired cannot be obtained, ring rubbings are useful as supplements. In this work, a sheet of carbon paper is laid with the carbon side up on top of the stump or fence post, which has been cut long enough ago so that the surface is not pitchy and yet not so long ago that the surface is badly weathered. A sheet of moderately heavy typewriting paper is placed on top of the carbon and a soft pencil is used to rub across the wood in a radial area. This produces a record of the rings on the surface of the white paper and also gives a carbon record on the under side of that paper. The carbon record often proves easier to read than the pencil record. It is found that the records appear clearer when the pencil rubbing is done across the grain of the rings.

Cataloguing.-- If specimens were collected in only one area in which a single institution had been doing archaeological work, it would have been desirable to use the catalogue system of that institution in marking the specimens of wood, ancient and modern, taken from that area. Into the Chicago laboratory, however, came material from a number of areas in which different catalogue systems were being used on archaeological material, and consequently it was thought best to arrange a simple device which could be used consistently for marking wood. The designation adopted consists of the first letter or two letters of the county from which the wood came. These letters are followed by a dash and the serial number of the specimen in the group taken from that county and that state. Thus, the mark "MO-S-22" on a specimen indicates the twenty-second specimen taken from Shannon County, Missouri. Archaeological specimens catalogued by the institution collecting them before they are sent to the laboratory are not remarked.

Preparation of Modern and Historic Specimens for Study

When the cores reach the laboratory, they are removed from their containers and are mounted on fifteen-inch lengths of screen molding scored with either one or two furrows into which the cores are cemented with Ambroid or one of its substitutes, or, if there is a chance that the core may be removed later, with one of the rubber cements. The cores are held tight against the mounts by cord wrappings until the cement is dry. The person mounting cores must be careful that he sets the base at a 45° angle with the grain so that the razorblade cut which later prepares them for study may be made to the best advantage.

After the specimens are unpacked in the laboratory and their cataloguing is completed, the cores are oiled with kerosene and the entire upper portion is removed in slices made with a razor-blade knife equipped with a heavy Durham Duplex blade or another blade of the same general type. No really efficient commercial knife has been found; hand-made knives or commercial knives trimmed into shape for this work are used.

The cut must be made at a 45° angle across the grain of the wood. For the best surface, one should cut from the outside to the inside of the specimen on the right-hand side when the inner end of the specimen is held against the worker. If the specimen is held with the outside towards the worker, the cut should be from the inside to the outside on the right-hand side of the specimen. This means, of course, that the worker always cuts toward himself on the right-hand side. The blade in the holder must be changed frequently so that a fresh cutting edge is always available. A new razor blade is sharper than any other instrument, even a microtome, which can be used for this work. The sharp edge cuts the cells cleanly without breaking them and hence allows a good view of the ring structure if the wood is touched with kerosene and examined with a ten-power magnifying glass. The kerosene may be applied with a small swab or with a good atomizer which produces a fine spray.

The ten-power triple aplanat or triplex hand glass has been found to be the best for this work unless the laboratory is equipped with a binocular microscope, which eases eye strain. For examination of especially small rings, the fourteen- or the twenty-power hand glass is used, and questionable rings are studied with a glass of forty to sixty power.

V-cuts and cross-sections of the softwoods and even of some of the hardwoods are oiled with kerosene and cut with a razor-blade knife; but the wood of the oak is so tough that a very good surface can be obtained only by use of a sharp draw knife. The specimen is put into a vise with the edge to be cut uppermost. A well-sharpened draw knife is pulled along this edge with a slicing motion at a 45° angle, the knife being moved from left to right as well as towards the cutter to produce the best surface. Punky spots and areas in which the rings are so small that the wood is made spongy by the great numbers of large spring pores crowded into a small area must be finished off with a razorblade. It is usually convenient to have one man skilled in the use of the draw knife prepare a number of specimens for study.

Preparation and Preservation of Mound Specimens

In the Southwest many of the specimens taken from ruins are sound and in good shape, and a few of those taken from mounds of the Mississippi Drainage are in good condition with the exception of their exteriors having been rotted away. Some of the southwestern pueblo specimens and most of the mound specimens, however, are of charcoal (see Pl. VIII) and a few are of decayed wood, which must be preserved before they can be used for dating.

Douglass has used a saturated solution of paraffin and gasoline for such preservations. He soaks a specimen in the solution and then binds it firmly around with strips of cheesecloth gauze.

The mound specimens when removed from the ground are usually much damper than those from the Southwest and often are actually wet and incased with wet soil. If these are allowed to dry out before they are put into the solution, they break apart; but if they are put into the solution before they are fairly dry, the solution penetrates so little that after the specimens have actually dried they fall apart. The Chicago laboratory and the field workers of the University of Tennessee have found that if a specimen is wrapped upon being removed from the ground and then is put into the solution which has been prepared with warm gasoline and which consequently takes up as much paraffin as possible, the solution will sink part way into the wood and will help stabilize the wood by strengthening the wrapping. The specimen is then allowed to dry for a day or two and is again submerged in the solution, the process being repeated several times until the solution has taken the place of the water which bit by bit dries out of the charcoal or of the decayed wood. The wrapping must be firm enough to prevent the wood from breaking on radial lines or circumferentially as it dries and shrinks. It has been found that the most practical system is to wrap the specimen tightly around the circumference with a number of layers of gauze and then to put a few layers over the ends. When the specimen is to be studied, the gauze from one or from both ends is cut away with a razorblade, the circumference wrapping being left in place for protection and strength.

In the Southwest, charcoal is usually broken or chipped to obtain a good surface, because cutting, even with a razor blade, obscures the surface, especially if the paraffin preservative is too strong. Charcoal which has been damp for a considerable period, as in the Mississippi Drainage, is likely to break apart ring by ring if chipping is attempted even though the specimen has been preserved as indicated above. To avoid this difficulty, various experiments have been made. If the surface is cut as smooth as possible and a solution of bakelite and acetone is poured over it and allowed to harden for about twelve hours, the surface may be recut with a sharp blade and the rings will stand out clearly enough to be studied and even to be photographed, (Pl.VIII). Cutting the surface at a 45^{o} angle is preferable, as always, but a flat cut may be used, especially if the razorblade is held in the fingers rather than in a knife handle and a slice is made flat but at about a 45^{o} angle on the horizontal surface.

The surface thus prepared will not later cloud but will remain perfectly clear. If the bakelite solution is put into the charcoal without the previous preparation of the paraffin solution, the wood becomes brittle and cannot be cut to advantage. The paraffin solution gives a soft resiliance to the wood, and the bakelite provides the proper body. Heating the bakelite-treated wood for further hardening has been tried but appears to have a tendency to make the wood more brittle -- an undesirable quality.