Harold C. Fritts

TREE-RING MATERIALS AS A BASIS FOR CULTURAL INTERPRETATIONS

by

William James Robinson

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PREFACE

My awareness of the problems presented in this study came during the course of four years association with the Laboratory of Tree-Ring Research. During that time, I was in charge of the archaeological organization and integration for the Laboratory's Synthesis of Southwestern Dendrochronology Project which was supported by grants GS-247 and GS-908 awarded to The University of Arizona by the National Science Foundation. Bryant Bannister was principle investigator of the Project and provided the original concepts and inspiration. My colleague, Jeffrey S. Dean, was in charge of the dating analysis.

As with most projects of this nature, many other people have contributed to its overall success and smooth operation. I am happy to acknowledge the help in the dating analyses of John W. Hannah, Richard L. Warren, and Ward F. Weakly. Under Dr. Dean's direction, this team reanalyzed a prodigious number (nearly 50,000) of tree-ring samples. In the archaeological organization, I have been aided by Cheryl A. White, Candace S. Lane, and Forrest W. Meader, all of whom performed their often exasperating duties with cheerfulness and dispatch. Both S. Alan Skinner and Elizabeth A. M. Gell have shared many of the difficult organizational problems with me and have contributed their wide knowledge of Southwestern archaeology to the betterment of the project. Dr. Gell's personal interest in the Red

Rock caves which her father excavated in 1931 provided me with the stimulus to look carefully at the unusually well-preserved tree-ring collections from these early sites.

Not all of the archaeological controls for the tree-ring materials were resurrected in the files. I revisited many sites, notably the Red Rock caves, with Doris O'Bryan, now of the United States Geological Survey--Water Resources Division, who had gathered much of the original collection for Gila Pueblo around 1940. I appreciate his continued interest in the problems of tree-rings and his unfailing enthusiasm in relocating archaeological sites he had not seen for nearly 30 years. I would be remiss if I did not also mention the help and hospitality provided by the Museum of Northern Arizona in Flagstaff. The Director, Edward B. Danson, allowed me to make unrestricted use of the Museum's permit to perform archaeological investigations on the Navajo Indian reservation, and Alexander J. Lindsay, Jr., Curator of Anthropology, has cheerfully extended the use of his facilities and files on many occasions.

Throughout the course of the project, I have benefited greatly by my association with my colleagues at the Laboratory of Tree-Ring Research. Jeffrey C. Dean has been my companion of sage flats and talus slopes, and our discussions, often held in the isolation and splendor of the Colorado Plateau, have more than all else served to crystallize much of my thinking on the nonchronological aspects of tree-ring dating. His astute observations during the dating procedures provided the first indications of the type of analyses done here. I

have been equally aided by the encouragement of Bryant Bannister who has provided every opportunity for the completion of this study. Without his support, I could never have undertaken this work. Other members of the staff of the Laboratory whose help, although less specific, is much appreciated are Harold C. Fritts, C. Wesley Ferguson, and Marvin A. Stokes.

The final form of this report owes a great deal to the efforts of my committee, Raymond H. Thompson, Emil W. Haury, and Bryant Bannister. The benefits of their diligence and skills are obvious in the presentation. I am also much indebted to Pat Dean who undertook, on short notice, the job of editing and typing a draft of my manuscript. Her efforts contributed immeasurably to the successful and timely completion. The line drawings are the work of John W. Hannah whose skills with drawing instruments nearly equal those of dating analysis.

Finally, I owe much to many professional colleagues throughout the Southwest who bore with equanimity a myriad of inquiries on my part in an effort to reconstruct provenience and association details. They never failed to give me their wholehearted support.

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ABSTRACT

Since 1963, the Laboratory of Tree-Ring Research has been engaged in a systematic reanalysis of all samples from the prehistoric Southwest. Particular emphasis has been placed on archaeological controls of the samples to enhance the chronological interpretation. In the course of this work, other characteristics of the samples were noted that opened the way for deductions regarding nonchronological attributes of the prehistorically-used wood.

Tree-ring materials have traditionally been viewed both as chronological indicators and as tools for paleoclimatic reconstructions. These same materials, however, may be viewed as a valid category of raw material for study without regard to the inherent chronological characteristics or the climatic implications. Viewed as such, these materials possess attributes whose patterned distributions allow inferences concerning the cultural behavior of the users of the material.

These attributes---species of tree, nature of the terminal ring, and technology---are analyzed using the basic parameters of time, space, and content. The data presented are illustrative of the potential of this method rather than exhaustive. An exhaustive analysis is not practical since the necessary archaeological controls can be resurrected in only a few instances.

The physical evidence of three methods of felling trees is preserved on beam ends. The temporal distributions of these methods

indicates that prior to A.D. 600 trees were felled by breaking or fire girdling. After this time, felling was accomplished by breaking or cutting with a hafted stone axe. Thus the tree-ring materials indicate the technological development of the hafted axe about A.D. 600 in the northern part of the Southwest. A summary of the archaeological occurrences of stone axes corroborates this time of development.

The suggestion that dead wood was used in the main---thus distorting the relationship between tree-ring dates and archaeological remains---before the use of the stone axe is not supported. Date clustering of burned beam ends and presence of bark is evidence that refutes death of trees by natural causes and suggests, on the contrary, that even before the knowledge of the axe construction timbers were obtained from living trees.

Technological alteration of construction timbers often went beyond the realm of obvious practicality. Beams preserve evidence of both intentional bark stripping and of shaping and smoothing of the end. Occasionally, the natural taper of the bole of the tree was shaped to a uniform diameter.

Certain species of trees were preferred for specific purposes. The intra-site distribution of species reveals two repetitive patterns. Juniper wood is found, where a choice existed, in ground contact situations more frequently than the softer conifers. Recognition of the decay-resistant qualities of this wood is suggested. A similar high frequency of pinyon pine in firepits and trash areas is noted. Pinyon wood possesses both practical qualities of intense heat and little smoke and an aesthetic quality of pleasant smell.

In many areas, straight-boled conifers such as ponderosa pine and Douglas-fir are not readily obtainable. When these species do occur archaeologically in such areas, they are more common in ceremonial structures than in domestic or storage structures. These data parallel the common observation of unusual care in the construction of ceremonial structures and may reflect the nature of the activity for which the structure was built.

Some differences in frequency of species through time are noted, but, due to a lack of detailed data on prehistoric changes in environment, these are difficult to assess.

The nature of the terminal rings of trees provides information on the time of year that cutting took place. The patterns of terminal rings suggest that the summer months were favored for cutting activity at Basketmaker III sites. Such activity concentrated in the planting season may reflect the diminished role of agriculture in Basketmaker subsistence or a difference in division of labor from that of ethnographic pueblo populations. Terminal rings from later sites (Pueblo III) do not indicate cutting activity during the planting season.

The patterns of terminal rings of beams from a single structure may be used to detail the season of construction activity within the year. Basketmaker house building took place in early fall in contrast to later pueblo construction during the winter months.

CHAPTER 1. INTRODUCTION

Time, whether relative or absolute, is one of the basic dimensions of archaeology. To establish this dimension and to order archaeological materials chronologically, many methods have been developed. Some of these have been developed, or at least uniquely applied, within archaeology itself, while others have been developed in other scientific fields and have only later been applied to the problems of archaeology. Dendrochronology is one of the latter.

Annual rings of coniferous trees in the semiarid Southwest have been employed in two basic informational categories. The variable patterns of the rings have provided an absolute time scale by which man's activities in prehistory have been accurately placed. The techniques involved in this process have been described by Douglass (1919, 1937, 1946a), Glock (1937), and others. Problems of interpretation of dates derived from tree-ring studies have been discussed by Bannister (1962, 1965). The same rings have also been demonstrated to have a relationship to climatic events and have been used as a means for paleoclimatic reconstruction (Douglass 1919). In fact, dendrochronology was first developed by Douglass for this purpose. Its application to archaeology came much later and, in a sense, accidentally.

The Laboratory of Tree-Ring Research at The University of Arizona currently houses approximately 100,000 specimens from

archaeological sites throughout the Southwest. This collection includes both materials submitted directly to the Laboratory over the past 50 years, and the large collections made by the Museum of Northern Arizona, the Laboratory of Anthropology, and Gila Pueblo. These institutions initiated tree-ring studies in the 1930's, but discontinued this line of investigation by 1950.

In the decade after 1950, all these independent collections were transferred to the Laboratory of Tree-Ring Research. Since all of the institutions had duplicated each other's and the Laboratory's collections from many specific archaeological sites, it became obvious that an integrated reanalysis of all collections was necessary. This study was begun in 1963 with support from the National Science Foundation and is still continuing. One of the deficiencies which the project was designed to correct was the lack of detailed association and provenience data that had heretofore precluded highly specific relationships between derived dates and prehistoric events. The process of gathering and integrating these data, which has been under my direction, led to the realization that certain patterns relating to prehistoric wood use could be deduced from the samples viewed as raw material irrespective of their inherent chronological characteristics.

In the present project and over the past 40 years, many thousands of wood specimens, and here I do not distinguish wood in its unaltered form from charcoal, have been subjected to ring analyses in order to extract chronological information.

Only rarely, however, have the wood specimens been viewed as artifacts of man and subjected to analyses similar to those performed on other classes of preserved materials. The reasons for this oversight are outlined in a history of the archaeological uses and application of tree-ring dating, but can also be understood in terms of a rather traditional preoccupation with chronological ordering in archaeology.

It can be argued, as this study attempts to demonstrate, that wood, however used, constitutes a valid category of raw material for investigation. Further, the nature of certain empirical attributes suggests inferences concerning cultural behavior toward that material without reference to time placement per se. These attributes are: (1) the botanical species of tree, (2) the nature of the terminal growth ring, and (3) the technological alteration of the raw material. Not all of these attributes are present in all samples. The nature of the outer growth ring is easily lost by fire, erosion, or wear, and the technological alteration may be obscured by post-use burning or may not be noted in field observation.

The attributes are analyzed and described using the traditional archaeological parameters of time, space, and association. Fortunately, the chronological characteristics of tree-ring materials provide a built-in time scale that is used whenever possible, but analysis of the attributes through time is not restricted to dated tree-ring specimens. Specimens are also placed in time---less precisely, to be sure---by association with other items of archaeological assemblages whose

temporal limits are known and by their presence at single component sites whose chronological parameters are based on other specimens. Space is considered in both gross geographical and finite intra-site dimensions. Particular emphasis is placed on association because the nature of any interpretation depends heavily on associations of the tree-ring material and its inferred use as construction timber, firewood, or some other category. This parameter is the most fragile because association is a matter for field observation and cannot be resurrected in the course of later analysis.

The analysis and description of the attributes by these variable dimensions reveals certain patterning in the data. The patterns have an indicative quality that suggests relationships between them and cultural behavior (Thompson 1958: 3). The recognition of this relationship is basic to the inferential process outlined by Thompson (1958: 4-8). This process leads to an indicated conclusion which, however, must be tested for probability before acceptance. The most common test---and one of wide applicability in the Southwest---is the test of ethnographic analogy. Ideally, then, comparisons should be drawn between the observed patterns and the inferred behavior and ethnographic reality. Unfortunately, this form of specific historical analogy is not useful for testing in this case. Although there is indeed a historic continuity between prehistoric and historic Indian groups in the Southwest, the Pueblo Indians now use milled lumber and steel tools for construction, and have abandoned the aboriginal source of materials and technology. In addition, few observations were made by early

ethnographers on behavior relating to wood use at the time before the impact of modern technology and materials. Although houses are described, the only additional information on construction activity makes it clear that at Zuni the cutting and placing of timbers, and the stonework, was the work of men (Stevenson 1904: 349-50; Morgan 1881: 138-9).

Thus, the test of the indicated conclusions must rest on a more general comparative analogy in regard to the specific class of artifacts, but this is drawn from a rich and detailed description of other aspects of Southwestern ethnographic reality.

The chronological aspects of tree-ring dating have contributed to the interpretation of certain cultural practices which, to complete the record, should be briefly mentioned. These practices, it should be clearly stated, have been inferred from patterns of dates and date cluster analysis (Bannister 1962: 510) rather than from the non-chronological attributes of tree-ring material which form the basis for the present analysis.

Early in the history of tree-ring investigations Douglass (1935: 40) noted the reuse of timbers; that is, older timbers incorporated in more recent structures. He observed in the large collection from Oraibi that some of the beams must have been in continuous use for as much as 400 years. Douglass (1929: 754) documents one case of a beam in a recently abandoned room that was cut over 500 years previously. Reuse of wood is one of the factors affecting the interpretation of tree-ring dates (Bannister 1962: 509; 1965: 123). In his recent

study of late Tsegi Canyon sites, Dean (1967: 298-9, 510-11) demonstrated reuse of timbers at both Betatakin and Kiet Siel.

From the standpoint of chronological analysis, the reused beam has a counterpart in the repair timber. This is a more recent beam placed in a structure to replace or reinforce an original construction member. This again has been considered by Bannister (1965: 124).

Perhaps one of the best documented cultural practices resulting from chronological analysis is stockpiling of timbers. Bannister (1965: 151) considers stockpiling for future use the best interpretation for the range of dates of beams of a single roof in a room at Chetro Ketl, Chaco Canyon. Dean (1967: 300-01) demonstrated stockpiling by his chronological analysis of the beams at Betatakin. He shows, using detailed control of both dates and context, that many beams throughout the ruin were cut in the years A.D. 1269 and 1272, but none of them were used in actual construction until A.D. 1275. The specific reasons for this stockpiling is not clear, but the evidence for the practice is incontrovertible.

Other possible aspects of nonchronological information derived from tree rings involve paleoclimatic reconstructions and are not pursued in this paper. In particular, the conflict in interpretation of the relationship between a sequence of narrow rings and droughts is not discussed. A direct correlation between these events was first posited by Douglass (1929: 766-7), emphasized by Maury (1935: 107), and restated by Douglass (1935: 48-9). Although neither of these

authors advocated a monocausal relationship between the ring phenomena and man's activities, a polemic soon developed. Since studies are currently under way which hold promise of detailing the relationship between ring width and climate (Fritts 1965; Fritts and others 1965) and since little research has been directed toward relating ring-indicated drought (effective tree-moisture deficiency) to crop drought (effective economic crop-moisture deficiency), it would be premature to further discuss this nonchronologic aspect of tree-ring dating.

The data presented in the following sections are illustrative of the possibilities of extracting certain nonchronological information from tree-ring materials and are not intended to document exhaustively every occurrence of similar phenomena. Symbols and abbreviations used in the tables and throughout the text are explained in Table 1. I hope that by presenting such possibilities, future field investigations may be conducted in a manner that will enhance the value of the tree-ring materials in cultural interpretation.

Table 1. Symbols and Abbreviations

SYMBOLS USED WITH DATES:

With the inside date:

year	-	no pith ring present
p	-	pith ring present
fp	-	the curvature of the inside ring indicates that it is far from the pith
~~p~~	-	pith ring present, but due to the difficult nature of the ring series near the center of the specimen, an exact date cannot be assigned to it. The date is obtained by counting back from the earliest dated ring.
+	-	the innermost ring is not the pith ring and an absolute date cannot be assigned to it. A ring count is involved.

With the outside date:

B	-	bark present
C	-	beetle galleries are present on the surface of the specimen
L	-	a characteristic surface patination and smoothness, which develops on beams stripped of bark, is present
c	-	the outermost ring is continuous around the full circumference of the specimen. This symbol is used only if a full section is present.
r	-	less than a full section is present, but the outermost ring is continuous around available circumference
v	-	a subjective judgment that, although there is no direct evidence of the true outside on the specimen, the date is within a very few years of being a cutting date
vv	-	there is no way of estimating how far the last ring is from the true outside

Table 1--Continued

With the outside date (cont.):

+ - the nature of the dating is such that one or more rings may be missing near the end of the ring series whose presence or absence cannot be determined because the specimen does not contain enough additional rings to provide an adequate check

++ - a ring count was necessary due to the fact that beyond a certain point the specimen could not be dated

The symbols B, G, L, c, and r indicate cutting dates in order of decreasing confidence, unless a + or ++ is also present.

The symbols L, G, and B may be used in any combination with each other or with the other symbols except v and vv. The r and c symbols are mutually exclusive, but may be used with L, G, B, +, and ++. The v and vv are also mutually exclusive and may be used with the + and ++. The + and ++ are mutually exclusive but may be used in combination with all the other symbols.

ABBREVIATIONS USED FOR SPECIES:

DF - Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco)

PP - Ponderosa pine (*Pinus ponderosa* Laws.)

PNN - Pinyon pine (*Pinus edulis* Engelm.)

JUN - Juniper (*Juniperus* sp.)

WF - White fir (*Abies concolor* [Gord. and Glend.] Hoopes)

ABBREVIATIONS USED WITH TERMINAL RINGS:

INC - Terminal ring incomplete

COMP - Terminal ring complete

CHAPTER 2. TREE-RING DATING AND ARCHAEOLOGY

The systematic study of tree rings began nearly 70 years ago as the inspired brain-child of a single investigator. It was not until two decades later that the tree-ring phenomenon was applied as a dating tool in archaeology (Bannister 1963 : 162). Yet the entire period of its development is basic to the understanding of the applications of the tool in archaeology and the reasons behind some of the failures to use the phenomenon to maximum advantage in cultural interpretation.

Crossdating (1901-1914)

It seems somehow consistent that the study of tree rings was first applied in fields other than archaeology. Many, if not most, of the quantitative dating techniques used today had their origins in other sciences. In the case of tree rings, it was astronomy. Andrew Ellicott Douglass, the man whose fertile mind first saw and developed the potential of tree rings, was an astronomer at the Lowell Observatory in Flagstaff, Arizona, before the turn of the century. His particular interest lay in the cyclic nature of solar activity, particularly sun spots, and its relation to terrestrial climate. Because the written record of solar activity extended farther back in time than that of terrestrial weather, he envisioned tree growth as a measure of climate. Douglass' investigation began in 1901 and was based on the following premises: (1) that the rings of a tree are a measure of its food supply; (2) that the food supply depends largely on the amount of

available moisture, especially in drier climates where the quantity of moisture is limited and the life struggle of the tree is against drought rather than competing vegetation; and (3) that therefore the rings are a measure of precipitation (Douglass 1914 : 321). His method involved first the preparation of a tree-growth curve, and for this purpose pine trees growing in the immediate environs of Flagstaff were chosen. In addition to convenience, these trees had two obvious advantages. First, the moisture available to the trees was primarily in the form of rainfall and, second, the average age of the trees was 340 years, with some over 500 years (Douglass 1914: 322). This latter quality allowed a large backward extension of the growth curve in the record of a single tree.

As he worked on the growth curve, Douglass noticed that the same pattern of thick and thin rings could be identified in different trees that grew during the same time period. He also noticed that the same patterns could be seen in trees growing near Prescott, Arizona, which was nearly 100 miles to the southwest of Flagstaff and 1000 feet lower in elevation. The recognition of the recurrent patterns in the rings was the first step in the formation of the fundamental principle of all tree-ring investigation and is referred to as crossdating.

Crossdating was first established experimentally by Douglass in 1904 when he recognized the ring pattern in a dead stump which allowed him to specify the actual date of cutting---a fact that was verified by the man who had cleared the land.

For the next decade Douglass continued his work on rings as climatic indicators and on the establishment of long growth curves. He

succeeded in crossdating living trees growing as far away as southern Arizona (Douglass 1914: 325) and devoted a great deal of effort to the investigation of Sequoia in California which at that time held promise of extremely long growth records. It was during this period that Douglass' long association with The University of Arizona began in 1906.

At the end of this period of the development of the basic principle of dendrochronology, the crossdated sequence extended back in time nearly 500 years, based mainly on Flagstaff area trees.

Relative Dating (1914-1929)

Although Douglass never lost sight of tree growth as a climatic indicator, an event occurred in 1914 that led him off on a tangent. This was the application of the dating potential of tree growth to past events in man's history. In that year Douglass delivered a paper at the Carnegie Institution of Washington on the relationships between tree growth and climatic cycles. The substance of the paper came to the attention of Clark Wissler of the American Museum of Natural History who offered Douglass some beams for his general inspection (Douglass 1935: 10). These materials were received in 1916 and were sections of living trees growing near prehistoric ruins. As a result of his examination of the sections, Douglass became convinced that trees from as far as northwestern New Mexico had a potential of cross-dating with his Flagstaff trees (Douglass 1921: 27). A few years later Earl H. Morris sent Douglass a small selection of prehistoric beams from the Aztec Ruin and from Pueblo Bonito in Chaco Canyon. The

sections from Aztec were immediately crossdated among themselves, but not those from Pueblo Bonito. In hopes of obtaining an exact age correspondence for the Aztec beams, Douglass tried futilely to match them to the three millennia Sequoia record. Later in 1919, Douglass visited Morris at the Aztec Ruin and secured 37 additional specimens. These, with the original pieces, formed the basis for the first relative, often referred to as "floating," chronology. As a result of this initial success, Douglass formulated the dating technique that ultimately proved successful. In a letter to Wissler in 1919, he stated that the technique ". . . consists in obtaining groups of timbers of different ages so that one group will overlap another, and after combining them by crossdating, we may bridge over a great many hundred years in the past." Wissler's response to this suggestion was to send more beams from Pueblo Bonito, collected many years before during excavations by the Hyde Expedition. Without undue effort these sections crossdated well with each other.

But a great step forward was achieved when it was found that the Pueblo Bonito logs crossdated with the sections from Aztec. Thus Douglass was able to announce the relative dating between the great ruins at Aztec and Pueblo Bonito (Douglass 1921: 29). This event consummated the marriage between tree-ring phenomena and archaeology, and for the next 20 years Douglass concentrated on chronology building.

In 1922, Neil M. Judd, who had begun work under National Geographic Society auspices at Pueblo Bonito the previous year, encouraged the Society to support the approach that Douglass had suggested in

1919. So the mechanism was established to gather successively older groups of beams back from the present with the specific objective of dating Pueblo Bonito (Judd 1930: 169-71).

The First Beam Expedition, sponsored by the National Geographic Society, operated in 1923 under the field leadership of J. A. Jeancon of the State Historical and Natural History Society of Colorado and O. G. Ricketson of the Carnegie Institution of Washington. They collected about 100 beam specimens from viable pueblos, historic mission churches, and prehistoric ruins from the Hopi Mesas to the Rio Grande and to Mesa Verde (Fig. 1). Douglass in the meantime obtained additional beams from Wupatki, a ruin north of Flagstaff, Arizona. It was hoped that the sections from the Hopi villages and from the mission churches would crossdate at the early end of the chronology developed from living trees and, in turn, extend back far enough to crossdate with the outer rings of the prehistoric specimens. Although the desired result was not immediately achieved, it was recognized by the nature of the crossdating of many of the specimens that the entire area of collection acted as a climatic unit as regards tree growth. This crossdating also resulted in placing other ruins within the relative date chronology first developed from the Aztec and Pueblo Bonito beams. One ruin so placed was Wupatki. The link with the living tree chronology remained elusive, however.

In addition, a second relative or "floating" chronology was developed from Wupatki specimens that did not immediately crossdate with the established relative chronology. This was termed Citadel

Dating, as it included the ring record of a specimen from the Citadel, a ruin near Wupatki. Other ruins also fitted into this second chronology, including Mummy Cave in Canyon de Chelly and sections from the classic cliff ruins at Mesa Verde.

This chronology was approximately 140 years long without any suggestion of its proper placement in time. On the basis of ceramic seriation, however, Judd assured Douglass that it should fall between the living tree chronology and the one developed at Aztec and Pueblo Bonito.

As analyses proceeded on the collections made by the First Beam Expedition, more and more specimens gradually yielded to crossdating within one or the other of the two relative chronologies. These two were ultimately merged, in 1928, to form a single chronology of prehistoric ruins with a length of 585 years. The status, then, of chronology building early in 1928 consisted of two long records. The absolute chronology extended from the present back to about 1400 with confidence, and weakly---because it was based on few trees---to about 1300. The other was a floating chronology of 585 years of unknown absolute age based on specimens from approximately 30 prehistoric ruins.

In an attempt to strengthen the chronology before 1400, the Second Beam Expedition was organized in the summer of 1928 under the field supervision of Lyndon L. Hargrave. Since it was already known that material in the early end of the known time scale was present at the Hopi village of Oraibi, this expedition concentrated on early historic beams throughout the Hopi villages. A great deal of emphasis

was placed on the abandoned sections of Oraibi and on beams that exhibited stone-axe cut beam ends. In all, over 200 specimens were collected from Oraibi and other Hopi villages.

Since the chronology had already been developed for most of the time period represented by the new specimens, over 140 were quickly crossdated by Douglass into the known sequence, and he succeeded in extending the chronology back to near 1300 with confidence. Two specimens seemed to carry the series even farther back to about 1260. Still no crossdating was evident with the floating chronology of the prehistoric ruins.

Toward the end of the summer Hargrave collected from ruins in the Jeddito area, just east of the extant Hopi villages, with the hope that the material there would just predate Oraibi. Earl H. Morris was excavating a large ruin called Kawaikuh and was encouraged to look for and send charcoal or wood from his excavation to Douglass. In October of that year a piece of charcoal from Morris' excavations crossdated with the living tree series in the 15th century. Thus Kawaikuh has a double distinction: it was the first prehistoric ruin tied to calendar dates by the tree-ring method and it provided the first charcoal for dating. This latter success opened up a new and less restrictive source of material.

Shortly afterward, material from three other ruins were successfully crossdated into the known chronology. These were Turkey Hill near Flagstaff, Kokopnyama in the Jeddito area, and Chaves Pass southeast of Flagstaff.

The Second Beam Expedition, then, provided the first prehistoric ruin dates and served to extend and strengthen the known chronology, but no overlap was yet established with the 585-year long relative chronology that included the chronology from Pueblo Bonito.

It was evident by the close of 1928 that the collection of the proper material to close the gap, as it became known, would have to change from more or less random, easily obtainable, collection to excavation. During the 1928 Expedition much attention was paid to the pottery exhibited by each of the sites, and it soon became evident to Hargrave, Judd, and Douglass that the latest sites in the relative dating chronology showed red background polychrome pottery, whereas the earliest sites in the known chronology had orange and yellow background pottery. The search was then on for sites that fulfilled a threefold qualification: first, a site must be ceramically placed between ruins with orange and yellow pottery at the early end of the known chronology and the latest prehistoric ruins such as Kiet Siel, in Tsegi Canyon, with red background polychrome; second, a site must evidence burning in order that preservation be possible in the form of charcoal; and third, a site must lie in or near pine forests. Of all the candidates, the ruins at Pinedale, Showlow, Kin Tiel, and Kokopayama were chosen as the most likely.

Excavations were begun in June, 1929, at the Showlow Ruin by Hargrave and Emil W. Haury (Haury 1962: 12). On completion of that work, Haury went on to excavate at the Pinedale Ruin while Hargrave undertook Kin Tiel and Kokopayama (Haury and Hargrave 1931).

The solution to the problem came soon. Toward the end of June, Douglass and Neil M. Judd visited Haury and Hargrave at Showlow to check on the progress. One charred log, designated in the field as HH-39, seemed very promising. It had an outside ring near 1330 and extended back to 1237 (Haury 1962: 13). It did not, however, immediately crossdate with the prehistoric sequence. That night Douglass, whose memory for ring sequences was phenomenal, mentally reviewed HH-39 against the known and relative chronology and by the next morning was satisfied that it crossdated with the relative chronology in such a way that the gap was closed between the two series. Actually, no gap had existed. Rather, an overlap of about 25 years had been present but unrecognized because only one specimen (BE-269) on the known chronology extended inside 1300 and because of the almost universal defects in the growth patterns between 1276 and 1299---a phenomenon later to be characterized as the great drought. Later many pieces of charcoal from both Showlow and Pinedale verified the merging of the two series and strengthened this segment of the total chronology.

Thus, nearly 40 prehistoric Southwestern ruins were dated in terms of the Christian calendar (Douglass 1935: 41-3), and an absolute chronology was developed based on tree-ring patterns from 1929 back to about 700.

Absolute Dating (1929 to present)

Since the joining of the two chronologies into a single one of over 1200 years, much of the effort of the succeeding 30 years has been directed toward extending the chronology back in time and toward

strengthening and detailing many segments of the established chronology. Both of these efforts have had the side effect of dating hundreds of prehistoric ruins.

Shortly after the gap was closed a charcoal specimen was submitted by Earl H. Morris in 1931 from the La Plata district of northwestern New Mexico that bound together several short floating chronologies into a longer, but unplaced, series of 356 years. This was referred to as the Johnson Canyon Dating (JCD) by Douglass (1946b: 9). As has happened so many times before and after, this floating chronology did not crossdate with any known sequence. Shortly thereafter, however, in 1932, a piece from the ruin of Chetro Ketl in Chaco Canyon was dated from roughly A.D. 690 to 800 and, on its inner series, crossdated with the JCD. This, then, tied the Johnson Canyon dating sequence to the known chronology and extended the latter back to 475. The crossdating was confirmed by an excellent specimen excavated from the ruin at Allantown, Arizona, by Frank H. H. Roberts, Jr.

As early as 1927 Douglass had recognized yet another floating chronology which he termed the Early Pueblo Dating (EPD) that was based on specimens from Mummy Cave in Canyon del Muerto (Douglass 1946b: 9). Further collections were made in 1930 and 1931 by Earl H. Morris from Mummy Cave and from caves---notably Broken Flute and Obelisk---in the Red Rock district of northeastern Arizona. These were of high dating quality and soon allowed Douglass to identify the ring patterns in the known chronology and again make a leap back to A.D. 11. Thus by 1933 the Southwestern tree-ring chronology had attained a length of nearly 2000 years.

The last significant work on the backward extension was achieved by Edmund Schulman. Just before the Second World War, Douglass received a number of specimens from Earl Morris from very early sites in the area of Durango, Colorado. Although Douglass was able to date some of these in the first few centuries A.D., the war interrupted the complete analysis. After the war Schulman, who was both a student and associate of Douglass, took up the work where Douglass had left it (Schulman 1949a, 1949b). Schulman's work was greatly aided by a long piece, newly collected, from Mummy Cave that extended the known chronology to 59 B.C. Although this piece still holds the distinction of containing the oldest dated ring, its series allowed placement of many of the specimens from the Durango area. As a consequence, the earliest outside ring, and therefore archaeological date, was placed at 20 B.C. and the earliest established bark, or actual death, date at A.D. 46 (Schulman 1952).

In the two decades between 1930 and 1950, other individuals and institutions became involved in tree-ring studies, particularly from the archaeological point of view. At the Museum of Northern Arizona John C. McGregor, who had been trained by Douglass, engaged in independent tree-ring studies from 1930 to 1940. Basing his work on that begun by Douglass in the areas around Flagstaff and in the Tsegi Canyon--Marsh Pass area, McGregor established chronologies and dated many ruins under investigation by the Museum of Northern Arizona. His work has recently been reviewed by Harlan (1962).

Douglass recognized certain discrepancies in the ring patterns of material from east of the Continental Divide in New Mexico as early

as the First Beam Expedition. He suggested, therefore, shortly after 1930 that an independent chronology-building program be based at a New Mexico institution to pursue the so-called Rio Grande chronology with the same methodology that had culminated in success west of the Divide. W. S. Stallings, Jr., another of Douglass' students, was soon at work at the Laboratory of Anthropology in Santa Fe. He used the method suggested and started to build back from growing trees to Spanish missions and historic pueblos to late prehistoric ruins, and so back. Stallings began in 1931 and, perhaps because of the lessons in chronology building already learned, had extended the Rio Grande chronology back to A.D. 930 by 1939 (Stallings 1939: 16). Again, the Second World War interfered with the research program, and the study of Stallings' collection was continued and completed by Smiley, Stubbs, and Bannister (1953).

The third and last institution to seriously engage in tree-ring studies was Gila Pueblo in Globe, Arizona, under the direction of Harold S. Gladwin. The earliest dating of material was done by Emil W. Haury (1931, 1934, 1936) using Douglass' methodology. Soon, however, Gladwin embarked on a different methodology inspired by his lack of confidence in, and inability to use, Douglass' methods (Gladwin 1940: 9). He was concerned mainly with employing subjective judgments on relative ring widths and sought a more quantitative method of recording and manipulating ring widths. These efforts led to a series of disputes with archaeological sequences and chronological associations that had been established by followers of Douglass (Gladwin 1943, 1944,

1945, 1946). Although Douglass never directly refuted the methods used by Gladwin, his methodology has survived the test of time and is in general use today.

Most of the dating work produced by Gladwin and those associated in his method was never published. Gila Pueblo did, however, accumulate a large collection of tree-ring specimens through excavation and, in 1940 and 1941, through the collection activities of Deric O'Bryan, then a member of the Gila Pueblo staff. This latter effort duplicated by site, and often by actual beam, many of the beams already in the collections of the Laboratory of Tree-Ring Research.

By 1950 all these institutions had ceased their efforts in tree-ring dating, and ultimately the collections were transferred to the Laboratory of Tree-Ring Research for preservation and further analysis.

As a result of the efforts of the Laboratory of Tree-Ring Research only, Smiley (1951: 6) was able to compile tree-ring data that listed over 5600 individual dated specimens from 365 Southwestern sites. This valuable work has served for over a decade as the basic reference to prehistoric chronology in the Southwest.

The preceding summary of the history of the archaeological application of tree-ring dating reveals a dominant emphasis, at least until 1950, on chronology building and on the production of dates per se. In fact, until a series of publications by Bannister (1962, 1963, 1965), very little attention had been paid to the various interpretive problems that are inherent in independent dating procedures. The problem discussed by Bannister concerns the association of the dating

and the material remains. He outlines four basic areas of interpretive problems that potentially exist in the use of tree-ring data.

Even more than the associative problems, there has been a dearth of attention paid to the nonchronological information that may be derived as a by-product of the study of tree rings for their chronological information. Perhaps the most striking exception to this is a polemic, first stated as early as 1929, concerning the relationship between a series of below average ring widths and past climate with its consequent effects on aboriginal populations. The specific focus of the contention has been on a nearly consecutive series of narrow rings just preceding A.D. 1300. This time period roughly coincides with significant aboriginal population movements. One view holds that the rings represent a drought of sufficient magnitude to cause economic disaster among the agricultural peoples of the Southwest and, therefore, to also result in movements of these peoples that led to abandonment of areas occupied for thousands of years and concentrations in new areas. This view was introduced by Douglass (1929: 751), reiterated by him (Douglass 1935: 40), and later elaborated and entrenched by Haury (1935: 107) and Baldwin (1935: 11).

The opposition has credited the observed phenomenon to a variety of other causes (Dawson 1937: 110-18), but only E. S. Gladwin has attacked the view on its own grounds by using the tree-ring data. Gladwin (1947) presented evidence, adequate to him, that a series of narrow rings do not, in fact, represent drought. Therefore, he saw the population movement of the late 1200's as a correlative of another, not yet determined, phenomenon.

Recent work by Fritts (1965, 1966) and his colleagues (Fritts and others 1965) has tended to support the original view presented by Douglass. Since this work is far from complete and any further discussion along these lines would be premature, the question of the relationship between tree growth and climate is not pursued further.

CHAPTER 3. TECHNOLOGY

Some years ago O'Bryan (1949) presented a brief paper on the evidence preserved in prehistoric logs that allowed dating of the introduction of the hafted stone axe in the northern parts of the Southwestern culture area. He also suggested that logs utilized prior to the knowledge and use of the stone axe were, in the main, dead and dry before being felled and, therefore, that the death date of the tree preceded by some number of years the actual date of use of the tree in aboriginal construction. The error between the death date and use date may have approached on occasion as much as 200 years. Specifically, he states:

> Dates for the outermost or bark rings that antedate the seventh century are much poorer evidence regarding the use of wood than dates that fall in or after the seventh century. Before A.D. 600 the stone axe was unknown; dead, seasoned logs were collected and used. After 600 it is probable that the life of the tree was ended by an axe, and the axeman used the material himself. (O'Bryan 1949: 155-6)

O'Bryan then related a situation in which a tree, dead for nearly 200 years, was found perfectly sound and used to stabilize a kiva at Square Tower House, a well-known cliff dwelling at Mesa Verde. The fact that a standing snag of this age was still structurally sound led him to the suggestion that the margin of error in association might be in the neighborhood of 200 years.

Tree Rings and the Stone Axe

The data pertaining to the presence or absence of stone-axe cut beam ends are derived primarily from dry caves dating prior to A.D. 700 and located in the extreme northeastern part of Arizona. Unfortunately, many dated sites that cover the time range before the eighth century must be omitted because they are open sites where preservation of wood is in the form of charcoal which obscures the nature of beam ends.

The hafted stone axe has been adequately described by Woodbury (1954: 25-42). His typology, useful in ordering the artifacts themselves, is not the concern of this section since there is no way to distinguish from the cut beam which form of axe was used. In the broadest sense, and that used herein, an axe is a tool designed and used for chopping, and is hafted with a wooden handle to increase its efficiency.

Many years ago Earl H. Morris (1939: 37) noted the efficiency of the hafted stone axe as a result of experiments with an actual rehafted prehistoric axe. He demonstrated that the axe in the hands of a knowledgeable person was an extremely useful tool in felling trees of considerable diameter in a relatively short time. Similar experiments have been conducted in northern Europe (Iversen 1956: 36-41). Again, a prehistoric (Neolithic) axe was rehafted and used to experiment with the proper techniques required for its use. It was discovered that short quick strokes were vastly more efficient than the long swing associated with the technique used with a steel axe. The resultant

cut bore a remarkable resemblance to axe cut beam ends found in the prehistoric Southwest (Iversen 1956: 36, illustration).

Further experiments have been conducted by Halvor L. Skavlem (Pond 1930) who duplicated the lithic technology of prehistoric implements found in the Upper Great Lakes region. In addition to manufacturing grooved axes (Pond 1930: 89-94), Skavlem demonstrated that the axes he made were actually capable of felling trees. The resultant cuts, on hardwoods, resemble stone-axe cuts found in the Southwest (Pond 1930: 90, Plate 42).

Beam ends that date prior to A.D. 700 are presented in Table 2. The sites represented are concentrated in the Red Rock area (E. A. Morris 1959) and in the parallel canyon systems of de Chelly and del Muerto---both today encompassed in Canyon de Chelly National Monument. These two areas are both canyon systems which have been formed in an upland mass that extends southward from close to the Utah border just west of the Arizona--New Mexico state line. All of the sites have components that are classified as Basketmaker III in the well-known Pecos classification.

An examination of Table 2 indicates that three main methods of reducing trees to the required beam length are present. Broken, burned, and stone-axe cut beam ends occur in the data. These types are not necessarily mutually exclusive, as many beams whose basic felling was accomplished by burning or axe cuts exhibit breaking of the innermost portion of the tree as if the cutter, much as today, allowed gravity or human stress to finish the separation begun by him. However, the

Table 2. Dated Beam Ends from Rocketnaker Sites in Northeastern Arizona

Provenience	Catalogue Number	Species	Dates Inside	Dates Outside	Outer Ring	Comment on beam end
Obelisk Cave						
	GP-932	PIN	330p	- 446+vvB	Comp	Tool cut and burned
	MLK-152	DF	9p	- 478GB	Comp	One broken; one burned[a]
	GP-6673	PIN	405p	- 479vB	Comp	Burned
	GP-931	PIN	378p	- 480vv	Inc	Broken
	MLK-156	DF	2166p	- 480v	Inc	Burned, then broken
	MLK-280	DF	316p	- 480vL	Comp	Burned[b]
	MLK-150	DF	270p	- 484v	Inc	Both burned[a]
	GP-930	DF	419p	- 484vGB	Inc	Broken
	MLK-153	PIN	149+p	- 486B	Comp	Tool cut and burned
	MLK-154	PIN	292p	- 489vB	Comp	Three broken (two beams from same tree)
Broken Flute Cave						
Room 1	MLK-126	JUN	287p	- 501vB	Inc	Burned
	MLK-245	JUN	330p	- 508vLG	Inc	Burned

Table 2--Continued

Provenience	Catalogue Number	Species	Dates Inside	Dates Outside	Outer Ring	Comment on beam end
Broken Flute Cave (cont.)						
Room 2	GP-920	PHN	421p	- 499cLGB	Comp	Broken
Room 3	MLK-226	PHN	380p	- 505v	Inc	Not diagnostic
Room 8A	GP-866	PHN	283p	- 469rL	Comp	Burned
	GP-868	PHN	371p	- 469v	Inc	Broken
	GP-871	PHN	296p	- 470rL	Inc	Burned
	GP-870	PHN	376p	- 493v	Comp	Not diagnostic
	GP-869	PHN	359+p	- 494rG	Comp	Burned
Room 4[c]	MLK-103	PHN	422p	- 491rLGB	Inc	Broken
Room 5[c]	GP-887	PHN	312p	- 457+G	Comp	Broken
Room 6	MLK-134	DF	583p	- 622cL	Comp	Stone axe cut
	MLK-127	DF	521p	- 623cL	Comp	Stone axe cut[d]
	MLK-131	DF	580p	- 623cL	Inc	Stone axe cut
	MLK-133	DF	586p	- 623cL	Comp	Stone axe cut
	MLK-135	DF	548p	- 623cLB	Comp	Stone axe cut

Table 2--Continued

Provenience	Catalogue Number	Species	Dates Inside	Dates Outside	Outer Ring	Comment on beam end
Broken Flute Cave (cont.)						
Room 7	CP-6691	PIN	532p	- 623cB	Comp	Stone axe cut
	CP-6690	PP	593p	- 625v	Inc	Stone axe cut
	CP-875	PIN	525p	- 625cL	Inc	Stone axe cut
	MLK-137	PP	567p	- 625cL	Inc	Stone axe cut
Room 9	MLK-174	DF	404	- 515+v	Inc	One broken; one stone axe cut; probable splinter of dead tree
	MLK-170	PIN	512+p	- 623c	Comp	Stone axe cut
	MLK-173	PIN	529p	- 623rL	Comp	Stone axe cut
	CP-853	DF	556p	- 623rL	Comp	Stone axe cut
	MLK-164	DF	566p	- 624rL	Inc	Stone axe cut
	MLK-169	PIN	540p	- 624rL	Inc	Stone axe cut
	MLK-167	JUN	4424p	- 624rL	Inc	Stone axe cut
	MLK-171	PIN	547p	- 624rL	Inc	Stone axe cut
	MLK-176	JUN	527p	- 624L	Inc	Stone axe cut
	MLK-163	JUN	570p	- 624cLB	Inc	Stone axe cut

Table 2--Continued

Provenience	Catalogue Number	Species	Dates Inside	Dates Outside	Outer Ring	Comment on beam end
Broken Flute Cave (cont.)						
Room 9	GP-854	PSM	547p	- 624vLB	Inc	Stone axe cut
Room 11	GP-860	PSM	423vp	- 574vv	Inc	Broken
	GP-859	PSM	537p	- 621vB	Inc	Broken
	GP-6686	DF	544p	- 625cL	Comp	Stone axe cut
	GP-6683	PSM	515p	- 636+vvG	Comp	Broken
Room 12	GP-865	PSM	389vp	- 621B	Comp	Broken, later charred
	MLK-179	DF	534p	- 623L	Inc	Stone axe cut
	MLK-178	DF	558p	- 623cL	Inc	Burned and/or stone axe cut
No association	MLK-117	PSM	277p	- 437+vv	Inc	Broken
	MLK-109	PSM	460	- 597cB	Inc	Broken
	GP-901	PSM	430vp	- 623cB	Comp	Stone axe cut
	MLK-11A	JUM	503vp	- 623cB	Comp	Stone axe cut
	MLK-264	DF	572p	- 625cL	Inc	Stone axe cut

Table 2--Continued

Provenience	Catalogue Number	Species	Dates Inside	Dates Outside	Outer Ring	Comment on beam end
Cave 2, Red Rock						
	MLK-12	PP	571p	- 626cL	Inc	Stone axe cut
	GP-960	PMH	522p	- 665xL	Inc	Stone axe cut
	MLK-23-1	PMH	503p	- 668c	Inc	Broken
	MLK-21	PMH	476p	- 669vv	Comp	Broken (slightly axe cut?)
	GP-945	PMH	528p	- 669r	Inc	Stone axe cut
	GP-948	DF	574p	- 669cL	Inc	Stone axe cut
	GP-950	PMH	563+p	- 669cL	Inc	Stone axe cut
	GP-953	PMH	558+p	- 669c	Inc	Stone axe cut (?)
	GP-961	PMH	608p	- 670cL	Inc	Stone axe cut
Cave 6, Red Rock						
	MLK-200	DF	637p	- 674r	Comp	Stone axe cut
Mummy Cave						
	M-102	DF	351p	- 410c	Inc	Stone axe cut (?)
	M-142	DF	354p	- 433vv	Inc	Stone axe cut (?)

Table 2--Continued

Provenience	Catalogue Number	Species	Dates Inside	Dates Outside	Outer Ring	Comment on beam end
Mummy Cave (cont.)						
	M-129	DF	409p	- 486vv	Inc	Stone axe cut (?)
	M-125	PSM	388+p	- 489+vv	Inc	Tool cut
	GP-2990	PP	409+p	- 537vv	Comp	Stone axe cut
	M-147	PSM	475+p	- 649c	Inc	Stone axe cut
	M-137	PSM	510+p	- 657r	Inc	Stone axe cut
	M-139	PSM	515+p	- 658r	Inc	Stone axe cut
	M-145	JUN	495p	- 667c	Inc	Stone axe cut
	M-151	PP	647p	- 684cL	Inc	Stone axe cut
	M-155	PP	648p	- 703c	Inc	Stone axe cut
Vandal Cave						
	GP-972	DF	562p	- 672cL	Comp	Stone axe cut
	GP-973	PSM	573+p	- 672r	Comp	Stone axe cut
Twin Caves						
	GP-991	DF	631p	- 667r	Comp	Stone axe cut

Table 2--Continued

Provenience	Catalogue Number	Species	Dates Inside	Dates Outside	Outer Ring	Comment on base end
Twin Caves (cont.)						
	GP-282	DF	470p	- 667z	Comp	Stone axe cut
Yee-Ya-Tso Cave						
	GP-3137	PIN	328	- 381v	Inc	Heavily weathered
	GP-3108	PIN	282p	- 420+vv	Inc	Broken
	GP-3092	PIN	239p	- 421vv	Inc	Not diagnostic
	GP-3133	PIN	281p	- 475vG	Inc	Burned (recent camp-fire)
	GP-3090	PIN	359p	- 477+vvv	Inc	Both ends burned
	GP-3112	PIN	394p	- 504z	Inc	Tool cut
	GP-3129	PIN	375½p	- 504r	Inc	Stone axe cut (?)
	GP-3091	PIN	355p	- 506vv	Inc	Burned, then broken
	GP-3122	PP	479	- 523vv	Comp	Not diagnostic
	GP-3118	PIN	478p	- 525v	Comp	Burned
	GP-3109	PIN	393½p	- 527vB	Comp	Burned, then broken
	GP-3124	PIN	506p	- 657vL	Comp	Stone axe cut

Table 2--Continued

Provenience	Catalogue Number	Species	Dates Inside	Dates Outside	Outer Ring	Comment on beam end
Tse-Ya-Tso Cave (cont.)						
	GP-3126	PEH	516p	- 668v	Inc	Stone axe cut
	GP-3079	PEH	571p	- 700v	Comp	Broken
	GP-3117	PEH	623p	- 709v	Inc	Burned
	GP-3084	PEH	661p	- 712+v	Inc	Burned
	GP-3086	PEH	628p	- 715vv	Inc	Burned
	GP-3083	PEH	626p	- 715v	Inc	Burned and stone axe cut (?)
	GP-3085	PEH	553	- 715c	Inc	Stone axe cut
	GP-3121	PEH	673p	- 716c	Comp	Broken

a - Field observation only
b - Burned house
c - Rooms 4 and 5 also have beams dated in the 600's. These are probably reused from the earlier horizon.
d - Four main uprights from a single tree; all stone axe cut ends

classification here employed is based on the main method of felling only. The category of broken beam ends is restricted to those trees that show only that method of size reduction and, therefore, is normally found when diameters of the beam do not exceed 10 cm. With a very few equivocal cases, the time distribution of the three types of felling is clear. Stone-axe cut beam ends occur only after A.D. 600, whereas burned beam ends occur only before A.D. 600. Broken beam ends fall in both periods.

Some exceptions do occur within the time distribution. At Mummy Cave (Table 2) there are four beams that date before A.D. 600 and that seem to have stone-axe cut beam ends. Unfortunately, the true provenience of all of these is unknown since they were all located lying loose on the talus slope in front of the cave. I suggest that since the cave, unlike Obelisk, had a later Pueblo occupation, the stone-axe cuts may date from that period rather than the period of original use. I admit, however, that there is not at present any easy method to distinguish between cuts made on green living wood as against those made on dry dead wood.

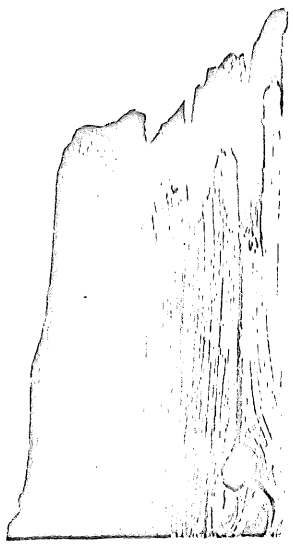
Caution must be exercised in the use of burned beam ends. Whereas stone-axe cut and other tool cut beam ends are fairly readily recognized, the presence of a burned end may represent either the method of felling or accidental charring during destruction by fire of the structure in which the beam was used. There are two observations that may resolve the issue. In the present data many of the houses in Broken Flute Cave were destroyed by fire (E. A. Morris 1959)

and beams which had been set upright in the ground were charred to near ground level. Fortunately, the nature of the dry cave preserved the below-ground portion of the upright and it is from these ends that an observation of stone axe cutting has been made. Obelisk Cave, an equally dry cave, also has charred beam ends, some of which may be due to post-construction burning of the structure. Since the excavation notes have been lost, there is no way to be sure if such did occur. However, unlike Broken Flute, no beam ends exhibit stone-axe cut ends. Those that are not charred are simply broken. A second observation leading to an assessment of burning as a method of felling rests in the nature of the burned end. In most cases noted in the data the diameter of the tree was reduced by fire only to the point where the tree either fell by itself or could be pushed over. This process left a core of broken and splintered wood near the center of the end that was not charred (Fig. 2). The remaining presence of this unburned part of the beam end implies charring before felling rather than after.

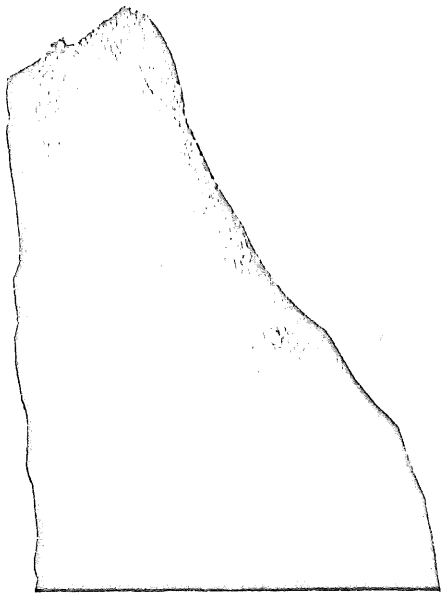
Because of the limited spatial distribution of the preserved evidence of dated beam ends, I must use observations of undated material and the distribution of stone axes to suggest the full range of the introduction of the stone axe.

The distribution of stone axes based on archaeological observations of axes themselves and on beam ends is in good agreement with the evidence gleaned from tree-ring dating analyses.

Basketmaker II sites in the Southwest have no stone axes. In fact, writing on Du Pont Cave in south-central Utah, Kidder (1932:

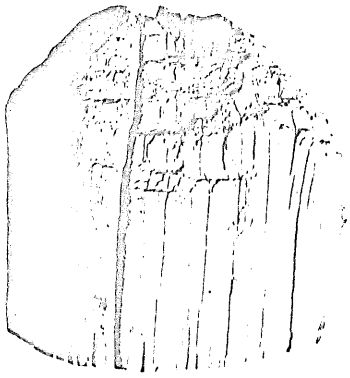


a



b

c



d

Fig. 2. Types of Beam Ends. a, broken; b, burned; c, steel-axe cut; d, stone-axe cut.

36-7) remarks ". . . stakes are all either burned off or broken off at the ends; these were the only methods ever used, apparently, for reducing the length of small stakes." Some years after the typological placement of Du Pont Cave as Basketmaker II, Stallings dated a single pinyon beam from the cave at A.D. 217 (Stallings 1941). A recent reanalysis of this beam by the Laboratory of Tree-Ring Research failed to verify the date and, in hopes of obtaining better material for dating, I visited the cave in 1966. Although the objectives were not met, I was able to verify that none of the beams (20± still extant) exhibited stone-axe cut ends. All beams were either broken or burned with a preponderance of broken ends.

In the well-known Durango, Colorado, Basketmaker II zone axes were also absent (Morris and Burgh 1954: 54-60, 84). These remains are dated approximately A.D. 1 to 400 (Morris and Burgh 1954: 48-9; Schulman 1952: 30-5), but preservation is entirely in the form of charcoal, thus masking the actual nature of the beam ends. Somewhat to the south, axes were similarly absent in the pre-A.D. 500 Los Pinos phase sites (Eddy 1961: 67-84). Nor do stone axes occur in the classic Kayenta Basketmaker II horizon (Kidder and Guernsey 1919: 187; Guernsey and Kidder 1921: 112; Guernsey 1931: 83). In fact, no axes appear in this area even in the following Basketmaker III period. In recent years Laboratory of Tree-Ring Research expeditions in the Kayenta region---notably, Tsegi-of-Soal Canyon---in search of datable Basketmaker timbers have verified by field observation the lack of stone-axe cut beam ends in sites of this age.

Stone axes do appear in the Basketmaker III period. Roberts (1929: 135-6) found no axes at Shabik'eschee Village, a Basketmaker III site in Chaco Canyon, northwestern New Mexico, and further notes that axes are rare elsewhere in this Basketmaker period. However, their presence was noted in Basketmaker III sites in southwestern Colorado (Martin 1939: 408-10), on the Hopi Mesas (Daifuku 1961: 54), and elsewhere.

A small number of stone axes was found during the excavation of Broken Flute Cave (E. A. Morris 1959: 265-7), but they are not present in the collection from Obelisk Cave. These data parallel precisely the evidence presented from the dated beam ends.

Toward the southern limit from which tree-ring evidence is available, axes are absent at the Bluff site (Haury and Sayles 1947: 83), a village dating in the fourth century (Bannister, Gell, and Hannah 1966: 34). Axes are still lacking among the tools from Mogollon Village in west-central New Mexico more than 200 years later (Haury 1936: 105-6). There are no axes at the SU site north of Mogollon Village in New Mexico (Martin 1940, 1943; Martin and Rinaldo 1947), but two axes were found at Crooked Ridge Village in the Point of Pines area. One of these was associated with a late pueblo, but the other came from the floor of a pithouse that was placed as pre-A.D. 600 (Wheat 1954: 129-30). The only other occurrence of the stone axe in a pre-A.D. 500 horizon was at Snaketown, a village of the Hohokam Culture on the banks of the Gila River in southern Arizona (Gladwin and others 1937: 110).

Thus the distributional data, confirmed in part by the observation of beam ends, indicate that the stone axe was part of the tool inventory of the southern portion of the Southwest in a pre-A.D. 500 period, and that it spread northward to become accepted in the tool complex of the more northern traditions by or shortly after A.D. 600.

Use of Dead Wood

The argument presented by O'Bryan (1949) on the use of dead wood before the stone axe came into use seems plausible at first glance. Succinctly stated, he suggests that, although many tree outside dates fall in the first half of the first millennium A.D., the dates do not represent the time of actual use by man because of the common practice of using dead wood---death having occurred by natural causes. He further suggests, based on known ages for still-standing dead trees, that the margin of error between tree death and use by man may approach 200 years in extreme cases.

The fact that some dead wood was incorporated into structures of later ages is indisputable. Dean (1967: 512-13) has observed a specific use of long dead material in the structures of late Pueblo III sites in Teegi Canyon. There many splints were used in the planking of roofs in the large cliff dwelling of Kiet Siel which consistently yielded dates earlier than the dates derived from the full-section beams supporting the roof. From the similarity in shape, Dean was able to deduce that the splints were, in fact, sections of dead, but probably standing, snags which even today will produce similarly shaped splints.

Although occasional construction timbers used before the knowledge of the stone axe may have been dead when felled by man, the data from Obelisk Cave (Table 3) suggest that living trees were also felled. The following facts logically suggest that the constructional timber in Obelisk Cave was used shortly after death and that death was caused by human agency without benefit of the stone axe.

The causes of natural death in trees are old age, fire, disease, and environmental stress. Obelisk Cave may be used as a test against each of these variables. There are 13 specimens, 10 of which---including all those with death (cutting) dates---have terminal dates that cluster within an 11-year period. Two species, pinyon pine and Douglas-fir, are represented.

The ages at death of the timbers in Obelisk Cave vary from nearly 500 years to only 65 years. This fact alone would argue strongly against natural death due to old age for the trees involved. Although a tree exhibiting a life span of around 500 years is old for either species, the younger trees' death cannot be considered to be due to old age. The distribution of the trees eliminates forest fire as a cause for the death of all trees. The immediate environment of Obelisk Cave restricts Douglas-fir to small discontinuous groves in the heads of short well-watered, and often spring-fed, rincons cut into the vertical cliffs of sandstone. Pinyons, on the other hand, grow mainly on the mesa tops and talus slopes in scattered stands mixed with juniper. Thus the distribution of the species is today nearly mutually exclusive and there is no reason to believe that it was different in the past. A

Table 3. Death Dates of Timbers from Obelisk Cave

Catalogue Number	Species	Outside Date	Cutting Date
CP-922	PNN	325v	No
CP-923	DF	436vv	No
CP-932	PNN	446+vrB	No
MLK-152	DF	473rB	Yes
CP-6673	PNN	479rB	Yes
MLK-151	DF	479rG	Yes
MLK-156	DF	480v	No
CP-931	PNN	480vv	No
MLK-230	DF	480rL	Yes
CP-930	DF	484rGB	Yes
MLK-150	DF	484v	No
MLK-153	PNN	486B	Yes
MLK-154	PNN	489rB	Yes

forest fire would not, therefore, affect both species, and it is unlikely that the Douglas-fir would be subject to this hazard at all. The effects of disease are difficult to assess. However, the fact that two dissimilar species are represented and that the age spread of the individual trees is so great would suggest that the cause of death of the trees was not disease. For reasons mentioned above, the aspects of environmental stress cannot now be assessed. But again the nature of the species and the ecological distribution strongly argues against this factor as a cause of death.

The presence of bark on many of the log specimens reinforces much of the argument. None of the timbers show any sign of burned bark except that near the symmetrically burned end, despite the fact that as much as 8 to 10 feet of the sound logs are still present in the cave. The bark also suggests that the trees were not exposed to the elements of weather for a great many years after death or some bark loss would have taken place.

The above data indicate that the death of the trees used as structural timbers in Obelisk Cave was due to human agency rather than natural causes, although it cannot be demonstrated that all were felled by man. It is certainly possible that a few may have died naturally, and this fact may account for the early dates. The death of so many trees in this restricted time period is interpreted as caused by men using techniques of fire-girdling and breaking as well as chopping with a hand-held stone chopper. The inference that actual use in structures was not long delayed after felling is logical.

Other Technology

One of the problems that has long plagued the chronological aspects of tree-ring dating has been the relatively large number of duplicate specimens in many large charcoal collections from a single structure. These have often resulted in the release of many dates when, for interpretive purposes, only one date is valid for each log or beam no matter how many pieces it presents to the collector. Specimens whose growth patterns are too similar simply to reflect normal inter-tree correspondence are usually assigned to a single original tree. Little consideration has been given, however, to the possibility that, although the specimens may indeed derive from the same original tree, they may also represent distinct structural components.

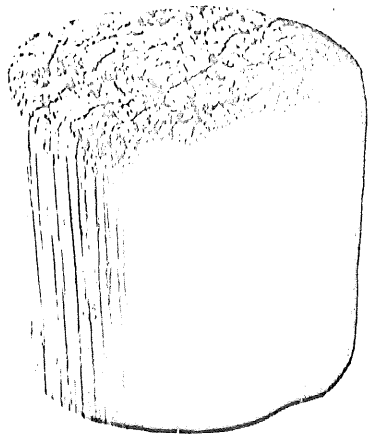
The recognition of the multiple structural use of a single tree is probably difficult at best in burned or in poorly preserved structures. In the well preserved and unburned cliff dwellings, however, this pattern can be recognized. There are two instances at Kiet Siel, a late Pueblo III cliff dwelling in Tsegi Canyon, where the same tree had been used for more than one beam in a room (Dean 1967: 398, 401). At the well-known Basketmaker III site, Broken Flute Cave, a single tree was sectioned and used for all four main uprights in Pithouse 6. Occasionally beams cut from the same tree are found in different structures.

The technological treatment of beams often went beyond the limits of necessary structural qualities. Scott (1966: 35-6, 75) noted the artificial shaping of beams at the ruin of Casas Grandes in northern

Chihuahua, Mexico. This shaping involved the reduction in diameter of the thicker end of the bole of the tree which resulted in a uniform diameter of the beam from end to end. Scott was not able to recognize any structural necessity for this practice and suggested that the shaping was done for purely aesthetic reasons.

Two practices at the ruins of Chaco Canyon seem more related to aesthetics than practicality. Judd (1964: 18, 26) remarks that the timbers were peeled of bark while still green and that the knots were abraded smooth. In addition, it may be noted that the shape to which the beam ends were finished contrasts sharply with most stone-axe cut beam ends in the Southwest. Figure 3 shows this contrast. The majority of beam ends are asymmetrical and have a core of broken and splintered wood (Fig. 3 *b*). The technology suggested by this form is as follows: trees were notched, as is done today with steel axes, perhaps to control the direction of fall, and pushed over, completing the felling operation by breaking. While this form is revealing of technology, it is far from aesthetic. Most Chaco Canyon beams, however, are smooth, rounded, and symmetrical (Fig. 3 *a*). Practically all of the characteristic dimpling effect left by the stone axe is removed by the smoothing process. Often a sharp line is incised just at the beam end, which suggests that the beams were marked for cutting to an exact length.

These practices noted mainly at the Chaco Canyon ruins and related ruins such as that at Aztec, New Mexico, have no obvious practical nature. They are harmonious, however, with the equally



a

b

Fig. 3. Stone-Axe Cut Beam Ends. a, trimmed and smoothed; b, unaltered.

aesthetic treatment of masonry in Chaco Canyon and the great degree of symmetry and planning of the communities themselves.

Evidence of technology, then, relating to tree felling and wood use is preserved on materials submitted for tree-ring dating. Analysis of the beam ends shows a distinct time difference in the main method of felling, emphasizing the introduction of the stone axe about A.D. 600. This distribution is corroborated by archaeological evidence. Prior to the use of the stone axe, felling was accomplished by fire girdling of living trees. The suggestion that only dead trees were so felled is contradicted by the close clustering of the time of death. In certain areas, notably Chaco Canyon, beam ends were aesthetically shaped and smoothed, but generally in the Southwest the marks of the stone axe were not removed from the beam end.

CHAPTER 4. SPECIES

Wood was used by the aboriginal inhabitants of the Southwest for many purposes. The most obvious categories are housing construction, firewood, and, in the traditional sense, various artifacts. These artifacts---tools made of wood---tend to be small in size and are rarely preserved except in dry caves or in the form of charcoal. In the latter case, the characteristic form of the artifact is usually destroyed by the burning. In addition, wooden artifacts, even if well preserved, are rarely submitted for tree-ring studies since, by its very nature, the analysis would destroy the integrity of the artifact. All the evidence, then, for the cultural selection of species comes from the remaining categories: constructional material and the residue of heating or cooking fires. Of these, a far greater number are construction timbers.

From archaeological sites in that part of the Southwest that has been successfully dated by dendrochronology, only a limited number of species are represented in the tree-ring collections. These are Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco), ponderosa pine (Pinus ponderosa Laws.), pinyon pine (Pinus edulis Engelm.), white fir (Abies concolor), and the genus juniper (Juniperus sp.). The identification of the various juniper species is dependent on characteristics of the living tree and, as a consequence, no specific nomenclature is possible based on the wood alone. White fir is included in the listing

because of its strong showing at a few sites, although, when considered throughout the Southwest, it occurs at only a few sites in very restricted localities. Other species, present but not usually datable, are oak (Quercus sp.), aspen or cottonwood (both Populus sp.), and box elder (Acer negundo). This group represents a very small percentage of the total collection from most sites (in all cases less than 5%) and does not enter into the discussion of selection of species unless present in quantity. The selection of these species for this study is obviously determined by their utility in dating or their concomitant existence in areas where dating is possible. There are other arboreal species, mostly in true desert regions, where tree-ring dating has not been applied, that have not been analyzed.

Since the aboriginal users of wood were confronted with choices of species, it should be possible in many cases to detect patterns in the remains that reflect the choice exercised and allow inferences regarding the basis of selective use.

Before discussing the evidence for such patterns, however, two elements must be introduced which actually or potentially bias the data. First, sites that have been sampled for the primary purpose of chronology building will not reflect the true distribution of species based on aboriginal selection. An excellent example of this bias is the collection from the village of Oraibi on the Hopi Mesas which shows a high proportion of Douglas-fir when compared to other sites in the Hopi region (Table 4). It must be kept in mind, however, that most of the sampling from this village was done for the specific purpose of

Table 4. Distribution of Species in Selected Sites

Site	Species					
	DF	FIN	JUN	YP	WF	Other
Vandal Cave	2	6	-	1	-	1
Twin Cave	3	8	-	3	-	-
Mummy Cave	72	43	31	24	-	3
Mummy Cave No. 2	4	14	14	5	-	3
Tse-Ya-Tso	4	41	6	7	-	2
Antelope Cave	1	1	3	2	-	1
White House	9	1	12	29	7	-
Sliding Ruin	4	4	4	11	-	1
Three Turkey House	1	2	3	2	-	2
Broken Flute Cave	75	77	47	20	-	-
Cave 1 (Red Rock)	2	4	-	6	-	-
Cave 2 (Red Rock)	25	24	2	24	-	1
Cave 6 (Red Rock)	14	1	-	-	-	-
Cave 7 (Red Rock)	5	-	-	-	-	-
Obelisk Cave	9	10	2	-	-	-
Prayer Rock Cave	4	4	2	-	-	1
Allantown	16	224	45	8	-	-
Ariz. K:12:5	1	19	15	-	-	-
Ariz. K:12:6	1	16	22	1	-	-
Ariz. K:12:8	2	19	3	10	-	-
Ariz. K:12:10	-	4	5	5	-	-
Black Creek Cave	-	-	-	11	-	-
White Mound Village	-	46	1	-	-	-

Table 4--Continued

Site	Species					
	DF	PIN	JUN	PP	WF	Other
Kin Tiel	-	313	12	17	-	-
Kin Li Choo	-	26	35	15	-	-
NA 3941A	-	24	1	-	-	-
Cross Canyon	-	75	9	79	-	1
Houck Group	-	167	93	-	-	10
NA 7512	-	20	-	1	-	-
NA 7424	-	4	2	-	-	-
Ariz. K:7:1	-	13	3	-	-	1
Ariz. K:7:12	-	34	-	-	-	1
Ariz. K:7:14	9	49	7	28	-	3
NA 8968	-	9	6	-	-	2
Awatovi	100	207	322	192	-	22
Chakpahu	-	12	5	-	-	1
Kawaikuh	3	107	34	2	-	2
Kokopnyama	-	207	104	1	-	6
Orailbi	134*	8	42	34	-	10
Payupki	-	-	5	-	-	2
Pink Arrow	-	28	-	-	-	-
Shungopavi	54*	-	-	3	-	-
Sichomovi	40	-	-	2	-	-
Site 4	1	20	2	-	-	-
Site 4A	-	56	16	-	-	-
Site 104	-	102	3	-	-	-

Table 4--Continued

Site	Species					
	DF	PNI	JUN	PP	WF	Other
Site 107	-	9	1	-	-	-
Site 111	-	16	2	-	-	-
Joddito 264	-	71	91	-	-	-
Walpi	9*	1	1	-	-	2
Homolovi	2	-	1	2	-	1
NA 2597	17	-	-	11	-	-
Site 108	-	7	1	-	-	-
Inscription House	3	4	8	-	-	-
Red House	-	2	-	4	-	-
Calamity Cave	6	4	-	-	-	1
Long House	9	2	2	-	-	-
RB-MV 551	11	15	20	-	-	-
RB-MV 568	-	8	10	-	-	6
Juniper Cave	-	5	4	18	-	18
Marsh Pass 7:4	-	1	38	-	-	-
Marsh Pass 7:10	2	3	-	-	-	-
Pottery Hill	-	9	8	-	-	-
Ruin 8	4	6	23	-	-	3
White Dog Cave	1	30	15	-	-	3
Cave 1 (Kin Biko)	-	76	47	2	-	27
Betatakin	113	29	86	-	-	56
Scaffold House	12	12	8	-	-	-

Table 4--Continued

Site	Species					
	DF	PEN	JUN	PP	WT	Other
KB-MV 1006	2	28	17	-	-	4
Klot Stal	97	38	80	-	54	217
Turkey House	4	2	4	-	1	3
Turkey Cave	13	62	13	-	1	3
Batwoman House	4	4	5	6	-	1
Lenaki	23	20	98	10	-	-
Twin Caves	65	8	10	8	-	1
NA 2606	3	-	4	-	1	-
Woodchuck Cave	-	30	2	-	-	1
NA 2543	4	-	1	-	-	1
NA 2629	10	1	10	2	-	1
NA 8163	-	2	22	-	-	-
NA 8166	-	1	9	-	-	-
NA 8300	57	5	3	1	-	-
Cave 3 (Kiln Diko)	-	5	-	-	-	-
Cave 4 (Kiln Diko)	-	9	-	-	-	-
NA 8000	45	5	10	-	-	-
Total	1095	2574	1572	607	64	425

[a]Known collection bias

chronology building (Douglass 1935: 24-6) and that Douglas-fir was thus preselected in the field by the collector. Consequently, the distribution of species from such a site is biased and does not represent aboriginal selection. Some cases such as Orabi are well known and may be easily avoided in discussion of species distribution, but there are undoubtedly other cases where preselection has been practiced by archaeologists in an attempt to eliminate undatable materials from submitted collections. Second, the present ecological distribution of species is not necessarily the same as that during the period of aboriginal occupation (Stein 1964). Many areas, especially canyon systems such as Tsegi Canyon in northern Arizona, do exhibit a species-to-species correspondence between prehistoric beams and living trees. However, there is no assurance that the relative proportion between species has remained constant over the centuries. Other areas exhibit a substantial difference between the mere existence of present and past species. It is not necessary to review this difference in Chaco Canyon, northwestern New Mexico, as it has been discussed at some length by Douglass (1935: 45-7) and recently by Vivian and Mathews (1965: 7). It should simply be noted that the great numbers of trees of the species used in the construction of roofs and doors at the vast ruins of Pueblo Bonito (Judd 1964: 17) and Chetro Ketl (Hawley 1934) are not present in or near the canyon today; nor are they found within such a distance that would allow aboriginal transportation to the canyon living sites. A similar situation is found along the Puerco River in Arizona where the sites show a strong preponderance of pinyon pine

(Table 4). Few trees of this species grow close to the river at the present time, however, and the only arboreal species present is juniper. Whatever the reasons for the changes in arboreal cover, whether deforestation or shift in species, the changes do lead to difficulties, and perhaps bias, in the interpretation of the selective use of species indicated in the distributional data.

Inherent Qualities of Wood

It is a well recognized fact in contemporary culture that certain woods resist the effects of ground decay better than others. Throughout the Southwest "cedar" is preferred and extensively used for fenceposts and other uses that involve contact of wood and soil. Although locally known as "cedar," this wood is actually one of the three main species of juniper (*Juniperus* sp.).

There are indications that this knowledge of the quality of juniper was also shared by the aboriginal inhabitants of the Southwest. Speaking of a structure (NA 2134A) at Winona, a 12th century village east of Flagstaff, Arizona, McGregor (1937: 20) states that its

> . . . main supporting posts, which were set into the ground, were of juniper, while almost all the rest of the supporting poles, and posts, were of pine. This might possibly indicate a knowledge that juniper would be more resistant to rot than pine when partially buried.

A similar case was observed by Stallings (1937: 51-60) at the Riana Ruin on the Chama River in north-central New Mexico. He noted that a burned kiva evidenced the same pattern of juniper upright posts and pine horizontal beams.

At the late Pueblo IV ruin currently under investigation by the University of Arizona Archaeological Field School at Grasshopper on the Fort Apache Indian Reservation in central Arizona (Thompson and Longacre 1966), two patterns of selection of species are manifest. The Great Kiva, a structure of large proportions, was roofed using 12 interior upright logs to share the weight of the roof load with the walls. Each of these uprights was a massive juniper post, as evidenced from the log butts still in the ground. However, nearly half of the specimens recovered from the fill of the Great Kiva were ponderosa pine, suggesting that the main cross beams were of this species. Thus another example of the repetitive pattern of juniper posts and pine cross beams is noted. Many of the domestic rooms at the Grasshopper Ruin contained samples of both juniper and ponderosa pine or Douglas-fir, but no observations were made regarding the possible differential use of the species.

In addition, another pattern relating to species and architectural features was noted at the Grasshopper Ruin. A series of contiguous masonry-lined pits or roasting ovens were excavated immediately outside the eastern limits of the pueblo. A number of charcoal specimens were recovered from the ovens and, with a single exception, all proved to be pinyon pine. The fragrance and thermal qualities of pinyon pine are known and enjoyed today and it is perhaps not unreasonable to infer that the inhabitants of Grasshopper Ruin appreciated one or both of these qualities of pinyon.

This pattern suggests that more attention should be paid to the species represented in fireplace residue, particularly in regions where

prehistoric man could avail himself of a choice of species. In Chaco Canyon, Hawley (1934: 34) reports an effort to date stratigraphic units in a large trash mound using the included tree-ring samples. She notes in passing that this material was almost entirely pinyon pine but fails to recognize that the pinyon is strongly over-represented in the trash when compared to the species used for construction. Bannister's very thorough study of the Chaco ruins makes it clear that ponderosa pine, Douglas-fir, and white fir are the dominant woods for construction (Bannister 1965). Trash mounds are accumulations of daily sweepings, broken and discarded tools and pots, and fireplace residue. The abundance of pinyon pine in this melange suggests that pinyon was a favored firewood in contrast to the favored structural woods.

In his recent and highly detailed study of the chronology of Tsegi phase sites in northeastern Arizona, Dean (1967: 519-21) also finds a preferential use of pinyon pine, and juniper in this case, in the fireplaces at the ruin of Kiet Siel. As at Chaco Canyon, this selection is supported by the abundance of pinyon pine charcoal in the village trash. Using a Chi Square analysis, Dean (1967: 310-15) was also able to demonstrate a relationship between species and use at Betatakin, a large Tsegi phase cliff ruin. Again, the denser wood, in this case pinyon pine, was preferred for uprights, and the long straight trunks of Douglas-fir for horizontal construction members. Dean's study is a model of the possibilities of nonchronological interpretation of tree-ring analysis where proper archaeological controls are employed.

Jeffrey S. Dean and I observed a preferential use of species in the course of excavation of a burned pithouse near Kayenta, Arizona (NA 8300, Museum of Northern Arizona Survey). More than 90% of the burned material in the house, representing the roofing members (both rafters and lagnars), was Douglas-fir. Yet three of the four main upright posts that were still in situ adjacent to the perimeter of the pit were juniper.

Perhaps three alternative explanations are credible for the suggested preferential use of juniper for posts. Although I favor the explanation of the aboriginal recognition of the decay-resistant qualities of juniper, it may be that the selection was based on the greater compression strength of the denser wood available or on the presence of forks in juniper which would easily hold the horizontal roofing members. The factor of compression strength is weakened when it is recalled that many of the Great Kivas in Chaco Canyon and elsewhere (Vivian and Reiter 1960: 90-1) had roofs supported, adequately it would seem, by ponderosa pine upright posts. The load of the roof in these kivas certainly exceeded that of most of the examples mentioned above. The presence of forks in juniper cannot be quickly dismissed since the evidence that the fork was actually present, although it is recognized in living trees, is not preserved at any of the sites where preferential use was noted. It is perhaps wise, then, to leave this alternative open.

Function of Structure

In addition to a cultural preference shown by use-category, there is evidence of the preference of certain species selected by type or function of structure.

In the general area of the Colorado Plateau, which also provides most of the data used herein, there are normally three categories of architectural types based on physical properties and the subsequently inferred function. These are domestic or living rooms, storage rooms, and ceremonial chambers. The latter are commonly referred to as kivas and bear an evolutionary relationship to the subterranean ceremonial chambers in use today on the Hopi Mesas. Smith (1952a: 154-65) has an excellent discussion on the problems of identification of prehistoric kivas.

Although the precise architectural form of each of these types changed through both time and space, the basic categories hold throughout the area of the Colorado Plateau from at least Basketmaker III times to the end of prehistory.

Of all of the sites listed for species distribution, three show a more frequent occurrence of the straight-holed conifers in kivas (Table 5). These sites are located in areas dominated by a pinyon pine--juniper community, and there is no reason to believe that the arboreal-type distribution was substantially different at the time of occupancy of the sites. Douglas-fir and ponderosa pine were available to the inhabitants of these sites only with the expenditure of a great deal of effort in transportation. This would suggest that the care and

Table 5. Species Distribution by Type of Structure

Site/Structure	Species PIN	JUN	DF/PP
AZ-MV 551			
Domestic Rooms	14	7	2
Detached Kiva	-	10	8
NA 3013, Grace Canyon			
Domestic Rooms	45	1	5
Kiva 1	30	0	74
Area. K:7:14			
Domestic Rooms	37	7	18
Kiva	12	-	19

effort in obtaining "proper" logs for the construction of kivas paralleled the additional care so often noted in the masonry of this type of structure.

At the Kiana Ruin in the Chama Valley of northern New Mexico, Stallings (1937: 51-2) found the same high frequency of pine in the kiva belonging to this site. Again the site is located in a pinyon-juniper arboreal association and these woods, along with cottonwood (Populus sp.), formed the materials strongly represented in the domestic structures. Furthermore, Stallings noted that the growth patterns of the ponderosa pine, which could not be dated, were characteristic of forest interior growth, suggesting that the trees used in the construction of the kiva were indeed transported from a considerable distance.

During the late 1930's the Peabody Museum of Harvard University excavated the large ruin of Awatovi located at the southern edge of Antelope Mesa, just east of the Hopi Mesas. The site was the location of a Spanish mission in the 17th century, but the occupation extends back into the 13th century (Burgh 1959).

Although segments of the excavations at Awatovi have been published (Montgomery, Smith, and Brew 1949; Smith 1952b; Woodbury 1954), most of the details of the nature of the aboriginal occupation remain obscure.

Nearly 850 original tree-ring specimens were recovered from the excavations. These were originally dated by a member of the Awatovi Expedition, E. T. Hall, Jr., who developed a long and useful chronology

(Hall 1951). The recent reanalysis divulged, in the course of dating, much information about species and associations within the ruin that is based on original field designations of provenience and the architectural descriptions in Smith (1952b) and in Montgomery, Smith, and Brew (1949).

The vegetation of the mesas in the Hopi region is characterized today by scattered pinyon and juniper with extensive stands of sagebrush (Mack 1942: 9). Douglas-fir and ponderosa pine grow mainly far to the north on Black Mesa at elevations at least 1000 feet higher than the elevation at Awatovi (about 6300 feet). The question arises immediately, due to the large numbers of these species represented in the Awatovi and Oraibi collections, about the nature and magnitude of environmental shifts that may have occurred in the Hopi region during the lengthy occupation of Awatovi. A trip of from 40 to 50 miles would be required to transport---by human back and arm---these species to Awatovi with the present ecological distribution. There is folklore that during the Spanish period the Hopis were required to bring beams from the San Francisco Peaks near Flagstaff to roof the mission buildings, but the growth characteristics of the tree-ring specimens available would belie this. Surely cutting activities on Black Mesa over five or more centuries may in part account for the present distribution, but, based on the inferred magnitude of climatic fluctuations in northern Arizona in the last millennium, I would hazard that although Douglas-fir and ponderosa pine may have once grown closer to Awatovi, they were never easily obtainable in terms of distance.

With this assumption, the distribution of various species at Awatovi reflects a familiar pattern. Table 4 shows the following totals for Awatovi: 100 (12%) Douglas-fir, 192 (23%) ponderosa pine, 207 (25%) pinyon pine, 322 (39%) juniper, and 22 (3%) nonconiferous, mainly cottonwood. In distribution, slightly over 50% of the Douglas-fir and 65% of the ponderosa pine were found in just eight architectural units of the more than 1300 excavated at Awatovi. The remaining amounts of these species were scattered widely and thinly through the other provenience units. Of these eight structures six may be identified with confidence as kivas (Smith 1952b: 10, Table 1).

The two remaining structures present a problem. One (Room 734) is identified as a sacristy for the final church of the mission complex, although it was very likely constructed as a domestic mission room earlier in the 17th century (Montgomery, Smith, and Brew 1949: 20). The fact that a great deal of roofing material was found suggests that the structure may have been reroofed when it was converted to a sacristy as similar amounts of roofing material are not found in older mission rooms that were abandoned earlier. Since all occupation of the site ceased at the approximate time that Room 734 was abandoned, the timbers of the roof would not have been stripped out for reuse. This does not, however, solve the problem of the original source of the timbers in Room 734. They may have been cut for that roof or robbed from elsewhere at Awatovi, perhaps from a kiva(s). Certainly the inhabitants of Oraibi reversed this process and reused Spanish mission beams in their kivas (Douglass 1929: 753).

The architectural classification of the second room (724) is unknown, but some indications lead me to believe that Room 724 is the field provenience for the third, and last, church. If this is correct, the structure would be contiguous and contemporaneous with Room 734 and share its problems. Normally, the dates of the timbers in a case like this could be expected to provide a clue in this dilemma. But no true outside rings were found on the specimens and, as a consequence, all dates fall much earlier than the historic dates for the mission and some fall earlier than the site occupation.

Despite the equivocal statement on these two rooms, the high frequency of Douglas-fir and ponderosa pine found in kiva context at Awatovi reinforces the preference noted elsewhere to obtain these timbers for kiva construction at some expense of effort.

Analysis of this kind is restricted to sites with a fairly narrow range of ecological conditions and cannot be applied universally. Sites located in or near extensive stands of ponderosa pine exhibit no patterns of preferential use of species. Similarly, sites located in the canyon systems of the Colorado Plateau show no such preference of species by type of structure, although a considerable choice in species was here available. This latter failure may be due to the nearly equal availability of many species that would tend to obscure the selection by structure type. Finally, the necessary archaeological controls and provenience information are lacking for many sites. The collection from NA 2597 (Museum of Northern Arizona Archaeological Survey) near Leupp, Arizona, is made up entirely of ponderosa pine and Douglas-fir.

Laupp today lies in a nearly treeless area, and I doubt if pine or Douglas-fir ever grew conveniently to the site. The species and situation suggest that the structure from which the specimens came is a kiva, but, unfortunately, no description whatever is available for the site.

Time Series

The attempt to analyze species use through time ran into many difficulties. The most serious of these was the lack of environmental controls. There is ample evidence that the arboreal distribution has changed substantially in many areas since the time of aboriginal occupancy. The Chaco Canyon forest disappearance is perhaps best known (Vivian and Mathews 1965: 7), but other shifts are equally well documented in tree-ring analysis by observation of species represented in prehistoric collections as contrasted with extant species in the same areas. This phenomenon occurs mainly, however, in open lowlands such as Chaco Canyon, the Puerco (west) River drainage, and parts of the Chinle drainage.

Less important, perhaps, is the lack of a sufficient sample in the data through a long enough time period in restricted environments. Since tree-ring collections are fortuitous in terms of both preservation and archaeological sampling, this condition is rarely met.

Although nature and extent of shifts in tree distribution that may have occurred during prehistoric occupancy of any given area is unknown, there is one possible environmental area which evidence suggests may remain relatively stable through time in regards to tree distribution. Dean (1967: 315-16) has shown that the species present

prehistorically at Betatakin, a Pueblo III site in a restricted canyon environment, are the same as the present assemblage of trees. This, of course, is based on simple presence or absence of species, since no estimation of relative frequency of each species can be made.

Assuming stable environmental conditions in restricted canyon lands, the sites in the Canyon de Chelly--Canyon del Muerto system of northeastern Arizona meet the further requirement of time depth and sufficient sample.

Table 6 gives the relative frequencies of the dated species from five main sites in this canyon system by the century to which the terminal ring dates. There is a smaller sample involved than in Table 4 which gives the distributions of all species by site, because only those samples accurately placed in time are considered. The sites are Mummy Cave, Tse-Ya-Too, White House, Mummy Cave No. 2, and Sliding Ruin (Dannister, Dean, and Gall 1956). The inclusive dates range from A.D. 306 to 1284 and a sample of 181 specimens is involved.

The fluctuating frequencies can best be seen in Figure 4. Douglas-fir occurs in highest frequency at the beginning of the time scale and again at the end. The dominance of ponderosa pine is between A.D. 900 and 1100, whereas pinyon pine has its peak incidence in the A.D. 600 to 900 period and drops out completely during the late Douglas-fir dominance.

The provenience data and other archaeological controls on these samples are not adequate to detect any patterns by use-category or type of structure, but certain observations are possible assuming that the time pattern reflects selection rather than environmental shift.

Table 6. Distribution of Species by Century in Canyon de Chelly

Century A.D.	Douglas-fir		Ponderosa		Pinyon		Total
	No.	%	No.	%	No.	%	
300 - 400	7	64	-	-	4	36	11
400 - 500	13	41	1	3	18	56	32
500 - 600	3	19	6	38	7	43	16
600 - 700	5	24	4	18	12	57	21
700 - 800	3	18	1	6	13	76	17
800 - 900	4	31	1	7	8	62	13
900 - 1000	1	14	5	72	1	14	7
1000 - 1100	5	18	22	78	1	4	28
1100 - 1200	-	-	-	-	-	-	0
1200 - 1300	30	83	6	17	-	-	36
Total	71		46		64		181

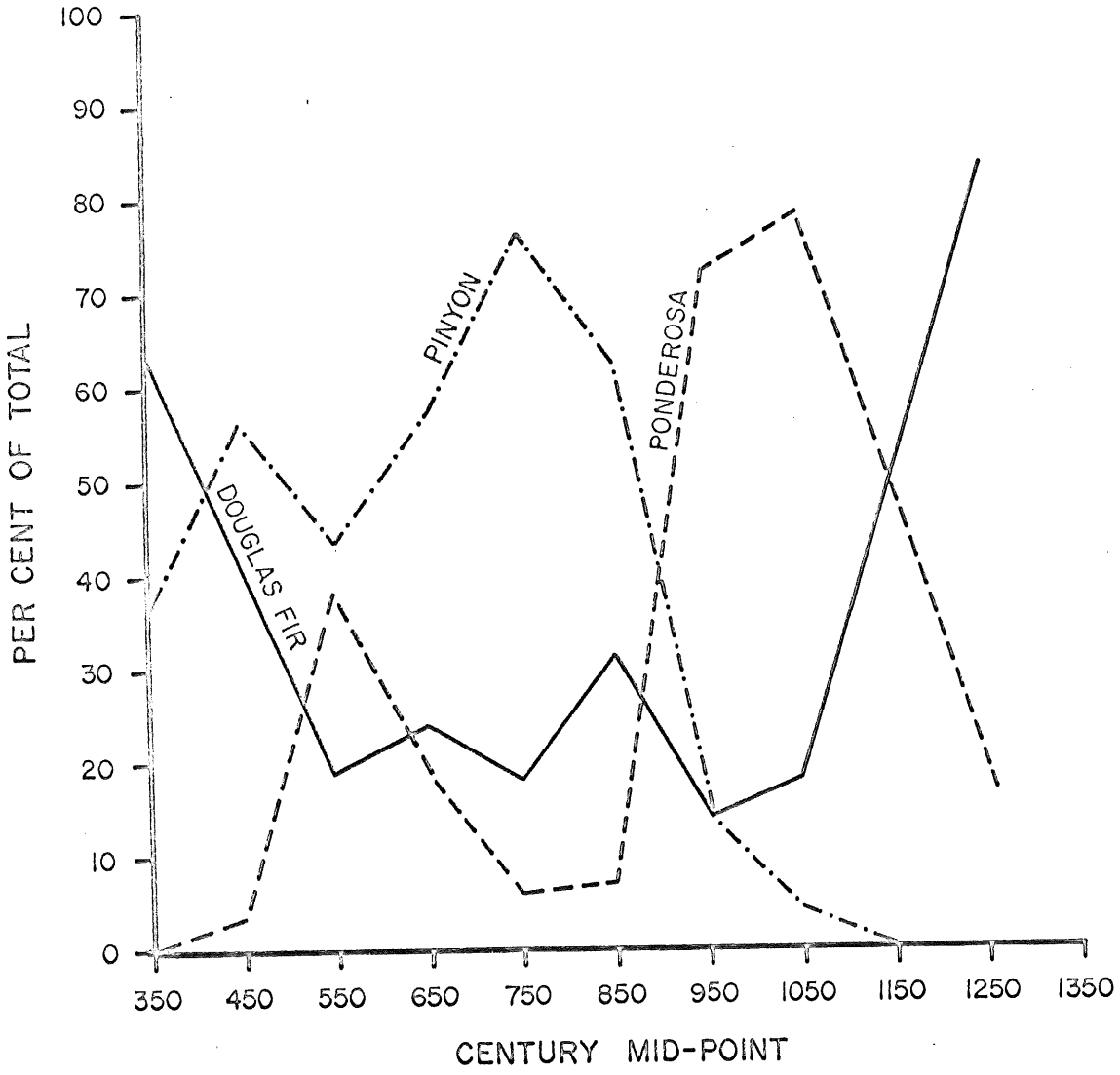


Fig. 4. Time Series of Species in Canyon de Chelly.

The dominance of ponderosa pine culminates in the A.D. 1000 to 1100 period, specifically at White House, a large ruin in Canyon de Chelly (Bannister, Dean, and Gell 1966: 27-8). This ruin has architecture and ceramics characteristic of the ruins in Chaco Canyon and is nearly contemporaneous with them. It has often been considered to have been built and occupied by people from the Chaco center. Since the Chacoans preferred, or at least were most familiar with, ponderosa pine (Bannister 1965), it is not surprising that this preference should extend to a new area despite the availability of other species.

The latest occupation at White House, and at Mummy Cave in nearby Canyon del Muerto, exhibits a cultural pattern characteristic of Mesa Verde rather than that of the Chaco. It is interesting to note the resurgence of Douglas-fir. In fact, the few beams at White House that date this 13th century Mesa Verde reoccupation are Douglas-fir, as are nearly all those used in the 13th century construction at Mummy Cave.

The dominance of pinyon pine in the A.D. 600 to 900 period has no ready explanation.

Although the pattern noted here in a time series cannot be assigned to cultural selection with confidence, neither can it be attributed to environmental shifts in arboreal vegetation on the basis of present knowledge.

To summarize, the analysis of the distributions of species leads to the recognition of nonrandom patterns. The inherent qualities of wood were appreciated by aboriginal users in much the same way as in modern times. Juniper uprights were preferred for their decay

resistant qualities and pinyon was favored as a fire wood. The presence of ponderosa pine or Douglas-fir in ceremonial structures in areas where these species were difficult to obtain reflects a patterned use by type of structure. Certain areas, with stable arboreal communities, exhibit changes in frequencies of use through time, but the underlying reasons for these changes are difficult to specify.

CHAPTER 5. TERMINAL RINGS

Each annual ring of conifers is subdivided into two parts. The early growth of the tree in the first part of the growing season is made up of large, relatively thin-walled cells of light coloration. Later growth, laid down toward the end of the growing season, is made up of small thick-walled cells of a perceptively darker color. The two parts grade into each other gradually in the growth of a single year, but the late growth terminates abruptly at the end of the growing season. This abrupt termination provides a sharp contrast between the end of one growing season and the beginning of the next (Glock 1937: 7).

Thus the morphological characteristics of the final growth ring reveal the time of death of a tree if the last ring is in fact the last put down by the tree rather than the last ring remaining due to erosion or other loss of rings. Bannister (1965: 125) discusses the problem of outside rings. If the dark late wood terminates abruptly with no evidence of the large cells of early growth following, it may safely be assumed that death of the tree occurred during the tree's dormant period---roughly the winter months. If, however, the last cells of the terminal ring are still large and thin with no sharp termination, the assumption must be that the tree died during the growing season of the species.

The Growing Season

Few studies have been conducted on the various growing seasons of Southwestern coniferous species. It may be assumed that it varies, however, even intra-species, with both altitude and latitude, but the magnitude of the variation is not known. As a part of the recent dendrochronological study of the Wetherill Mesa Archeological Project at Mesa Verde (Osborne and Nichols 1967: 3-6) some data are now available concerning the growing season of two of the four common species under consideration. In an effort to develop a biological model for paleoclimatic interpretation of tree rings, trees at various locations near weather stations at Mesa Verde were subjected to intensive instrumentation and observation. Daily measurement of radial growth increments showed that Douglas-fir at Mesa Verde commences growth in May and ends in June. Pinyon pine, in contrast, commences in early June and terminates in late July or August (Fritts, Smith, and Stokes 1965: 101-21). Although no direct measurement was obtained for ponderosa pine or juniper at Mesa Verde, the growing seasons of these may more nearly coincide with pinyon pine than with Douglas-fir (Fritts 1965: 874).

Single Site Analysis

The site of Broken Flute Cave in the Red Rock Valley of extreme northeastern Arizona offers a unique opportunity for a synchronous analysis of the intra-site distributions of final growth ring characteristics. Not only are the archaeological controls adequate, but the sample size is relatively large and the bulk of the material is

made up of full sections of wood, either charred or sound, which allows confidence in the fact that the final ring is in fact the last ring ever put down by the tree.

Broken Flute Cave lies at the head of a short rincon cut into the nearly vertical wall of reddish Wingate sandstone forming the boundaries of Red Rock Valley. The valley is essentially a large cove, opening to the east, in a sandstone mass that forms a high mesa between two mountainous areas: the Carrizos to the north, the Lukachukais to the south.

The valley today is dissected by a number of deep arroyos that coalesce at its margin to form Black Horse Creek, a tributary of Red Wash and the San Juan River. The valley floor is deeply filled with sandy alluvium and covered with sage and an occasional juniper. Nearly every rincon has a live spring near its head, and many of them, facing north or east, have groves of Douglas-fir growing in protected situations. Pinyon pine and juniper dot the talus slopes that fall from the cliffs to the edge of the alluvium and also grow in profusion on the mesa top. The higher elevations of the two mountain masses support Douglas-fir and ponderosa pine.

Broken Flute Cave, and a number of other caves in the valley, was excavated in 1931 by Earl H. Morris for the Carnegie Institution of Washington. It consisted of at least 17 pithouses, numerous storage cists, a possible Great Kiva, and substantial trash deposits along the talus slope in front of the cave (E. A. Morris 1959: 98-133). Since tree-ring dating was a fully accredited partner of archaeology

in 1931, Morris sampled the wood from every possible structure. Figure 5 gives an impression of the nature and the quantity of the material found. Later collections of tree-ring specimens were made by Emil W. Haury and Morris for Gila Pueblo in 1936 and by Doris O'Bryan, again for Gila Pueblo, in 1948.

The occupation of the cave has been placed in Basketmaker III times on the basis of ceramics and architecture (E. H. Morris 1936). A few ceramics of later periods indicate occupation, probably brief and seasonal, in Pueblo II and III times.

The recent dating of all tree-ring specimens from Broken Flute Cave (Bannister, Dean, and Gell 1966: 25-9) gives the chronological details on specific domestic structures. Basically there were two periods of building activity. Pithouses 1, 2, 8A, and possibly 3 date to about A.D. 500 and are nearly contemporaneous with the occupation at nearby Obelisk Cave. Whether this occupation is to be considered an early expression of Basketmaker III or a representative of a preceding cultural period is discussed by E. A. Morris (1959: 197). Pithouses 4 through 9, 11, 12, 14, and 17 date in the first half of the seventh century A.D. and are part of a widespread occupation of the valley noted at a series of other caves (E. A. Morris 1959).

The distribution by species of the characteristics of the terminal growth rings determined for Broken Flute Cave is given in Table 7. Using the data from Mesa Verde regarding the length and time of the growing season for each species, and assuming that tree-cutting activity took place randomly throughout the year, the frequency for

Fig. 5. Broken Flute Cave, Pithouse 8. (Courtesy of the Arizona State Museum)

Table 7. Nature of Terminal Rings at Broken Flute Cave

Species	Complete		Incomplete	
	No.	%	No.	%
Douglas-fir	22	51	21	49
Ponderosa pine	2	29	5	71
Pinyon pine	30	60	20	40
Juniper	11	37	19	63
Total	65	50%	65	50%

Douglas-fir should approximate 17% incomplete final rings (two-month growing season). The frequencies, based on a three-month growing season for pinyon pine and perhaps the other species, should approximate 25% for ponderosa pine, pinyon pine, and juniper. The data indicate, however, that the frequencies of incomplete outer rings are far greater than would be expected under these assumptions. Thus it would seem that the actual growing season (roughly the summer months) was a favored time for tree-cutting activities. In fact, nearly 56% of all cutting took place between early May and the end of August. That some trees were cut at all times in the year cannot be doubted, but major cutting evidently occurred in May and June (Douglas-fir) as well as during the midsummer months of July and August (pinyon pine, ponderosa pine, and juniper).

This distribution of terminal ring characteristics contrasts strongly with the data from Betatakin (Dean 1967: 302-10), a late Pueblo III cliff dwelling in Tsegi Canyon. Although no detailed information is available regarding the comparative lengths of growing seasons of the species in these areas, certain other similarities allow comparison. Both the Red Rock Valley and Tsegi Canyon are at the same latitude and at approximately the same elevation---Red Rock Valley being slightly higher. The sites are both located in caves in sandstone formations. The distribution of arboreal vegetation is similar, more noticeably in the living trees than in the archaeological tree-ring collections. The only major discrepancy is the presence of white fir in Tsegi Canyon (Dean 1967: 59) and its absence in the Red

Rock Valley (E. A. Morris 1959: 22-3). Aspen has a different habitat in the Red Rock Valley area where it is restricted to the higher elevations of the adjacent mountains. In Tsegi Canyon aspen occurs in the canyon near the sites, and was present in seemingly greater numbers in prehistoric times. The archaeological collections from the two sites share only three species (Table 7; Dean 1967: 302, Table 12). Ponderosa pine, which is weakly represented at Broken Flute Cave, does not occur at all at Betatakin. Aspen, on the other hand, occurs only at Betatakin----perhaps due to its ready availability.

The data from Betatakin show that the frequency of Douglas-fir incomplete terminal rings is 16%---very close to the expected frequency assuming random cutting throughout the year. The frequencies of pinyon pine and juniper are 74% and 40% respectively. The data from Broken Flute Cave exhibit quite different frequencies (Table 7). In fact, except for Douglas-fir which is equivocal, the comparative frequencies are in opposite directions.

Dean suggests (1967: 307-10) that the correlation of the growing season and the nature of the terminal rings of each species indicate late summer cutting as the only activity time that would produce the distribution in his data. He further suggests that this time of activity may be further correlated with agricultural practices. Corn agriculture in the semiarid Southwest has two periods of peak activity. Both planting in the spring and harvest in the fall call for mobilization of the total work force (Forde 1931: 364-95; 1961: 227-31). A lull occurs between these periods in which agricultural

activity, although still requiring some time and effort, is not demanding. It is this lull in the seasonal round of agriculture that coincides with tree-cutting activity at Betatakin.

The distribution of terminal rings from each species at Broken Flute Cave, especially those of Douglas-fir, show a great deal of tree cutting took place at the normal time of planting in May or early June. Using Dean's model, this pattern would suggest that agricultural activities were not as demanding to the Basketmaker III inhabitants of Broken Flute Cave as to the Pueblo III people of Betatakin. The evidence of emphasis on other activities at the time of year that agricultural activity reaches a peak has alternative explanations. Either agriculture was not as important in the subsistence economy of these Basketmaker III people or, assuming that tree cutting has always been a male activity, the female may have performed a greater share of the agricultural duties than is common among the pueblo people today. The changes that have occurred in these factors may have been coincident. Speaking of the prehistory of the Hopi from an ethnographic viewpoint, Eggan (1950: 31) states:

> . . . there was a shift in the division of labor by which men took over the agricultural activities. I suspect that this shift was coincident with a change in the balance of subsistence in the direction of greater utilization of corn, beans, and squash as over against hunting and gathering. . . . I would tend to put the time of this shift relatively late, since it did not occur until after the pattern of matrilineal ownership and inheritance of land was well established--a situation I would associate with the larger aggregations of population which took place in the fourteenth century.

Dean's evidence from the Tsegi phase sites (late Pueblo III) places this shift somewhat farther back into time, perhaps about

A.D. 1250, but, whatever the period of this transition, I suspect that the shift had not yet taken place at Broken Flute Cave in Basketmaker III times.

Evidence from dendrochronological and entomological studies at Mesa Verde seems to support the Broken Flute pattern of tree cutting activity more than the one at Betatakin of cutting in spring or early summer. Based on a frequency of 70% incomplete terminal rings of a selected sample of all species and the pattern of activity by phloem or phloem-wood insects, Graham (1965: 172-3) concludes that most of the trees were felled during the growing season and lay unbarked on the ground until late July or August when the bark was removed by the users, taking advantage of the insect activity as debarking agents. The comparability of this data to either Betatakin or Broken Flute may be questioned. First, there is no attempt to place the sample used in time although all the timbers used came from two ruins that both have a final Pueblo III occupation. Second, the relative proportion of species used in the sample was not representative of the total collections from the ruins. The relative proportion of both ponderosa pine and Douglas-fir were in excess of that in the collection.

Far to the southwest of Mesa Verde, a pattern of summer tree cutting activity was noted by Maury (1934: 57). The terminal rings from the Canyon Creek Ruin exhibited approximately 60% incomplete rings. This far exceeds the expected frequency based on random cutting through the year. Since the only species, however, was ponderosa pine, this pattern may more closely resemble the late summer pattern noted at Betatakin than the early summer pattern at Broken Flute Cave.

The analysis of the nature of terminal rings from a single structure at Broken Flute Cave is very instructive of the pattern of tree cutting. Disregarding the first three items in Table 8, which are not considered to be death or cutting dates for interpretive purposes, it is clear that the wood for Pithouse 9 (Fig. 6) was cut during the growing season of A.D. 624. Assuming that tree cutting for this structure was more or less a continuous operation once started, the terminal rings allow the following reconstruction. The rings for the year 623 are all complete and represent two species: Douglas-fir and pinyon pine. These were cut before the growing season of either began for that year. For Douglas-fir, this would mean April or very early May. Pinyon might possibly be cut as late as the latter part of May without exhibiting growth for 624. The terminal rings for all the specimens dated 624 are incomplete, represent three species, and were cut during the growing season. Since the growing season for Douglas-fir and pinyon pine barely overlap, this cutting took place throughout the summer months and was completed before the end of the latest growing season----early September at the outside limit. Thus if construction was begun immediately or had been in process all along, I suggest that the house was actually completed before cold weather or most likely in the fall of A.D. 624. Evidence for a fall or early winter building period is supported by the condition of the carrizo cane reeds that were used to cover the wooden frame of the houses and to provide a base for the mud plaster covering (E. A. Morris 1959: 34).

Thus the pattern of the nature of terminal rings from this single structure corroborates the interpretation based on all terminal

Table 8. Terminal Rings from Pithouse 9, Broken Flute Cave

Catalogue Number	Date	Species	Terminal Ring
MLK-174	515+v	DY	Incomplete
CP-848	611+?LCB	PNN	Complete
CP-849	613v	PNN	Complete
MLK-170	623e	PNN	Complete
CP-853	623eL	DY	Complete
MLK-175	623eL	DY	Complete
MLK-173	623eL	PNN	Complete
MLK-176	624L	JUN	Incomplete
MLK-164	624eL	DY	Incomplete
MLK-167	624eL	JUN	Incomplete
MLK-169	624eL	PNN	Incomplete
MLK-171	624eL	PNN	Incomplete
CP-854	626eLB	PNN	Incomplete
MLK-165	624eLB	JUN	Incomplete

Fig. 6. Broken Flute Cave, Pithouse 9. (Courtesy of the Arizona State Museum)

rings that the summer months were favored for tree-cutting activities.

Single Species Analysis

The terminal rings of a single species may also be analyzed by contrasts in a gross time scale. It would be expected, using Dean's model of the relationship between agricultural activity and tree-cutting activity, that sites later in time would exhibit a pronounced pattern of complete rings; that is, trees cut during the dormant period when agricultural activity was at a minimum. Additionally, this might be expected to be especially true for the terminal rings of Douglas-fir whose growth during the year coincides so closely with the period of intensive activity associated with planting.

A complete time series analysis was performed for Douglas-fir terminal rings for all sites in northeastern Arizona with a sample size of five or more. It was hoped that this would indicate a unidirectional shift in the frequencies between complete and incomplete rings. Although there is an almost imperceptible tendency for a greater frequency of incomplete terminal rings at the early end of the time scale, as exemplified by Broken Flute Cave, when all data were combined the intergradation was far from consistent or unidirectional. The great amount of variation very possibly resulted from inadequate samples during intermediate time periods---especially Pueblo II and, to a lesser extent, Pueblo I. The same analysis was tried again using all species combined, but the results were much the same. The use of samples widely separated in time, however, do show the

tendency toward a greater frequency of complete terminal rings in the late samples.

An area with extensive use of Douglas-fir was chosen: Teegi Canyon and immediate environs. The data for the later sites have already been analyzed by Dean (1967). These late sites, by architecture, ceramics, and actual tree-ring dates, fall in late Pueblo III or approximately A.D. 1250-1300. The early sites, based on the same criteria, belong to an early Pueblo I horizon of approximately A.D. 800-850. Thus the two site clusters are separated by about 400 years. Table 9 gives the frequencies of the terminal rings of the sample of Douglas-fir from each group of sites. It is obvious that the frequency of complete outer rings of the later sites is twice that of the early group. Again the repetitive evidence that more tree cutting took place during the months of May and June at the early time range tends to reinforce the inference that the nature of terminal growth rings reflects the increasing agricultural commitment through time.

The nature of terminal rings, then, provides patterns of tree cutting activities. The analysis of the rings, combined with the species, allows inferences regarding the time of cutting. The favored season was evidently not static through time, a fact that may be correlated with agricultural activity. In addition, similar analysis of single structures allows highly specific statements regarding the actual time of construction.

Table 9. Terminal Rings of Douglas-fir by Time Group

Time Group/Site	Complete No.	Complete %	Incomplete No.	Incomplete %
Late Pueblo III				
Betatakin	79		14	
Kiet Siel	41		10	
Scaffold House	2		1	
Twin Caves	12		1	
TOTAL	134	84	26	16
Early Pueblo I				
NA 8300	6		16	
NA 8300	8		6	
TOTAL	14	39	22	61

CHAPTER 6. SUMMARY AND INTERPRETATIONS

The message of this study, and there is a message, is a familiar one in archaeology. How much charcoal was summarily thrown out before radiocarbon became an established technique for dating? Even many standard categories of materials now are subjected to new physical analyses to more precisely chronicle the past. The point is that many materials are handled and viewed in traditional ways until unrecognized potentials are discovered, opening new and fruitful avenues of analysis.

And so it is with tree-ring materials? Dendrochronology had its beginnings rooted in astronomy and was, in the early years, dominated by research interests in the climatic aspects of the rings. Specimen dating for archaeology, performed frequently as a necessary evil, has often been incidental to the other research interests. Despite encouragement from the field of archaeology, the potential of cultural interpretations from tree-ring materials was, under these circumstances, either ignored or not recognized.

Yet there is a great potential. Tree-ring materials have non-chronological characteristics that may be organized, without reference to the inherent chronological aspects, in the traditional manners of archaeology that are applied to other classes of artifacts. This primary description and integration involves the dimensions of time, space, and content of the materials. The results are consistent patterns of distributions of the attributes from which conclusions are inferred

regarding the cultural behavior involved in the use of the material. The conclusions are tested for possibility by comparisons in the general ethnological background of the Southwest and by a good deal of common sense.

Throughout the study two deficiencies are prominent. One is the lack of archaeological controls for much of the material which I hope will be corrected in future collections by careful field observation and documentation of the material with the nonchronological aspects in mind. The second deficiency is the inadequacy of information concerning the ecological distribution of trees during prehistory. The work under way at the Laboratory of Tree-Ring Research will in time aid our understanding of this factor immeasurably.

Technology

The interpretations of technology of tree-ring materials are closely intertwined with the introduction and use of the hafted stone axe.

Three methods of felling trees for construction are evident in the preserved beams from Basketmaker caves in northeastern Arizona. The time distribution of burned, broken, and stone-axe cut beam ends clearly indicates that felling by burning and felling by axe cutting have little, if any, temporal overlap and that the separation between these two methods falls close to A.D. 600. Broken beams, restricted to timbers of small diameter, occur throughout prehistory. A review of the distribution of stone axes in time and space corroborates this dichotomy.

The interpretations based on the few experimental studies of the use of the stone axe and the morphological characteristics of the beam ends indicate that felling was accomplished with short, closely-spaced strokes all around the perimeter of the tree. Most beam ends, if not later shaped, are asymmetrical, suggesting the use of a notching technique. Whether this technique was used to control the direction of fall is unknown, but this conclusion is indicated by the common notching technique of steel axe users. The end customarily retains a core of splintered wood as evidence of the final felling by either gravity or human push once the diameter is sufficiently reduced.

In limited areas and times in prehistory, wooden construction timbers were shaped and altered beyond the apparent needs of structural practicality. Beams at Casas Grandes, Chihuahua, were planed to remove the natural taper of the bole. At Chaco Canyon the beams were cut to precise lengths so that the ends were flush with the outside of masonry walls rather than projected through the wall, and the ends were smoothed and flattened to remove all the dimpled effect of the axe marks. The smoothing was accomplished by careful trimming with a sharp tool and, often, by a final abrading process that left the end of the beam nearly as smooth as the shank (Judd 1964, Plate 61).

The use of dead wood is both a chronological and a nonchronological problem. That it was used, even in construction, has been adequately demonstrated, but it has been argued that before the knowledge of the stone axe, dead wood was preferred for building. The data from Obelisk Cave indicate that this preference cannot be supported.

The timbers in Obelisk Cave, none of which are stone-axe cut, have terminal rings that cluster in an 11-year period. Using the species of trees, the ages at death, the presence of bark on the timbers, and the physical appearance of the beams, each of the possible causes of natural death of this assemblage of beams is eliminated. Thus, even before the stone axe, living trees were preferred by aboriginal man for building.

Species

The natural arboreal vegetation of the Colorado Plateau provides a number of tree species for selection by the aboriginal inhabitants. Of these, only four types---Douglas-fir, ponderosa pine, pinyon pine, and juniper---are represented in large numbers in the tree-ring materials. Other species such as aspen and cottonwood, oak, and box elder occur in small and usually insignificant numbers. It should be noted that the species in the collections are mainly those which yield dates, so that the over-all representation of species may be biased somewhat by precollection for datable species.

The collections of preserved wood and charcoal include both firewood residue and construction members. Few portable wooden artifacts are available in the tree-ring collections.

The distributional data for species indicate that preferential selection of types of wood was a common occurrence. The inherent qualities of the material were recognized by the aboriginal user in much the same way as in contemporary non-Indian cultures. There is a distinct pattern in association of juniper with upright posts that is

interpreted as the recognition of the decay-resistant qualities of this wood in ground contact. A concomitant of this pattern is the preferred use of straight-boled trees, Douglas-fir or ponderosa pine, as horizontal roofing members (vigas) in many of the same structures. An equally patterned relationship between tree species and architectural type is found in the use of pinyon pine in fireplaces, roasting pits, and in the firepit sweepings in trash areas. Pinyon is noted for its qualities of intense heat, slow burning, and little smoke. Perhaps even its fragrance was a preferred feature.

There is additional evidence that certain species, often not easily obtained, were preferred for ceremonial structures. Many areas of the Colorado Plateau are characterized by a pinyon-juniper community of trees. Smooth straight-boled trees such as Douglas-fir or ponderosa pine are available to such localities only by considerable effort and time in transporting the trees from distant stands. Yet there is a pattern for these less available species to occur at sites, and when they do they are associated with kivas in much greater frequencies than with any other type of architectural unit. This may be a reflection of the emphasis placed on ceremonial architecture that is often also noted in the careful masonry and basic symmetry of such structures. It is also suggested that this pattern reflects the nature of the available work force. Kivas, to judge from ethnographic comparisons, are the physical manifestation of a complex which serves to integrate a community or segment of community. Although the exact nature of the social group is not known in the prehistoric record, it

may be assumed that the group involved in kiva life is larger than that of domestic family life. With a larger labor force available for kiva construction than for domestic house construction, transportation of logs from some distance might be possible for kivas, improbable for domestic structures.

Terminal Rings

The nature of the terminal growth ring of the species under discussion provides information about the time of year during which the death of the tree occurred. If death occurred by man's hand, as the axe cut been and amply demonstrates, then the terminal ring also indicates the time of cutting. Since the growing season of each species is somewhat different, the combination of species and the nature of the terminal rings reveal patterns of tree-cutting activity.

The analysis of the terminal rings of beams from Broken Flute Cave, a Basketmaker III occupation, suggests tree-cutting activity during the summer months in preference to the winter months based on a greater than 50% frequency of incomplete rings of all samples. Further analysis of a single structure details this patterned activity. Cutting for the wood for this house evidently began in the early spring before the growing season for any of the species and continued throughout spring and summer. All cutting must have ceased before the end of the latest growing season---around September 1. All necessary timber having been cut, the actual construction of the house was under way in the fall and probably completed before cold weather. The preparation

of the roof in the fall months is corroborated by the growth characteristics of the carrizo cane used as a base for the mud coating.

This pattern of the time of tree cutting at Broken Flute Cave is supported by similar patterns in the Kayenta area a few centuries later, but contrasts with the inferred time of cutting activity at late Pueblo III sites. Whereas the Basketmaker III and Pueblo I sites exhibit patterns of cutting during the growing season of Douglas-fir (May and June), the patterns at Pueblo III sites indicate little cutting at this particular time. Although many other variables are hard to assess, I conclude that this shift in the cutting pattern relates to the increasing commitment to agriculture with time. The primary planting time of corn, and the time that requires maximum expenditure of labor, occurs during the months of May and June. The fact that much tree-cutting activity was pursued during this time of year in Basketmaker III--Pueblo I times would argue for less commitment to agriculture, unless, of course, the cutting was related to field clearance. But nowhere in the Southwest, to the best of my knowledge, does Douglas-fir grow on lands suitable for farming.

Tree-ring materials possess nonchronological attributes whose patterns of distribution suggest new interpretations of the material. These interpretations are not only nonchronological---as are paleoclimatic reconstructions based on tree rings---but they are in the realm of culture. From the patterns, cultural behavior relating to the use of the wood material is inferred. These inferences are

presented at a relatively basic level of technic culture, but there is no reason to assume that more sophisticated interpretations are precluded. As with so many studies, the problems assume a greater share of the discussion than the conclusions. But until many of the patterns are more widely tested by firmer archaeological control of the tree-ring material, until much more is learned about the growing season of trees and the past ecological distribution of species, and until adequate comparative ethnological data---general or specific---is available, the inferential level of these data rests most comfortably on technic culture.

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