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THE DYNAMICS OF WESTERN NAVAJO SETTLEMENT, A.D. 1750-1900: AN ARCHAEOLOGICAL AND DENDROCHRONOLOGICAL ANALYSIS

by

Meade Francis Kemrer

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ABSTRACT

Site reports from the Navajo Land Claim archaeological survey, supplemented with survey information from the Long House Valley, northeastern Arizona, were used in the analysis of Navajo settlement within the 1882 Executive Order Hopi Reservation and its immediate environs. Dated pinyon pine (*Pinus edulis*) tree-ring samples from Navajo sites, informant dating, and dated historic artifacts provided the time controls for the A.D. 1750-1900 study period.

An analysis of Navajo wood use behaviors was conducted to maximize the dating potential of the tree-ring samples. There is minimal evidence for the extensive use of dead pinyon wood for construction purposes. Wood cutting was generally performed in the late spring-early summer. The timbers were generally incorporated immediately into architectural features without a wood stockpiling period. Wood was also re-used, and there is evidence for repair activities. Wood re-use increases through time as population levels and the availability of abandoned structures increase.

Relationships between the pinyon wood in its environmental setting were evaluated to improve death-date estimates in tree-ring samples. Partially cross dated specimens, where ring counts are made to the exterior, were found to consistently date earlier than the fully cross dated samples from the same structure. The error is produced by locally absent rings in the ring-count period. The ring-width range in which

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this error would occur was estimable. The resultant equation was used to re-estimate the death date of partially cross dated specimens.

Maps were generated from the Land Claim site survey reports. Many of the sites were composed of spatially discrete architectural aggregates. A chronological analysis of the sites identified the spatial cluster to be occupationally distinct units. The spatial aggregate is the basic social and behavioral unit of Navajo settlement. All clusters contain one or more dwellings. A structural analysis of the activities performed within the cluster specified two organizational components: the domestic group component and the corporate component. The organization of the cluster persists for the entire time period.

A chronological analysis of construction activities and their location shows continuous westward expansion into the study area. Peaks in construction frequencies, from A.D. 1750 to 1867, correspond to major political changes in the Southwest and increased raiding, and probably represent migrations into the area. After A.D. 1867, the peaks in construction correspond to Navajo westward migration and population increases within the study area.

The major shifts in Navajo site selection and use of the environment occur after Fort Sumner, in A.D. 1868. From A.D. 1750 to 1867, the landforms selected for community location provide seclusion or seclusion plus high visibility of the surrounding terrain. Community structures are purposely camouflaged. Clusters are spatially compact for mutual defense. Pastoralist activities are performed in forested zones to reduce herd visibility. The site selection criteria precluded the maximum utilization of pasturage resources. From A.D. 1868 to 1900,

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communities were located on all types of landforms, particularly in open, rolling country, flatlands, and valleys. Camouflaging activity is significantly reduced. Herding is performed in all types of plant zones, with a significant shift to the exploitation of grassland environments. Communities are located within plant zones that would provide optimum grazing potential.

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CHAPTER 1

INTRODUCTION

My research was directed toward understanding how several Navajo activity systems operated and changed within the 1882 Executive Order Hopi Reservation area from A.D. 1750 to A.D. 1900. The spatial and temporal controls available in the reports of the Navajo Land Claim (NLC) Commission were helpful in defining the boundaries of my basic problems:

(1) How were Navajo local groups organized within the 1882 study area between A.D. 1750 and 1900?

(2) What were the Navajo site locational strategies during this period?

(3) How did Navajo economic systems operate and change from A.D. 1750 to 1900?

I use the term "research strategy" to denote a methodological departure from the "research design" concept introduced by Binford (1964). The former emphasizes flexibility in archaeological research, whereas the latter is generally operationalized as a highly structured, unidirectional sampling design. Throughout the course of this study I made an explicit effort to minimize the role of programmatic schemes or to become overly dependent upon the relative merits of generalized hypotheses generated prior to or during intensive research activity. I produced a number of such schemata and subsequently abandoned them when

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they were no longer heuristically useful. I have chosen to focus upon the discovery of behaviorally based relationships and how these relations were found to be structured and referable to contemporary problems, rather than confining my research to legislating "fit" to preselected problems or concepts.

In the chapters that follow, several examples illustrate inadequacies in previous studies that are directly related to the failure to discover how Navajo activity systems operated and changed. Preconceived interpretive frameworks did not produce statements that could be made intelligible in terms of these systems and consequently are minimally useful for intra- or cross-cultural comparative (ethnological) purposes (Goodenough, 1956, 1970).

Research Methodology

Serious rethinking of archaeological methodology is required to alleviate the incompatibilities of many current schemes with the changing aims, goals, and standards of ethnography and ethnology. The interest that archaeologists have shown in explanatory processes proposed by philosophers of science and history has been an invaluable source of methodological innovation (Taylor, 1948; Thompson, 1958). A current example to be discussed briefly here is the deductivo-nomological model of Hempel (1966) as it has been adopted for archaeological research by Fritz (1968), Fritz and Plog (1970), Hill (1970a), and others.

Hempel advocates the "correspondence theory" of assessing true (highly probable) statements of relationship whereby a statement is true if the facts fit or correspond to it (Walsh, 1960, pp. 73-76). However,

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Tuggle, Townsend, and Riley (1972) have questioned the applicability of this methodology to the full anthropological scope of archaeological inquiry. Archaeology is reduced to a science of historical exemplification when research is limited to testing "general laws" that are no more than arbitrarily isolated hypothetical statements or systems. A multitude of interrelationships therefore remain unspecified and untested.

More fundamental than the criticisms raised by Tuggle and associates (1972) is that correspondence-based methodologies have consistently produced studies in which the fallible assumption has been made that identical facts constitute comparable units (Gummerman, 1971; Hill, 1970a, 1970b; Leone, 1968). Facts viewed as outcomes of any information gathering technique are not comparable unless it can be argued otherwise, for nonrelated or independent but relevant events or processes might well produce identical outcomes.

The explanatory approach employed here as one phase of the research activity process is based upon the "coherent theory" whereby a statement is considered to be true or highly probable if it fits or coheres systemically with other relational statements (Walsh, 1960, pp. 77-80). That is, the emphasis of research is placed upon argument formulation, rather than facts alone, and the search for the many different relationships among facts that are found to mutually support one another. Arguments or conceptual statements abstracted to represent them may then cohere in such a manner that hierarchically higher, nomothetic arguments can then be made (Kemeny, 1959, pp. 167-169; Wilcox, in press).

If archaeologists are indeed interested in making contributions to contemporary ethnographic and ethnological theory, the organization

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and activities that specify human groupings must be realistically viewed as highly complex and continuously changing systems. The propositions that archaeologists entertain must likewise be recognized at the outset to be no less complex than the group or groups being studied.

I therefore conducted my research using a two-phased feedback process: generating statements of relationship through question and answer, and structuring these statements into arguments. The structure of an argument itself was an important source of new questions when relationships required support, or had to be accounted for, in an argument and had not been investigated. Answers to these questions either supported or led to the modification of an argument. Other relational statements developed independently of an ongoing argument system were often found to be consistent, or again led to argument reformulation.

The performance of most of my research was not based upon a propositional methodology but rather a logic of question and answer (Collingwood, 1967). Questions arise within the context of an investigator's background and experience, or arise as the interactive product of prior experience being brought to bear upon a new body of information. A question or a series of alternative questions is answered by transforming sensory information into analytical frames designed to evaluate the kinds of relationships implied by the questions. Virtually all sciences have devised standard methods to answer often-asked questions and elicit new queries. Archaeologists, for example, routinely produce stratigraphic profiles, site maps, and statistical descriptions.

Unsolicited questions frequently arise in the context of examining outcomes generated by these methods, or through procedures that were

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invented to pursue the answers to previous queries. In some cases, new questions may be related to their predecessors such that a complex system of interrelated answers develops. In others, new queries are potential leads into more distantly related areas of inquiry.

The epistemological requirements of a logic of question and answer differ somewhat from research strategies predicated upon propositional logic. The former approach requires that the investigator ask the right question and receive the right answer. As Collingwood (1967, p. 37) points out:

> Each question and each answer in a given complex had to be relevant or appropriate, had to "belong" both to the whole and to the place it occupied in the whole. Each question had to "arise"; there must be that about it whose absence we condemn when we refuse to answer a question on the grounds that it "doesn't arise." Each answer must be the "right" answer to the question it professes to answer. The "right" answer to the question is the answer that enables us to get on with the process of questioning and answering.

Research based solely upon the examination of propositions, however, requires that logical, epistemic, and substantive conditions be fulfilled (Nagel, 1961, pp. 30-34). Logical conditions include the rules of logic, i.e., that one of the premises should contain a universal law, or one more general than the others, or that the relations specified in the premises should cover more ground than the cases to be explained. Epistemic conditions specify the cognitive relations between the investigator and the premises of his argument. That is, the premises should be better known or more likely accepted to be true than the cases to be explained. The substantive conditions for explanation within a propositional logic framework are related to empirical content: what assumptions are being made and to what degree they are empirically warranted.

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The differences between the two logics in measuring how well a researcher is getting on with his study signify different emphases in investigative behavior. I found the question-and-answer approach to be more open-ended and discovery oriented. I continued to pursue a set or a sequential series of (inter)relationships until I was constrained by time, funds, my perceptive abilities, and the information potential of the material I was studying.

Although the same constraints apply to propositional-based research, an investigator can find himself restricted by the structure of argumentation while simultaneously attempting to interact with his information. That is, he may become more attentive to the relations and limiting conditions within and between sets of premises and remain unreceptive to indirect relationships that appear to fall outside the immediate structural requirements of his argument. I found, however, that these cases were often the sources of new concepts that added more strength to an argument than I had initially suspected (Buchler, 1955, pp. 215-217).

The coherent argument formulation phase of my research is based upon propositional logic. Thus, relationships generated through the logic of question and answer were subject to the rigors of propositional logic when I periodically attempted to fully reassess what I had learned. Most significantly, however, the process of constructing arguments did not in any manner interfere with the process of finding new relationships and integrating them into the research product.

The results of my research are interrelated arguments and the empirical evidence that was found to support them. The report, however, is not a transcription of my research activities.

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The Use of Research Materials

The field work that provided the greater portion of the information utilized in this study was conducted between 1953 and 1960 by archaeologists and their assistants working for the Navajo Land Claim (NLC) Commission. Their primary goal was legalistic--to discover and demonstrate the extreme boundaries of Navajo land use and occupancy from A.D. 1846 to A.D. 1868 (Van Valkenburgh, 1956a, p. 1; Littell, 1967, pp. 126-1227). The year 1846 marks the officially sanctioned date of American involvement in the Southwest with the beginning of hostilities between the United States and Mexico. In 1868, the U.S. Government ratified a lasting treaty with the Navajo people. Under the Indian Claims Commission Act of 1946, the Navajo Tribe could and did sue the United States for land or monetary compensation for lands outside the boundaries established in the treaty that had been lost or otherwise forfeited to the U.S. or its citizens prior to the treaty of 1868.

The endeavors of the NLC represent the most extensive archaeological survey of an ethnically identified population in the Southwest, covering approximately 73,000 square miles within southwestern Colorado, northwestern New Mexico, northeastern Arizona, and southeastern Utah. Criteria for identifying structures and features as outcomes of Navajo activities were derived from ethnohistoric research and from interviews with Navajo and other persons who experienced intimate contact with the Navajo people (Van Valkenburgh, 1956a; Littell, 1967, pp. 733-883).

Legally acceptable evidence of Navajo use and occupancy within contested or extra-reservation areas during the 22-year test period required rigorous time controls. These were provided by tree-ring dating,

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trade items associated with sites, Navajo ceramics, and informants who had direct or indirect knowledge of the former inhabitants of the sites.

For my purposes, a detailed study of Navajo settlement through time entailed the selection of a discrete, intensively surveyed area. The NLC survey problem was designed to delineate the areal limits of Navajo occupation. Although a total of 4,729 sites were used as evidence for the entire claim area (Littell, 1967, Appendix I), site densities are higher along the periphery of the claim. Exceptions to this generalization are intertribal conflicting claim areas, where the land claim site survey was particularly intensive and site densities are correspondingly high. One such region was selected for this study: the 1882 Executive Order Hopi Reservation and its immediate environs (Fig. 1).

Prior to the survey, the 1882 area was divided into 23 subregions based upon such physiographic criteria as washes, valleys, mountains, and so forth (Van Valkenburgh, 1956b, Exhibit A). More than 1,000 sites were located within the study area. However, the lack of time and available funds prevented the presentation of all of the site reports as evidence in the NLC case. The 453-site sample made available to me from the Navajo Tribal Museum and used in this study constituted the material used in the Land Claim case (Correll, 1961). The subsample was selected by the NLC staff using the following criteria (Stokes and Brugge, 1971):

(1) There was sufficient evidence to assign a given site to Navajo occupancy.

(2) A sample was drawn independently from each subregion.

(3) Each sample was designed to be chronologically representative of Navajo occupation within each subregion.

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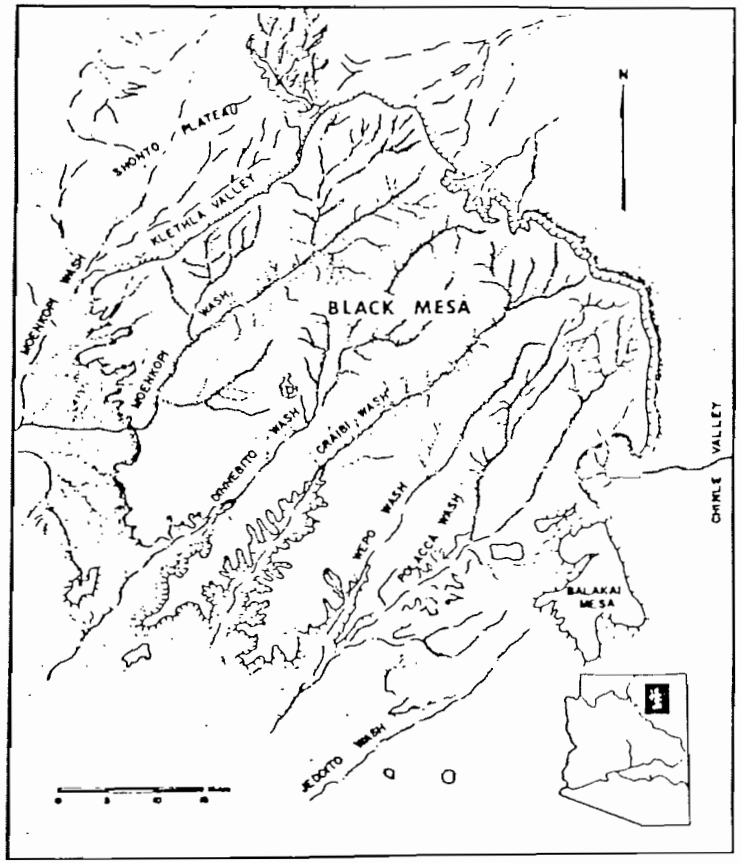

Fig. 1. Map of the Study Area.

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With respect to the last criterion, all of the sites that could be dated by one or more of the dating methods mentioned above were included in the sample.

There is no evidence that the sample was selectively skewed or biased toward the A.D. 1846-1868 test period. One of the aims of the archaeological survey was to demonstrate continuous Navajo occupation within a given subregion. Therefore, sites attributable to the pre-1846 and the post-1868 periods were included in the sample. A number of subregions, in fact, do not show any evidence of Navajo occupation until after 1868.

The site sample, however, is not a true spatially random sample. This necessarily limited the kinds of analyses that could be performed. Changing site density configurations through time, for example, cannot be accurately estimated. Survey techniques may have obscured intersite relationships. Sites were generally located through local Navajo inhabitants who served as guides and informants. Guided survey was supplemented with reconnaissance. Another source of error is that the size of the subregional samples could vary with dating potential and thus would not necessarily reflect subregional site densities through time.

Six major sources of information were used in the research: the Navajo Land Claim site reports, historical studies, dendrochronological information, environmental data, ethnographic material, and a personal survey of Navajo occupation within a portion of the study area. The NLC survey reports supplemented with my personal survey data constituted most of the available primary source material and thus were the principal focus of study.

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I have endeavored to avoid the "common denominator effect" that has plagued cross-cultural studies where the quantity and quality of information in the poorest reports become the standards for constructing observational units or data-bit categories. The detailed descriptions of abandoned Navajo structures and features in the survey reports far exceed previously published documentation for the 1882 area. Therefore, the survey information was not directly referred to explanatory frameworks generated by historians and ethnographers, but was analyzed and structured independently.

An extensive body of published literature documents Spanish, Mexican, and American observations of Navajo activities and events that affected the Navajo people during the period A.D. 1750-1900. A larger corpus of pertinent information remains unpublished but available in archives within this country, Mexico, and Spain. An empirically sound approach to directly interrelating historical and archaeological inferences would require intensive archival research for cross testing purposes. Such a monumental task, however, falls beyond the scope of this study.

Three classes of published historical documentation were recognized to have different information potentials. Consequently each class was eventually incorporated into the research strategy in a unique fashion. (1) Secondary sources that are generally sociopolitical or socioeconomic histories were used in an heuristic sense, to stimulate questioning activity--a procedure that made some of the archaeological survey material initially intelligible. (2) Published Euro-American diaries, records, and transcripts contemporary with the Navajo archaeological material were regarded as primary sources. Statements that

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arose from the archaeologically derived arguments were then compared with those generated independently from this set of historic documents, and vice versa. (3) The NLC site reports contained informant statements about the history of Navajo occupation within a site or region. The statements were used as transcriptions of Navajo oral histories. The material was an invaluable means of independently testing inferences derived from the archaeological information.

If the number of studies were a reliable estimate of anthropological knowledge, the Navajo would rank as one of the best known ethnic groups in this country. Nonetheless, several qualifications limit the applicability of ethnographic information for direct comparisons in this study:

(1) Useful ethnographic statements must be at least as empirically warranted as those generated from archaeological information.

(2) Ethnographic statements concerning the lifeway of an ethnic group must not impede the search for alternatives or differences that may have occurred in the past (Freeman, 1968).

(3) Ethnographic statements generated from the study of a societal segment are not assumed to be coextensive with those that pertain to other contemporary or antecedent groups within a given culture.

Despite these limitations, many Navajo ethnographies were heuristically useful in that they provided a background from which questions

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arose. Other kinds of information supplied by ethnographers were directly incorporated into the study although these cases cannot be conveniently labeled "ethnographic analogues." It was useful, for example, to know the maximum distance sheep could be driven in a single day within this environment. This information was used to estimate pastoralist activity boundaries around sites where evidence was available to infer that herding activities were performed. Many of the informant statements collected by the Navajo Land Claim survey teams met the stipulations stated above and provided an independent means of testing inferential statements.

The dendrochronological data were the most useful source of primary information outside of the survey reports. Tree-ring samples were systematically collected from Navajo structures and from living trees throughout the entire land claim area. Specimens from Navajo features are potentially datable artifacts that were used to discover regularities in Navajo wood-use activities. Arguments based upon the combination of archaeological and dendrochronological inferences were then used as conditional probability statements to increase the dating potential of the specimens.

The Navajo and modern tree-ring samples are also ecofacts that contain precise, sensitive records of climatic variation through time and space. A dendroclimatic network was established within the 1882 study area and the surrounding claim area to evaluate the impact of climatic change on western Navajo demography from A.D. 1750 to 1900.

Environmental research within the 1882 area provided the necessary background for evaluating appropriate environmentally-oriented

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questions. The results of geological and hydrological studies were useful in assessing environmental variation within the region. Thus some notion as to how refined microenvironmental site settings should be characterized was available when attempting to discover what categories were most likely meaningful. It is fortunate in this regard that the NLC site survey forms were not designed in terms of a fill-in-the-blank format, but elicited open-ended descriptive statements under such general headings as "Terrain," "Plant Cover and Density," and "Site Description." Consequently there was consistently more than one option available to generate "facts" about a site and its setting.

The Land Claim staff independently assembled a vegetation map for the entire claim area (Correll, 1958), a montage of currently available botanical information. Vegetative changes accompanying grazing and increased erosion, and several plant species introduced to the area, have altered the distributions of plant communities during and since the A.D. 1950–1900 period. Historical statements and archaeological information, however, indicate that most of the plant species have persisted to the present. Gross changes in Navajo biotic selection strategies could nevertheless be argued through the use of the Land Claim map and were cross tested with the biological information contained in the survey reports.

The analytical potential of the NLC reports significantly increased after my survey conducted in July 1970 in Long House Valley, northeastern Arizona. The valley is situated within the north-central section of the study area, east of the Klethla Valley, immediately west of Marsh Pass.

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A survey of prehistoric occupation as well as historic and contemporary Navajo settlement in Long House Valley was then being carried out by Alexander J. Lindsay, Jr., Museum of Northern Arizona, and Jeffrey S. Dean and William J. Robinson from the Laboratory of Tree-Ring Research. At their invitation, I designed a comprehensive survey form to evaluate Navajo structures and features that was compatible with the NLC categories (Lindsay and Dean, 1971, pp. 131-125). I accompanied the survey, visiting abandoned Navajo sites located by previous and current reconnaissance.

Previous survey data made available to me in addition to my own field notes were most helpful in increasing my sensitivity to the information contained in the Land Claim reports. A number of relationships were discovered concerning the distribution and structure of Navajo activities in Long House Valley which were found to be consistent with information in the reports but which had not been recognized in preliminary analyses of the NLC material.

The Environmental Setting of the 1882 Area

The 1882 study area is located near the south-central boundary of the Colorado Plateau in northeastern Arizona. The topography is variable in this upland province, with elevations ranging from 8,200 feet on the northern protuberance of Black Mesa, to 5,500 feet near the exit of Moenkopi Wash from Black Mesa to the w t. Virtually all of the major landforms shown in Fig. 1 are composed of Mesozoic sandstones and shales (Cooley and others, 1969; Gregory, 1917; Harshbarger, Repenning, and Irwin, 1957; Repenning and Page, 1956; Repenning, Cooley, and Akers,

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1969), with the exception of the small buttes to the southeast that are the structural remnants of Pliocene volcanic vents (Repenning and Irwin, 1954; Williams, 1936).

Black Mesa is the prominent feature within the 1882 area and contains the majority of the Navajo sites used in the study and most of the Hopi towns. The edges of the mesa are sharply bounded by cliffs on the north and east sides that drop vertically to the Klethla, Laguna Creek, and Chinle valleys, respectively. The steepness of the cliffs is a function of the thickness of the more resistant sandstones. Differential erosion of the shales interbedded with thinner sandstone formations has produced less dramatic, stepped escarpment boundaries on the southern and western flanks of the mesa (Thornthwaite, Sharpe, and Dosch, 1942, p. 53).

Black Mesa is dissected by a series of northeast-to-southwest intermittent runoff systems. Quaternary alluvial deposits have accumulated to a depth of several hundred feet along the bottoms of the major channels (Cooley and others, 1969, p. 17). Sand dunes and other redirived colluvial deposits are common in the southern and western portions of the study area, and in the valley system to the north of Black Mesa (Cooley and others, 1969, Plate 2; Hack, 1941).

The highly visible outcomes of geological processes specify limiting conditions for human activities in this country. The stepped escarpments on the mesa edges are to a lesser extent distributed laterally along the major drainages. Pediments formed by slumpage from the cliffs and the alluvial fans developed on the narrow benches are physiographically bounded settings for contemporary and earlier Navajo agricultural

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activity (Thornthwaite and others, 1942, pp. 58, 94). Other exa
these interrelationships will be discussed in the chapters that follow.

Three major soil types are recognized within Black Mesa and its immediate environs (Thornthwaite and others, 1942, p. 60):

(1) Thin residual soils produced by the decomposition of the underlying bedrock on mesa tops and pediment slopes.
(2) Old valley fill soils deposited and reworked in the valley flatlands, generally heavier than the sandy upland soils.
(3) Recent alluvial soils deposited on active alluvial fans at the base of escarpments.

All of the soils are nearly devoid of organic matter, but their mineral content is highly variable, depending upon the sandstone or shale parent material from which they were derived. The relative erosion resistance of these soils and the kinds and density of plant cover that the soils can support are therefore diverse. A distinctive soil series has developed from the volcanics in the southwestern portion of the study area. The cinders have partially decomposed and are extremely permeable. Vegetation is therefore lush in this region (Hicks, 1969, p. 33).

Meteorological conditions within the study area are important in understanding natural processes that produce the physiographic and biotic outcomes to be selected for use by human groupings. The 1882 area is a semiarid environment with mean annual precipitation ranging from 12 to 17 inches. The average variance of annual precipitation ranges from 9

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to 25 inches although any given locus might receive as much as 50 inches or no precipitation whatsoever within a given year. Precipitation is bimodally distributed throughout the year, with over half falling between the months of July and September, and about one third in the months of November through February (Green and Sellers, 1964).

The extremely variable range of annual precipitation falling at any one point is primarily related to the frequent but areally small, violent, conventional summer storms that range from less than one acre to about six square miles. The less frequent winter frontal storms, however, are generally larger, covering several hundreds or thousands of square miles (Thornthwaite and others, 1942, pp. 47-53).

Temperatures within the region are significantly less variable than precipitation. In the southern part of the 1882 area, the mean monthly temperatures range from 74°F in July to the monthly low of 28°F in January. Temperatures are lower in the north in the higher elevations of Black Mesa with the monthly high of 65°F in July and the low of 25°F in January. Maximum and minimum temperatures vary within a range of ±10°F from the monthly mean. Temperature sharply regulates the scheduling of successful Hopi and Navajo agricultural activities throughout the study area. The minimum and maximum growing season is from 90 to 120 days, with corn requiring approximately 100 days to mature (Thornthwaite and others, 1942, Fig. 26).

The tree-ring record for northeastern Arizona indicates no evidence of major climatic change for the past 2,000 years although there is abundant evidence for annual climatic fluctuation (Schulman, 1956; Fritts, 1965; Robinson and Dean, 1969). Preliminary dendroclimatic

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studies indicate that this is true of intra-annual climate as well (Kemrer, Robinson, and Dean, 1971).

The selection of the 1882 area for settlement by the prehistoric and historic Hopi and later historic Navajo groups may be partially related to meteorological conditions within the region. Because precipitation is nonrandomly distributed throughout the year, intra-annual drought is common in the Southwest. The driest months in Arizona are February through May. Drought or low effective moisture, measured by evapotranspiration rates and the water retention properties of the soils, is more probable during this four-month period. Significantly, however, severe intra-annual droughts are less likely to occur within the study area than in any other portion of the State (Steila, 1972).

The composition and structural morphology of the rock formations play a significant role in structuring human water usage activities within the region (Cooley and others, 1969). Although annual moisture is limited, some precipitation is absorbed by the porous sandstones. Prior to well-drilling in the area in the late nineteenth century, perennial water supplies were, and continue to be, naturally available in highly localized springs and seeps. The sandstone aquifers are recharged with water that collects in joints and fissures over an area of 25,000 square miles. The water is sealed within the aquifers by impermeable shales, reducing evaporative loss. Diastrophic forces have warped the sandstones, forming a hydrologic basin that centers on Black Mesa. Collected water supplies from the region are stored within a roughly ovoid basin, oriented northwest-southeast, and covering an area of about 400 square miles. Approximately half of the basin is within the present Hopi

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reservation, immediately north of the village of Oraibi and west of Keams Canyon, with the remainder of the basin to the northwest within the 1882 area. The water-bearing deposits are buried up to a depth of 500 feet within the basin. Drilled wells and springs are under rock and water pressure and are strongly artesian. Local faults and eroded uplifts north and east of the basin proper make a few dozen scattered springs available on Black and Balakai mesas.

Changing water resource availability has undoubtedly had its impact upon human groupings. Thousands of linear drainage miles dissect the study area, but only 50 miles are now continuously flowing. The active segments are located on major drainages and are supplied with water from seeps and springs, and a few cases exist where the water table approaches the present ground surface (Cooley and others, 1969, p. 39, Plate 2). Most of these stable water resources are near Hopi towns.

Accelerated erosional and arroyo-cutting activity, attributable in part to the loss of plant cover through drought and overgrazing, has significantly lowered the water table. Documentation through local informants within the 1882 area shows that downcutting began between 1880 and 1890 (Gregory, 1917, pp. 130-131). Arroyo-cutting has continued to the present. Since 1909-1913, the amount of perennially flowing stream length has been reduced by half. Gregory (1917, Plate 2) reported an additional 50 miles of active stream segments that are generally extensions of currently flowing stream sections.

It would appear that the number and length of permanently flowing streams were not significantly more abundant prior to 1880. If the extent of downcutting and headward erosion from 1909 to the present is

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equivalent to that from 1880 to 1909, the total length of active streams prior to 1880 would be 200 miles, or a fraction of 1% of the total number of drainage miles within the study area.

The lowered water table through downcutting has reduced the amount and the extent to which moisture is available by rudimentary excavation in the alluvial sediments of the drainage systems. This is particularly true in the upstream basins above the headward erosion zones. The amount of this moisture, however, is not constant but varies with the amount of precipitation that is collected and absorbed by the alluvium. Arroyo-cutting has revealed, in part, the areas where springs and seeps are contributing to the groundwater, and specify most if not all of the more stable water sources derived from the sandstone aquifers (Cooley and others, 1969).

In terms of the region as a whole, water resources are largely intermittently available and fluctuate directly with precipitation. The highly stratified alluvial sediments and the presence of prehistoric water control devices on Black Mesa and its immediate environs would indicate that this was the case in the past as well (Stewart, 1940).

A qualitative and quantitative knowledge of vegetation is critical for understanding the environmental exploitation strategies of human groups within the study area. The Navajo have herded horses, sheep, and goats since the seventeenth century (Bartlett, 1932, pp. 29-30). Thus the browsing and grazing potential expressed by plant communities has played an important role in Navajo site selection and movement.

The Navajo Land Claim staff divided the kinds of vegetation found within the 1882 area into three major classes that appear to be sensitive

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to the environmental constraints on plant growth (Correll, 1958):

(1) Southern Desert Shrub: desertic shrubs, yucca, cacti, winter annuals.

(2) Grasslands: grama grasses, Mormon tea, salt grasses, creosote, saltbushes, weedy plants.

(3) Pinyon-Juniper Woodlands: blue grama, sagebrush, weedy plants, pinyon, juniper.

The distributions of these classes over the study area vary with the geology of the region. Soils derived from the underlying bedrock are highly variable in their ability to support plant cover. Siltstone derivative soils from the Chinle and Moenkopi formations located outside of the 1882 area, to the east in Chinle Valley, to the north in Monument Valley, and to the west and southwest of the study area generally support sparse desert shrub vegetation. The Mancos and Menefee shales and silty sandstones similarly have produced soils that support little vegetative cover (Hicks, 1969; Repenning and others, 1969, Plate 1); these formations literally surround Black and Balakai mesas, cropping out in a zone approximately 6 miles wide along the southern boundary of Black Mesa (Cooley and others, 1969, Plates 1-4). Erosion has exposed the Mancos and Menefee shales in a series of dendritic outcrop patterns along the major drainages, specifying most of the desert shrub zones on Black Mesa proper. The sandstones on Black Mesa, Skeleton Mesa, the Shonto Plateau, and the northern boundary of Klethla Valley support grassland and pinyon-juniper woodland vegetation. The grassland and woodland species also thrive on the alluvial sediments within the drainages (Hicks, 1969).

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The kinds and densities of plant species growing on alluvial and sandstone derived soils fluctuate with available moisture. Perennial water sources are sites for such hydrophyllic species as cottonwood, aspen, willow, tamarisk, and hackberry. Soils derived from the Wepo sandstone formation that crops out over most of the surface of Black Mesa are favored by the pinyon-juniper woodland species. Consequently, this plant class covers most of the mesa top, with the exception of the western third and the mesa surface between the Dinnebito and Oraibi washes (Third Mesa), where grassland species predominate. This floral division is probably related to physiography and runoff. The pinyon-juniper zone is highly dissected by thousands of minor washes that would retain moisture in the alluvial sediments somewhat longer for perennial species growth. Plants growing on the less dissected western and south-central portions of the mesa top are predominantly annuals dependent upon the lower effective moisture properties of the thin soil cover. In addition, Hopi wood-cutting activity has affected the quantity of pinyon and juniper on Third Mesa. Arroyo-cutting has therefore probably had more of a quantitative than a qualitative impact on vegetation in the region with the density and areal extent of desertic shrub increasing and the pinyon-juniper woodland and grasslands decreasing (Thornthwaite and others, 1942, pp. 61-70; Hicks, 1969).

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CHAPTER 2

DENDROCHRONOLOGY AND THE STRUCTURE OF NAVAJO LOCAL GROUPS

Tree-ring dates from archaeological sites have little or no intrinsic meaning. The archaeologist must demonstrate how the dates are related to the context in which the specimens were found (Douglass, 1929; Haury, 1935; Bannister, 1962; Robinson, 1967; Dean, 1969a, 1969b). These arguments of relationship constitute interpretations of tree-ring dates. The methodology I employ to perform this task has been discussed in the previous chapter.

The number of possible relationships between tree-ring dates and other kinds of archaeological information approaches infinity. However, the number of interpretations that the archaeologist actually makes is restricted primarily by his problem interests and secondarily by the availability of research time and funds. The relational statements presented in this chapter are answers to questions that arose in the context of my three basic research problems:

(1) How were Navajo local groups organized within the 1882 study area between A.D. 1750 and 1900?

(2) What were the Navajo site locational strategies during this period?

(3) How did Navajo economic systems operate and change from A.D. 1750 to 1900?

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The interpretive potential of the dated tree-ring samples in the context of the Land Claim site reports must be maximized to infer such microtemporal events as community establishment, growth, use, and re-use. These behaviors must be identified and separated from one another in order to understand the behavioral organization of the local group in temporally significant terms. Dendrochronological data are also necessary to construct the temporal framework for discovering regularities in Navajo economic change and changing site selection strategies.

In this chapter I attempt to show that much of the dating and interpretive potential of archaeological tree-ring specimens can be realized. The dating controls for microtemporal analyses can be further refined if it can be stated with measurable, probabilistic confidence that (1) the death date of a tree-ring sample, cross dated to the exterior and exhibiting a particular set of observable exterior ring characteristics, is specified by the outside date, or (2) the death date of a specimen cross dated, but not to the exterior, and exhibiting a particular set of terminal ring characteristics, is estimable within a specified range or error, or (3) the death date of a specimen cross dated to the exterior, but missing one or more outside rings, is estimable within a specified range of error.

A number of previous dendrochronological studies in archaeology have approached the problem of estimating the death date of a specimen on two informal argumentative levels: nonquantified estimation and quantified but nonprobabilistic estimation. Both types have been, on occasion, supported with evidence derived from testing.

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The earlier archaeological tree-ring reports illustrate an example of nonquantified death-date estimation without testing. In specimens lacking evidence of a true death date, the dendrochronologist often assigned after the outside date a *n* years range in which he felt the death date of the specimen would fall. The basis for such estimation, however, was not stated (Stallings, 1933, pp. 804-806; Smiley, 1949, p. 171). The necessary evidence to support these estimates might be present, but the dendrochronologist has not made this information fully explicit to himself to evaluate these suspected relationships further.

Terminal ring characteristics such as complete or incomplete growth, combined with the presence of phloem or bark on the exterior of the specimen, have been demonstrated on a *de facto* basis to be useful indicators of the last ring being the final growth event recorded by the sample prior to death (Bannister, 1962, p. 511). Thousands of cross dated tree-ring samples from living trees have been collected by dendrochronologists who were the agents and witnesses of the exact time of specimen death. The fact that the outside date coincides with the date that the specimen was collected constitutes an informal, *de facto* test of the relationships between terminal ring characteristics and tree death. Tree-growth studies provide additional *de facto* support of these relationships (Fritts, Smith, and Stokes, 1965).

Quantitative methods have been used to estimate the death date of specimens when other terminal ring characteristics were absent. Douglass (1939) found that the heartwood-sapwood ratio in ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*) was highly uniform. The number of years from the exterior boundary of the darker

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tissue in the central stem (heartwood) through the lighter tissue (sapwood) to the outside of cross dated specimens showing evidence of a true exterior was found to be 60 to 75 years in ponderosa and 30 to 35 years in Douglas fir.

The heartwood-sapwood contact method was tested further by Smiley, Stubbs, and Bannister (1953, pp. 10-11). They discovered that the ratio varied considerably by species and environmental setting. Thus the ratio must be empirically established in living datable trees growing within each study area. In their archaeological study, they found that their estimated dates in specimens with exterior rings eroded or exfoliated from them correlated well with historical information concerning architectural feature construction events.

These methods, however, are informal estimating techniques. Until the relationships between the observed phenomena and the death date are transformed into formal probability statements, there is no measure of confidence in the strength of these relations.

Death-date estimation techniques should not be confused with cross dating. The procedures employed in tree-ring cross dating are separate methods and involve a separate relational universe (namely, relative ring width covariation with real time). Cross dating and the associated cross checking techniques are designed to answer the question "What exact span of calendrical years is represented in the sequential array of rings in this specimen?" whereas death-date estimation methods are designed to answer the question "In what calendrical year did this specimen die?" Since tree-ring cross dating is an absolute chronological method and usually the only such technique available to the archaeologist,

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it is virtually impossible to obtain an accurate answer to the second question without answering the first. Thus death-date estimation using probability statistics in these analyses is not only warranted but useful with the following provisions: that empirically demonstrable relationships between the physical and behavioral environmental system from which the tree-ring samples were collected can be interrelated with the biological growth system of the dated species, and the number of cases is sufficiently large for statistical analyses.

NLC Dendrochronological Methods

Tree-ring samples were systematically collected from abandoned sites throughout the entire Navajo land claim area between 1953 and 1960. Approximately 3,600 specimens were forwarded to the Laboratory of Tree-Ring Research in Tucson for analysis. More than 90% of the specimens were pinyon pine (*Pinus edulis*). The Navajo made extensive use of several species of juniper available within the claim area as well as pinyon for construction purposes. Time and money consideration, however, precluded the collection of juniper specimens, for the dating potential of these species was regarded to be significantly lower than that of pinyon (Stokes and Smiley, 1964a; Stokes, 1970). Consequently, features constructed of juniper were not sampled and, in some cases, entire communities remained unsampled.

Several members of the Laboratory of Tree-Ring Research, with Marvin A. Stokes as principal field investigator, worked with the Land Claim archaeological survey crews, sampling sites and instructing field personnel in tree-ring sampling and related observational procedures. In

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addition, the dendrochronologists collected sets of core samples from mature living trees within each subregion to establish a series of local chronologies throughout the Navajo Land Claim area. The modern samples were removed from trees of greater age and diameter than those generally selected by the Navajo for construction purposes. The modern cores therefore represent longer, continuous temporal spans of tree growth than most of the archaeological specimens. The ring-width values of the modern samples were averaged into subregional chronologies four or five centuries in length.

Local chronologies reflect some variation in ring-width patterns that are unique to an area. Thus comparing the archaeological specimens with the subregional chronologies facilitated the dating process and increased the datability of the specimens (Stokes and Smiley, 1963, 1964b, 1966, 1969). More than 30% of the NLC samples collected from archaeological sites were dated (Stokes and Smiley, 1964a).

A subsample was removed from each archaeological tree-ring specimen for dating analysis. A transverse cross section of each timber sample was made, ranging from 1/4 to 3/4 inch thick. This subsample constituted the universe for observations made on all datable or partially cross dated specimens. The set of observations that are of particular interest in evaluating tree-ring dates from archaeological features are those made on the exterior portions of dated specimens. A set of symbols that represent these observations appears after each published tree-ring date. Essentially the symbols are informal probability statements made by the dendrochronologist to signify the degree to which the exterior date represents the exact year of death for the specimen.

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The symbols used by Stokes and Smiley (1963, 1964b, 1966, 1969) to describe the exterior portion of a dated or partially cross dated specimen may be viewed as a sequence of interchangeable elements within the subsets of the ring condition set:

[(+,∅1)(inc,c,∅2)(C,∅3)(G,∅4)(B,∅5)].
1 2 3 4 5

The subsets and their elements are defined as follows:

Subset 1: Datability of the specimen toward the exterior.

\+ The outermost rings are very small and/or complacent, and the sequence of ring-width variation in the outer part of the specimen cannot be cross dated with the known ring chronology for that period; therefore a ring count was made to the outside. Or: The outermost rings fall into a period in which very small ring(s) are known to occur, but the specimen does not have enough additional rings to permit the presence or absence of this ring or rings to be verified.

∅1 (= blank) The specimen is datable through the final ring.

Subset 2: Growth condition of the specimen.

inc The outermost ring is incomplete in growth.

c The outermost ring is complete in growth.

∅2 (= blank) The condition of growth is indeterminable.

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Subset 3: Relative position of the terminal ring of the specimen to the true exterior of the stem (I).

C The outermost ring is continuous around the circumference of the specimen; hence erosional activity has been minimal, implying that the date is close to that of the death of the stem.

ϕ3 (= blank) The outermost ring is not continuous. Or: This observation is not necessary in the light of more conclusive information.

Subset 4: Relative position of the outside ring of the specimen to the true exterior of the stem (II).

G Beetle galleries are present on the exterior of the specimen. Since these organisms thrive on the phloem layer located between the bark and the woody portion of the stem, the terminal date is close to, if not the true date of, stem death.

ϕ4 (= blank) Galleries are not present on the specimen.

Subset 5: Presence or absence of the true exterior of the specimen.

B Bark is present on the specimen; hence the outside ring is the true exterior of the specimen.

ϕ5 (= blank) Bark is absent from the specimen.

The elements or their combinations within the ring condition set represent a considerable array of probability assignments as to the exact

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death date of a sample. These statements of set content stand as informal estimates and cannot be transformed into formal probability statements until they are quantitatively related to the behavioral and the physical environmental contexts in which the specimens were found. One of the major goals of the present study is to demonstrate that this transformation is both possible and warranted in evaluating and maximizing the use of tree-ring dates in archaeological analyses.

More than 1,000 specimens were collected from the 1882 study area. A total of 316, or approximately 30% of these samples, were successfully cross dated either completely or partially. Informal probability estimates that the exterior (terminal) date specifies the actual death date of the specimen vary considerably. The number and the proportion of the dates listed by various element combinations are presented in Table 1. The order in which the listings appear are in terms of decreasing likelihood that the terminal date accurately records the death date of the specimen.

Table 1. Ring Condition Element Combinations.

Ring condition set outcome	Frequency	% of total
(∅1)(inc or c)(C or ∅3)(G or ∅4)(B or ∅5)	123	39
(∅1)(∅2)(C or ∅3)(G or ∅4)(B or ∅5)	27	9
(+)(inc or c)(C or ∅3)(G or ∅4)(B or ∅5)	60	19
(+)(∅2)(C or ∅3)(G or ∅4)(B or ∅5)	38	12
(+)(∅2)(∅3)(∅4)(∅5)	68	20
Tree-ring sample totals	316	100

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Navajo Wood Use

Refined time controls are required to define the composition and the behavioral organization of Navajo local groups as occupational units and through time. In this section, I attempt to evaluate the tree-ring dates in their behavioral settings. The questions I am asking are stated below:

(1) How was wood used in construction?

(2) How are the outside ring characteristics of dated tree-ring samples related to wood use?

(3) How well do tree-ring dates with various kinds of outside ring characteristics approximate the actual construction dates?

The fundamental strategy to a formal evaluation of the NLC archaeological tree-ring dates was found to be twofold: (1) to assign a definite probability range as to the exact death date of a specimen, and (2) to discover, as precisely as possible, how closely the tree-death event approximates the use of the specimen in the feature in which it was located. The two facets of this strategy are interrelated.

An initial phase in the interpretation of the outside dates of tree-ring samples collected from structural features is to develop arguments as to the behavioral alternatives that were employed in the construction of these features. Haury (1935), Bannister (1962; 1965, pp. 123-126), and later Robinson (1967) have outlined the basic behavioral options in a wood procurement-use activity system. The behavioral elements in the sequential subsets of the wood procurement-use activity set may be viewed as follows:

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Subset 1: Wood procurement.

1a Wood is removed from live trees.

1b Wood is removed from dead trees.

1c Wood is removed from previously constructed features.

Subset 2: Wood storage.

2a The procured wood is stockpiled for some indefinite period prior to use.

2b The procured wood is used immediately for construction purposes.

Subset 3: Wood use.

3a The wood is used to construct a feature *de novo*.

3b The wood is used to repair a portion of a previously constructed feature.

3c The wood is used to completely repair or rebuild a previously constructed feature.

Strictly speaking, the outcomes from the subsets of the wood procurement-use activity set are applicable to individual specimens. A considerable body of evidence must be presented to argue that only one or two behavioral option combinations were employed in the procurement and use of *all* of the wood in a given structure, community, or collection of communities. A research problem, therefore, was to discover as much as possible about Navajo wood-related activities and to what degree behavioral regularities could be identified.

Wood Harvesting

Several distinctive patterns emerged from the analysis of outcomes from the second subset of the ring condition set (growth condition

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of the specimen). Table 2 illustrates that there are far more dated specimens exhibiting incomplete growth of the terminal ring than completed growth.

Table 2. Outcomes from the Growth Condition Subset.

Growth condition of the terminal ring	Number of dated specimens
Incomplete (inc)	157
Complete (c)	23
Indeterminate (Ø2)	136
Total number of specimens	316

Although the biology of tree death in pinyon has not been studied in detail, it is unlikely that the death event related to nonhuman agents would occur during growth (Fritts, 1970). If this is true, then at least half of the dated specimens were harvested from live trees during the growth event.

The fact that so many of the specimens exhibit the incomplete growth condition may indicate a pattern as to the scheduling of wood harvesting activity. In the southern Colorado Plateau, the growth event in pinyon begins in mid June and continues into July and early August (Fritts, Smith, and Stokes, 1965, pp. 102-106). Assuming that the inc and the c dated samples were harvested from live trees, and the inc condition is observable in pinyon within the months of June through August, or one fourth of the year, the following hypotheses can be initially tested:

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H_0: Tree-cutting activity occurred randomly throughout the year.

H_1: Tree-cutting activity was significantly restricted to the summer months.

If the null hypothesis (H_0) cannot be rejected, then three fourths of the samples should exhibit the c condition, and one fourth of the samples should exhibit the inc condition. A comparison of the observed versus the expected outcomes of the growth condition subset is shown in Table 3. A chi-square analysis, using Yates' correction factor (since $df = 1$) indicates that the observed sample is significantly non-randomly distributed ($p < .001$) and supports the H_1 hypothesis.

Table 3. Observed and Expected Growth Condition Outcomes.

Growth condition	Observed outcomes	Expected outcomes	Totals
inc	157	45	202
c	23	135	158
Totals	180	180	360

It is possible that trees could have been killed during the growing season by animals such as porcupines. There is, however, evidence that corroborates the assumption that both inc and c dated samples represent wood that was harvested by human agency from live trees. A complete listing of all terminal ring condition set outcomes from the 1882 study area is presented in Table 4. The information is cross

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Table 4. Consistency of Element Combinations with Independent Dating Evidence.

No.	Ring condition set outcome	Consistent No.	%	Inconsistent No.	%	Unknown No.	%	Total No.
1.	(+)(Ø2)(Ø3)(Ø4)(Ø5)	21	30	27	40	21	30	69
2.	(+)(inc)(Ø3)(Ø4)(Ø5)	14	61	5	22	4	17	23
3.	(+)(c)(Ø3)(Ø4)(Ø5)	1	50	0	0	1	50	2
4.	(+)(Ø2)(Ø3)(G)(Ø5)	27	71	7	18	4	11	38
5.	(+)(Ø3)(G)(Ø5)	24	80	1	3	5	17	30
6.	(+)(c)(Ø3)(G)(Ø5)	2	67	1	33	0	0	3
7.	(+)(Ø2)(Ø3)(Ø4)(B)	1	100	0	0	0	0	1
8.	(Ø1)(inc)(Ø3)(Ø4)(Ø5)	25	58	7	16	11	26	43
9.	(Ø1)(c)(Ø3)(Ø4)(Ø5)	1	50	1	50	0	0	2
10.	(Ø1)(Ø2)(C)(G)(Ø5)	1	100	0	0	0	0	1
11.	(Ø1)(Ø2)(Ø3)(G)(Ø5)	23	92	1	4	1	4	25
12.	(Ø1)(inc)(Ø3)(G)(Ø5)	51	88	3	5	4	7	58
13.	(Ø1)(c)(Ø3)(G)(Ø5)	11	85	0	0	2	15	13
14.	(Ø1)(inc)(Ø3)(G)(B)	2	100	0	0	0	0	2
15.	(Ø1)(c)(Ø3)(G)(B)	1	100	0	0	0	0	1
16.	(Ø1)(inc)(Ø3)(Ø4)(B)	1	100	0	0	0	0	1
17.	(Ø1)(c)(Ø3)(Ø4)(B)	2	100	0	0	0	0	2
18.	(Ø1)(Ø2)(Ø3)(Ø4)(B)	2	100	0	0	0	0	2
	All outcomes	210	66	53	17	53	17	316

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classified in terms of the degree to which independent evidence is consistent with the thesis that a given specimen was initially harvested from a live tree. Those dates considered to be consistent were characterized by the following criteria or their combinations:

(1) Temporal clustering of tree-ring dates within a site:
Outside dates falling within a decade of each other were considered to represent wood harvesting activity from living trees to a highly probably degree. If dead wood was collected for construction purposes, the disparity between the dates would probably be greater than 10 years, for the decay rate of wood is low in this semiarid environment, and usable dead wood can persist as long as three centuries (Dean, 1969a, pp. 144, 190).

(2) Informant estimates of site occupancy:
Tree-ring dates falling within a decade of an informant's estimate of site occupancy were considered to be consistent with this estimate.

(3) Dated historic goods:
Tree-ring dates falling within a decade of those dates assigned to historic goods located within the site were considered to be consistent with those dates.

When independent evidence did not meet those criteria, the dated specimens involved were considered to be "inconsistent" with this evidence. Dated tree-ring samples from sites where there was no means of independent evaluation were assigned to the "unknown" category. This

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categorization of the dated specimens was found to be a necessary and conservative starting point that eventually led to the discovery of more refined relational statements regarding Navajo wood use behaviors.

An examination of Table 4 shows that both the inc and the c conditions (inc = 2,5,8,12,14,16; c = 3,6,9,13,15,17) are more highly associated with the "consistent" category. A compilation of these numerical classes, presented in Table 5, shows the evidence for this conclusion. Note that there is little difference between inc and c in the percentage of "consistent" and "inconsistent" dates. For every occurrence of inconsistency, there were at least seven samples that were found to be consistent. An analysis of the relative consistency of inc and c dated specimens from early through late settlements showed no significant differences that would suggest any shifts from the general practice of harvesting wood from live trees.

Table 5. Consistency of Samples by Growth Condition.

Growth condition	Consistent		Inconsistent		Unknown		Total
	No.	%	No.	%	No.	%	No.
inc	117	75	16	10	24	15	157
c	18	78	2	9	3	13	23
Total	135	75	18	10	27	15	180

The preference for harvesting wood during the summer period of tree growth coincides with the season for most domestic structure construction activity. A domestic structure is defined here by the following criteria:

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(1) A walled, roofed architectural feature possessing a single entrance or doorway.

(2) Interior and/or exterior hearth, stove, or oven features spatially associated with each structure.

(3) Midden and/or ash deposits located outside of, and generally opposite the doorway of, each structure.

(4) One or more concentrations of wood chippage and fragments spatially associated with each structure.

These criteria identify a set of activities that occurred within and around the domestic structure. The structure itself provided space for sleeping and storage and is constructed for protection from the weather. The other features specify food preparation, heating, ash and trash dumping, and fuel maintenance activities. By virtue of their repetitive occurrence, this set of behaviors was presumably performed independently by the occupants of each domestic structure.

The NLC survey teams attempted to locate as many of these features as possible, describing and measuring remains revealed by test pitting and surficial evidence. Time and available funds, however, prevented the systematic excavation of any site within the 1882 study area.

One observation that was recorded for most domestic structures was the orientation of the doorway, which nearly always faced the eastern hemisphere. The practice of orienting the doorway toward the rising sun has been noted for many American Indian societies, including the Navajo (Mindeleff, 1898). Although this behavior is often ascribed to religious beliefs, there may well be other, more pragmatic reasons as

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well. Early morning light shining through the entry, for example, may have served as an "alarm clock" to awaken the inhabitants of the structure. Another intentional or unintentional purpose of doorway orientation toward the sunrise would be access to radiant solar heat that would provide some warmth to the interior of the structure in the cooler early morning hours.

Information concerning the location of the entrance was not uniformly available from sites within the 1882 area. Some structures had completely collapsed or the wood had been removed, thus precluding such observations. The data used in Fig. 2 are based upon magnetic compass readings. Other recorded information such as "doorway faces sunrise" or "doorway faces east" when not accompanied by an actual compass reading was omitted from the sample.

There are only four cases out of several thousand where two domestic structures are contiguous. On the basis of this fact, it is assumed that the direction that each doorway faces is an event that is the product of a behaviorally independent construction episode, and thus is independent of any other entrance orientation event.

The frequency distribution of the total sample in Fig. 2 shows a sharp peak in the number of doorways that face directly east. The question remains, however, to what degree the location of entrances is related to sunrise location at the time of domestic structure construction.

The location of the sunrise point on the horizon is not constant but shifts across the eastern hemisphere as the earth tilts on its axis every year. The extreme northerly and southerly sunrise points, the solstices, occur every June 22 and December 22, respectively. The loci

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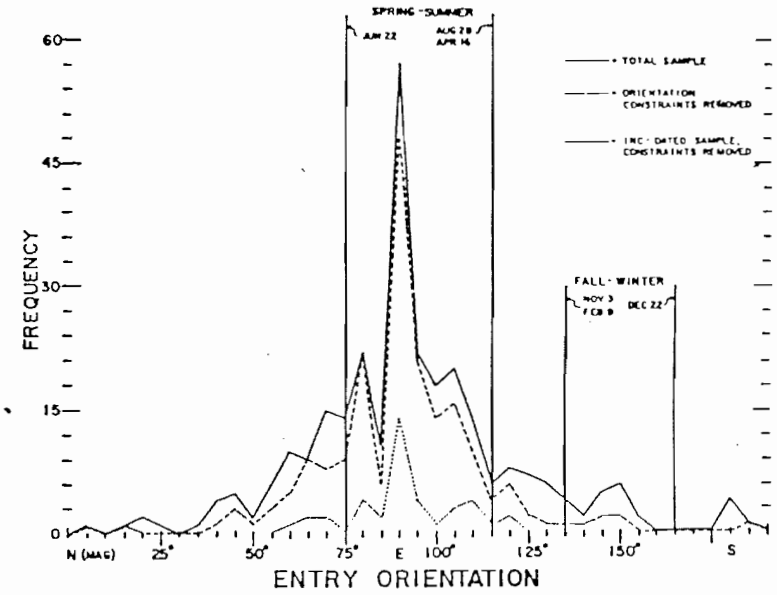

Fig. 2. Distributions of Navajo Domestic Structure Entry Orientations.

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of the two solstices for 35° north latitude (the approximate latitude of the 1882 study area) are shown in Fig. 2 (List, 1951, p. 501). The location of the two solstice points have been adjusted for magnetic declination (E 14.5° N) for the latitude of the study area, to compensate for the Land Claim Survey magnetic compass readings of entry orientation.

For the total sample, most of the doorway orientations fall within the range of the annual sunrise loci, with 224, or 78%, on or between the solstices, and 62, or 22%, falling outside the solstices.

The sunrise point is continuously shifting between the solstices. Any other point within the solstices marks the location of the sunrise for two different days of the year: the day that the sun reaches the point as it approaches a solstice, and the day that the sun reaches the point as it returns from that solstice. Two seasonally distinct divisions within the solstices are indicated in Fig. 2. The first seasonal range of sunrise points is the mid spring through late summer, beginning with April 16 through the June 22 solstice, and back again to the April 16 point on August 28. The second seasonal range is the late fall through late winter, beginning with November 3 through the December 22 solstice and the return to the November 3 sunrise point on February 9. The distributional array of entry orientations for the total sample indicates that more doorways are located within the spring-summer range (184, or 64%) than the fall-winter range (15, or 5%).

In the process of collecting entry orientation data for this analysis, it became apparent that, in some cases, conditions in the environment that existed prior to the construction of the domestic structure

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had some constraining effect on the location of the doorway. The kinds of physical restrictions encountered were as follows:

(1) The structure was incorporated into a geological feature in such a manner as to restrict the range in which an entry could be oriented toward the sunrise. Examples of these cases are domestic structures incorporated into bedrock forms such as ledges and caves, and derivative geological forms such as boulders and talus slopes.

(2) The doorway architecture was composed of natural features that existed in the environment prior to construction, which served to eliminate doorway orientation options. A few examples encountered were those cases in which the entry was located between two boulders, or between two living trees or a combination of these two classes of natural phenomena.

(3) A domestic structure was built contiguous to another structure such that the range of possible entry orientations was restricted.

The domestic structures that met one or more of the above criteria were removed from the sample. The frequency distribution of the less likely constrained entry orientations is shown in Fig. 2. In the nonconstrained sample, 156, or 79%, fall on or between the solstices, and 42, or 21%, fall outside the range of sunrise points. The proportion of doorways oriented toward the spring-summer range is 150, or 76%, and those within the fall-winter range is 6, or 3%.

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The p[illegible]l increase of entry orientations within the spring-summer range in the nonconstrained sample may accurately specify the preferred season for building domestic structures. An inspection of the total versus the nonconstrained populations in Fig. 2 appears to indicate that eliminating doorway orientation "error" produces a significant reduction in variation. Analyses of the central tendency and dispersion characteristics of the two populations, summarized in Table 6, supports this contention.

Table 6. Statistical Comparison of Two Entry Orientation Populations.

Sample population	Sample mean	s	95% μ	95% σ	N
Total population	92.4°	±27.8°	±3.23°	±2.27°	286
Nonconstrained population	89.7°	±20.1°	±2.80°	±1.98°	197

s = sample standard deviation
μ = population mean
σ = population standard deviation

A comparison of the two sample means shows that they are within three degrees of each other and bisect the spring-summer range. The representativeness of the two sample means to the true mean (μ) of an assumed normally distributed population of entry orientations for all Navajo domestic structures was evaluated at the 95% confidence level, and is given by

$$95\%\ \mu = \bar{x} \pm 1.96(s/\sqrt{N}),$$

where $\bar{x}$ is the sample mean.

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Table 6 illustrates that the range of the 95% confidence limits is less in the nonconstrained sample and thus is a more accurate estimate of the mean of a normally distributed population than the total sample of doorway orientations (Croxton, 1953, pp. 231-235).

The two sample standard deviations presented in Table 6 exhibit the same kind of relationship. The 95% confidence estimates for the standard deviation (σ) of a normally distributed population using the two sample standard deviations were computed, where

$$95\%\sigma = s \pm 1.96(s/\sqrt{2N}).$$

Again the range of the nonconstrained population estimate is less than that of the total sample population (Croxton, 1953, pp. 231-235).

A third analysis, the ratio of variances, indicates that the variance (s^2) of the nonconstrained population (s_2) is significantly smaller than that of the total sample population (s_1). Given the hypothetical relationship,

$$(s_{e2})^2/(s_{e1})^2 = (s_{o2})^2/(s_{o1})^2,$$

the expected ratio of variances (s_e) would be 1.00, but the observed (s_o) ratio is 0.52, which is smaller beyond the 0.001 level of significance (Croxton, 1953, pp. 288-295, 332-333).

A third population of entry orientations was generated from the nonconstrained sample and is shown in Fig. 2. The sample is composed of those structures having one or more dated tree-ring specimens exhibiting a terminal ring that is incomplete in growth. In this population of entries, 36, or 88%, fall within the solstices, and five, or 12%, fall

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outside the solstice range. A total of 34, or 83%, of the entries are oriented within the spring-summer range, none within the mid fall-mid winter range.

An analysis of the dispersion characteristics identical to those presented above showed that there was no significant difference in the mean, standard deviation, or ratio of variances between the nonconstrained sample and the inc-dated population.

Another means was found to independently evaluate the sensitivity of Navajo doorway orientation to solar phenomena. The sun describes a southerly arc as it moves across the sky every day. The daily solar path becomes more pronouncedly south-trending during the year, as the sunrises approach the winter solstice. If the entry of a domestic structure faced any protuberance above the "true" horizon (a smooth, spherical surface), the sunrise would be later in the day and hence south of the "true" sunrise point. Therefore, if entrance orientation is directly related to the location of the sunrise, those domestic structures with a relatively unobstructed view of the "true" horizon should cluster somewhat more northerly than those facing surficial features that obstruct the view of the "true" horizon. These differences, moreover, should not be nonmeasurable, for the discrepancy between the location of the sunrise point on the "true" horizon and 30° above the horizon ranges annually between 20° and 30° at 35° north latitude (List, 1951, p. 501).

The proposed relationship was tested by selecting two samples of domestic structure doorway orientations. One sample was drawn on the basis that the structures were located in physiographic settings whereby they would be least likely to face the "true" horizon. The other sample

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was drawn on the basis that the structures would most likely face the "true" horizon, owing to their physiographic dispositions. Both samples were drawn from the nonconstrained population shown in Fig. 2. The criteria for selecting the two samples must be stated on a most likely, least likely basis, for the Land Claim site reports contain no information as to the view of the horizon from the interior of any domestic structure. The frequencies and proportions of both samples within each entry orientation range class are presented in Table 7. Note that there are proportionately more doorways within the north-through-east range in the "unobstructed" sample, and proportionately more doorways within the south-through-east range in the "obstructed" sample. These patterns are consistent with expected outcomes and support the proposed relationship.

Table 7. Entry Orientations by Physiographic Setting.

Entry orientation range (mag.)	Probable view of "true" horizon			
	Unobstructed[a]		Obstructed[b]	
	No.	%	No.	%
N-N75°E	1	3	3	3
N76°E-N80°E	4	13	5	5
N81°E-N85°E	4	13	9	10
N86°E-E	14	45	33	36
S[illegible]3°E-S85°E	2	6	13	14
S84°E-S80°E	3	10	7	8
S79°E-S75°E	1	3	10	11
S74°E-S70°E	1	3	9	10
S69°E-S5°W	1	3	2	2

[a]Mesa top, ridge top, flatlands.
[b]Canyon bottom, ridge slope, valley slope, rolling country.

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To summarize the findings thus far, a number of general regularities characterize Navajo construction activities:

(1) Live wood was preferred for construction purposes.

(2) Wood was preferentially harvested in the late spring and early summer months.

(3) The scheduling of wood harvesting activity coincides with the preferred season for domestic structure construction.

Wood Storage

The high frequency of specimens with beetle galleries may indicate another regularity in Navajo wood-use behavior. Over half of the dated specimens (54%) exhibited the G condition. An examination of Table 4 shows that specimens with galleries are more consistently compatible with independent dating evidence than specimens where the G condition is absent. A compilation of outcomes from both the G and the non-G subsets from Table 4 is presented in Table 8.

Table 8. Outcomes from the Gallery Condition Subset.

Beetle galleries	Compatible	%	Incompatible	%	Unknown	%	Total
Present (G)	142	83	13	8	16	9	171
Absent (G)	68	47	40	28	37	25	145
Total	210	66	53	17	53	17	316

The over-all proportionate occurrence of compatible G-dated specimens is higher than those exhibiting the inc or c conditions (see

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Table 5). The presence of beetle galleries on specimens is therefore highly associated with live wood that was harvested and used for construction purposes. The question raised in the context of these facts is whether or not beetle galleries are an intentional or unintentional artifact of Navajo wood-related activities.

Bark beetles do not attack trees indiscriminately. Dead or freshly killed trees and stems are most susceptible to beetle infestation (Graham, 1965). However, living trees weakened by environmental stress conditions are also liable for beetle infection. Entire pinyon groves are reported to have been killed by massive beetle activity during periods of extreme drought in the Southwest (Little, 1944). An analysis was therefore conducted to evaluate the possible relationships between the high occurrence of galleries and environmental stress.

Tree-ring characteristics are accurate indicators of changing environmental conditions. In the American Southwest moisture is the primary limiting factor to annual tree growth (Douglass, 1914; Schulman; 1956; Fritts, Smith, and Stokes, 1965). Therefore, tree-rings smaller than average generally specify the years of increased moisture stress, and, conversely, decreased moisture stress conditions are reflected in rings that are larger than average (Fritts, 1965).

Another pair of environmentally related measures in tree-ring series is mean sensitivity and standard deviation, the amount of variability exhibited by a ring series. Trees growing under optimum conditions with abundant water supply will usually show little interannual ring-width variation. Similarly, trees growing under extreme stress

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conditions frequently produce small rings with little year-to-year variation (Fritts, Smith, Cardis, and Budelsky, 1965; Fritts, 1966).

Both environmentally related measures of tree growth, annual variation and total variability in ring widths, were compared with beetle gallery incidence. The four most populous subsets of the ring condition set were selected for analysis: +G, G, incG, and +incG.

If the high frequency of beetle galleries in the study area specimens is related to environmental stress, it is expected that (1) for specimens exhibiting galleries, the year of tree death should be one in which less than normal growth conditions prevailed and hence should correspond to smaller than average ring widths, and (2) trees living in habitats where annual growth is severely inhibited should be more susceptible to beetle infestation, particularly in those years demonstrably inimical to growth. Thus the incidence of galleries should be highest on specimens that reflect these combined sets of conditions.

The first set of conditions is measured by annual deviation from average growth, expressed as tree-ring indices. Samples of modern and archaeological specimens from the 1882 area were combined into an array of chronologically ordered index series (Stokes and Smiley, 1964b; pp. 24-25). As trees increase in age, the amount of annual radial growth decreases. This nonclimatically related growth factor was eliminated from each specimen in the sample by fitting a curve to the plotted ring width measurements. The line of the growth curve essentially corresponds to the mean and is assigned a value of unity or one. Thus annual ring width departures greater than or less than 1.00 would signify above or below normal growth, respectively. The curve-fitting and numerical

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assignment to the mean renders the index departures comparable between specimens for any given time period (Stokes and Smiley, 1968).

No significant relationship was found between below normal terminal ring width and the presence of galleries. An examination of Table 9 shows that the various G-condition subsets are not significantly associated with tree death in a year when below normal growth (<1.00) was expressed in trees within the study area. Moreover, the total combined outcome presented in Table 9 closely approximates the proportionate distribution of below normal growth (45%) and above normal growth (55%) departures for the total time range represented by the sample of G-condition dated specimens.

Table 9. Outside Ring Index versus Gallery Condition.

Ring condition subset	Terminal ring index <1.00	%	≥1.00	%	Totals
G	16	38	26	62	42
+G	26	53	23	47	49
incG	37	51	36	49	73
+incG	26	42	36	58	62
Totals	105	46	121	54	226

The second set of conditions can be measured by comparing those specimens that reflected prolonged growth inhibition with those that exhibited less growth constraint. The subset (+) was assigned to partially cross dated tree-ring samples, where a ring count was made to the exterior of the specimen. More than 90% of the (+)-dated samples possessed

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compacted, smaller than average ring series that accompanies chronic tree growth inhibition (Fritts, 1966; Stokes and Smiley, 1964a; Stokes, 1970).

No significant relationship can be demonstrated between relatively poor habitat and gallery incidence. The +G and the +incG frequencies listed in Table 9 are not proportionately higher than G and incG. Moreover, an expectable positive association +G and +incG with terminal ring indices less than 1.00 does not consistently obtain. Therefore the high frequency of beetle galleries on the NLC specimens is not significantly related to environmental stress and bark beetle infestation of living trees.

The remaining alternative relationship between galleries and bark beetle activity in dead or freshly killed tree stems appears to be the most likely. The high degree of association between specimens exhibiting the G condition and consistency with independent dating evidence, illustrated in Table 8, would indicate that galleries specify wood harvesting from living trees that were subsequently attacked by bark beetles. The question remains, however, why the high incidence of galleries occurs on the NLC specimens.

The extent of galleries on the surface of a given stem segment increases with the amount of time the beetles have access to the phloem layer beneath the bark (Graham, 1965). In some cases in the prehistoric Southwest, wood was apparently harvested and stockpiled for a period of time until the beetles loosened the bark sufficiently for peeling from the woody stem (Graham, 1965; Dean, 1969a). After bark removal, however, beetle activity is terminated. Judging by the high occurrence of

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beetle galleries and the high degree of dating compatibility with G-dated specimens, two alternative behavioral options appear to be likely: (1) the wood was harvested from live trees, stockpiled for a considerable period of time until the beetles had thoroughly burrowed beneath the bark, then the bark was removed and the wood was incorporated into a structure, or (2) the wood was harvested from living trees, incorporated into structures immediately with the bark remaining on the stem segments, and extensive beetle gallery activity occurred while the stem was in the structural usage.

There is more evidence to support the second behavioral sequence than the first. As demonstrated previously, the preference for Navajo wood harvesting activity in the late spring-early summer period coincides with the favored season for constructing domestic structures. It is possible, therefore, that both of these activities took place in the same year. Also, as shown by Table 10, specimens exhibiting the G condition are found with virtually the same proportional frequency in both domestic and nondomestic structures.

Table 10. Gallery Incidence by Architectural Type.

Architectural type	Galleries		No galleries		
	Specimens	%	Specimens	%	Totals
Domestic[a]	147	70	62	30	209
Nondomestic[b]	25	69	11	31	36
Totals	172	70	73	30	245

[a]Hogans, lean-tos, windbreaks.
[b]Sweathouses, corrals, lamb pens, game traps.

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More refined analyses of gallery incidence indicate that Navajo wood-related activities varied with time, space, and the type of structure being built. Specimens from habitation structures that exhibited evidence of a true exterior were plotted through time on a cumulative graph, shown in Fig. 3. Each sample with galleries was assigned a unit value of +1.00, and each specimen with no observed galleries was given the value of -1.00. Unit values were algebraically summed in cases where more than one specimen dated to the same year.

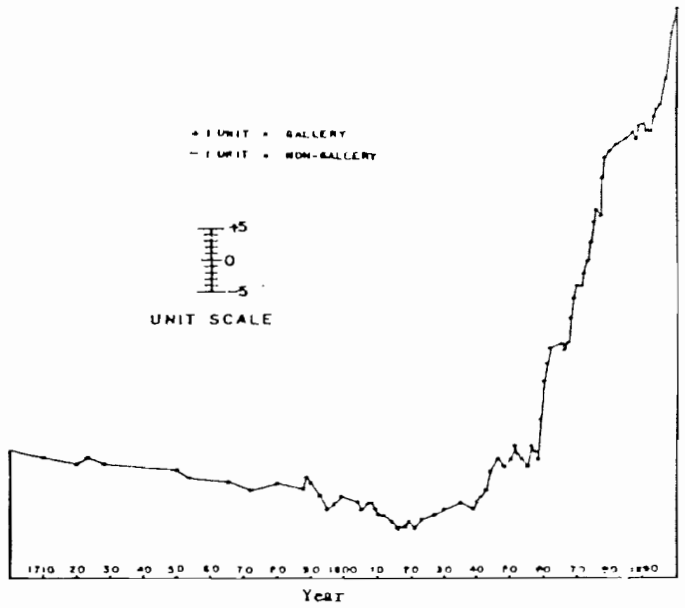

Fig. 3. Cumulative Graph of G and non-G Wood from Dwellings.

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Figure 3 illustrates that, from A.D. 1700 to 1817, the incidence of non-G specimens outweighs that of G samples. From A.D. 1818 to 1858, the opposite is true although on a year-to-year basis there appears to be an admixture of the two trends. However, from A.D. 1859 to 1900, galleries more consistently occur with higher proportionate frequency than nongalleried specimens. This reversal in gallery incidence through time is shown in Table 11, where the outcomes within the sample population used in Fig. 3 are presented.

Table 11. Beetle Galleries in Wood from Dwellings.

	Galleries		No galleries		
Time period	Specimens	%	Specimens	%	Totals
1700-1817	14	35	26	65	40
1818-1900	113	75	37	25	150
Totals	127	67	63	33	190

A comparison of relative gallery frequencies within the entire Land Claim survey area, listed in Table 12, provides answers to a number of questions that arose in the context of the patterns observed in the 1882 study area. The data were compiled from Stokes and Smiley (1963, 1964b, 1966, 1969).

First, the low incidence of galleries on wood from habitation structures within the A.D. 1700-1817 period is shared in sites within a zone that is geographically contiguous to the study area. This zone includes the San Juan drainage to the northeast, the Chinle region

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Table 12. Gallery Incidence Throughout the Land Claim Area.

Location	A.D. 1700-1817		A.D. 1818-1900	
	G	non-G	G	non-G
Upper San Juan	10	18	0	0
Middle San Juan	0	1	16	6
Lower San Juan	2	10	5	9
Total northern sector	12	29	21	15
Alamo Salado	3	6	38	13
Middle Little Colorado	5	1	0	1
Upper Little Colorado	28	18	39	11
Total southern sector	36	25	77	25
Rio Puerco	6	12	48	7
Chaco Canyon	2	3	5	4
Canyon Largo	25	78	4	14
Total eastern sector	33	93	57	25
Chinle Valley	1	10	0	0
Havasu Canyon	1	0	1	3
Navajo Mountain	8	1	20	3
Lower Little Colorado	44	19	16	4
Total western sector[a]	54	30	37	10

[a]Excluding the 1882 study area.

immediately adjacent to the study area, further to the east in the Chaco Canyon and Canyon Largo districts, and to the southeast in the Rio Puerco and Alamo Salado regions. The continuous distribution of this pattern beyond the study area lowers the probability that it is due to chance alone.

Second, the fact that gallery incidence is not insignificantly small in the early period is most consistent with the following behavioral sequence:

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(1) Wood is harvested from live trees.

(2) The wood is stockpiled, thus allowing beetle activity to commence.

(3) The bark is stripped from the wood shortly after beetle activity begins.

(4) The wood is then incorporated into habitation structures.

Previously demonstrated relationships are consistent with this hypothesized behavioral sequence. Hogan entry orientations from the study area specify an early spring to late summer construction, and there is a significantly high occurrence of trees that were harvested within the spring-summer growing season during the A.D. 1700-1817 period. The comparatively low frequency of galleried specimens indicates bark peeling shortly after harvesting or perhaps there was a relatively short wood storage period. The rate of gallery formation in pinyon, however, is unknown. Thus wood could have been harvested, perhaps stored, stripped, and used in construction with the orientation of the structure falling within the summer solstice range.

The Navajo occupying another geographically contiguous zone during the early period engaged in a different set of wood-related behaviors. As Table 12 illustrates, the proportionately low frequency of galleried specimens did not consistently obtain throughout the entire NLC area. Significantly higher gallery incidence is present in habitation structures south of the study area along the upper, middle, and lower portions of the Little Colorado River basin, and to the northwest in the Havasu Canyon and Navajo Mountain regions. The occupants of this

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zone either stockpiled wood for extensive periods of time before construction, or were incorporating freshly cut wood with the bark remaining directly into their dwellings.

Finally, the reverse trend in gallery incidence from A.D. 1818 to 1900 noted in the study area also occurs within the remainder of the Navajo Claim area. The fact that this pattern is present in other regions would reduce the probability that the 1882 area sample was skewed. Note in Table 12 that seven out of 11 areas show a predominance of galleried specimens during the later period. This shift through time would support the two behavioral alternatives mentioned above; either wood was stockpiled for a considerable length of time in the later period, or freshly cut wood with the bark remaining on it was incorporated immediately into habitation structures.

Navajo structures are generally spatially discrete entities, and, unlike contiguous puebloan room blocks, it is difficult to find independent microtemporal evidence to directly infer the presence or absence of a wood stockpiling phase. However, a number of statements can be made. Since there is no evidence to the contrary, the high frequency of galleries in the A.D. 1818-1900 period is more likely related to the absence of stockpiling and the use of freshly cut wood with the bark remaining on it in the construction of habitation structures.

First, dated specimens showing evidence of a true exterior from the same domestic structure constructed during the period A.D. 1818 to 1900 were compared to evaluate the following possibility: If timber used in the original construction phase of a structure was stockpiled, and wood used later in the repair or remodeling of the structure was cut

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and the bark removed on an *ad hoc* basis, the earlier material should exhibit the gallery condition to a greater degree than the later material. The results of this comparison, shown in Table 13, indicate that these expected outcomes did not obtain. The most frequent combination is for both the early and late specimens from the same structure to be galleried.

Table 13. Galleries on Samples Dating Early versus Late from the Same Dwelling.

N	Both G	G, non-G	Both non-G	Non-G, G
Specimen pairs (25 structures)	26	2	1	6

Second, wood harvesting and domestic structure construction were seasonally coincident, and thus consistent with the absence of a stockpiling phase.

Third, G-dated specimens are highly compatible with dates derived independently from informants and historic goods (see Tables 4 and 8). Although the boundaries of these estimates fall within a decade of the tree-ring dates, if there was a stockpiling period, it could not have been more than 10 years in duration. This evidence would decrease the probability of long-term continuous stockpiling, and again is consistent with the absence of a stockpiling phase.

Fourth, the G-condition outcomes from game traps, a set of structures that were most likely constructed and maintained on an *ad hoc*

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basis, are identical with those from habitation structures built in the 1818-1900 period. The tree-ring data from the traps are presented in Table 14.

Table 14. Galleries on Wood from Game Traps.

NLC designation	Tree-ring dates
W-LLC-MB-G	1819incG 1849incG 1840+incG
W-LLC-MJ-DD	1772incG 1798+incG 1795+incG 1806+incG
W-LLC-MJ-IDI	1809incG 1811incG 1804+incG
W-LLC-MJ-II	1817incG 1810+inc 1822+incG 1826G
W-LLC-P-F	1710inc
W-LLC-P-I	1754+

The Land Claim site designation system indicated in Table 14 locates the site within four increasingly specific geographical zones. The entire claim area was subdivided into four sectors defined by the cardinal directions. The "W" indicates the western sector. Each sector is then divided into areas, usually defined by a drainage or a drainage segment. The "LLC" represents the area that drains into the Lower Little

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Colorado River. Within each area is a subarea that is defined by a physiographic feature such as a mountain, a mesa, a drainage, or a drainage segment. The "MJ," for example, signifies the Middle Jeddito Wash subarea. Finally, sites within the subarea are designated by sequentially assigned letters. The letter "A" would indicate the first site designated within the subarea, and "AA" (= "A2") would specify the 27th site located during the survey of the subarea.

Game traps are functionally defined as deer and antelope drive pens, composed of cribbed wooden circular or subcircular catch pens measuring 65 to 250 feet in diameter and with walls up to 8 feet in height. Attached to each side of the 25- to 50-foot opening in the catch pen is a horizontally stacked wooden fence, extending ¼ to 1 mile in length. The two fences served as the drive chute (Hill, 1938, pp. 145-156; Van Valkenburgh, 1956a, pp. 33-38).

The nature of game trap pen and fence construction indicates that the bark was not stripped from the wood. Tree segments that include the smaller branches were stacked horizontally (Van Valkenburgh, 1956a, p. 34). Removing the bark from these highly branched tree sections would be difficult, if not impossible, without removing some of the smaller branches.

Several distinctive patterns in the terminal ring conditions of specimens from game corrals can be seen in Table 14. First, virtually all of the samples, where the observation was possible, show that the wood was harvested during the late spring-early summer growing season. Second, in all game traps that contain two or more dated specimens, there is direct evidence that tree-harvesting activity took place in at least

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two different years, indicating periodic maintenance of these structures. Third, all but three specimens exhibit beetle galleries. This pattern supports the likelihood that the bark was not stripped from the freshly cut wood. The fact that Navajo wood harvesting activity for game traps is reportedly performed immediately prior to construction (Hill, 1938, p. 150; Correll, 1961, p. 663) leaves only one likely alternative to account for the high incidence of galleries: Beetle galleries were produced on wood with the bark remaining on it while the material was in structural usage.

A direct line of evidence demonstrates the absence of stockpiling and the practice of building domestic structures with unpeeled wood in the period A.D. 1818 to 1900. The NLC archaeological staff recorded 31 cases where the bark had not been stripped from wood used in habitation structures. Table 15 lists the sites chronologically. The sample is spatially and geographically representative of the 1882 study area and includes nine scattered subregions out of 26, indicating that this was a widespread practice. The dates assigned to the structures fall within the period A.D. 1818 to 1900.

A higher incidence might have been available had the NLC staff made this observation consistently. Moreover, the poor preservation properties of bark exposed to the elements undoubtedly reduced the probability of finding this material on wood cut prior to A.D. 1850. These statements are supported by the fact that all 21 Navajo domestic structures that I personally observed in Long House Valley, attributable to the late 19th and early 20th centuries, were built with the bark remaining on the wood.

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Table 15. Dwellings Built with Unpeeled Timber.

NLC designation	Structure No.	Dating method	Date range
W-LLC-UO-KK	Hogan 6	Tree-ring	1850
W-LLC-UD-SS	Hogan 6	Informant	1850-1860
W-LLC-UD-VV	Hogan 1	Informant	1868
W-LLC-M-GGG	Hogan 1	Informant	post-1868
W-LLC-UD-GG	Hogan 2	Tree-ring	1872
W-LLC-DO-V	Hogan 7	Tree-ring	1869-1878
W-LLC-M-VV	Hogan 1	Informant	1870-1879
W-LLC-UO-TT	Hogan 3	Tree-ring	1877
W-LLC-UO-WW	Hogan 1	Artifacts	1870-1889
W-LLC-M-C23	Hogan 4	Informant	1880-1889
W-LLC-MP-F	Hogan 2	Informant	1880-1889
W-LLC-MB-BB	Hogan 1	Tree-ring	1887
W-LLC-UD-II	Hogan 2	Tree-ring	1888
W-LLC-M-D15	Hogan 1	Artifacts	1880-1899
W-LLC-M-E17	Hogans 1 & 4	Artifacts	1880-1899
W-LLC-PA-F	Hogan 1	Artifacts	1880-1899
W-LLC-TM-TT	Hogan 2	Artifacts	1880-1899
W-LLC-MJ-OO	Hogans 7 & 9	Informant	1890
W-LLC-MB-JJ	Hogan 2	Tree-ring	1898
W-LLC-M-E11	Hogan 1	Tree-ring	1898-1900
W-LLC-MJ-A11	Hogans 2 & 3	Artifacts	1890-1899
W-LLC-MJ-A15	Hogan 2	Informant	1890-1899
W-LLC-MJ-BB	Hogan 3	Artifacts	1890-1900
W-LLC-MJ-BBB	Hogans 1 & 4	Informant	1890-1900
W-LLC-M-RRRR	Hogan 1	Informant	1900±
W-LLC-M-C7	Hogan 1	Informant	1900±
W-LLC-M-E19	Hogan 1	Informant	1900±

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Finally, the temporal shift in wood-related behaviors appears to have accompanied technological change. As indicated previously, bark stripping is facilitated by stockpiling. Bark beetle activity, bark rotting, and wood shrinkage loosens the bark so that removal is easily accomplished manually. However, bark removal from freshly cut wood must be performed with an axe or an adze.

Bark removal can be viewed as an activity that renders a domestic structure comfortable. Otherwise, if the bark is not peeled, the inhabitants of a Navajo-style structure will be continuously showered by small bits of bark freed from the woody stem by the natural processes mentioned above. Although the Navajo occupants of Long House Valley were willing to endure these conditions, other groups trimmed the bark from the interior-facing wood. The NLC survey teams noted this interior trimming procedure in hundreds of domestic structures throughout the 1882 study area. All of the datable sites exhibiting this evidence fall within the A.D. 1818-1900 period. Moreover, the metal axe was used to perform this activity.

Figure 4 shows that the earliest datable tree-ring specimen from a domestic structure exhibiting metal axe marks is dated to A.D. 1750. The occurrences of metal axe and "other" wood-cutting techniques, where observed on dated specimens from domestic structures, are plotted on cumulative graphs in Fig. 4. The incidence rate of "other" techniques is consistently high from A.D. 1750 to 1821, and again in the period beginning in A.D. 1858 and ending in A.D. 1874. The incidence of metal axe use increases from A.D. 1808 to 1819, and the rate continues to steadily increase from A.D. 1830 to 1900.

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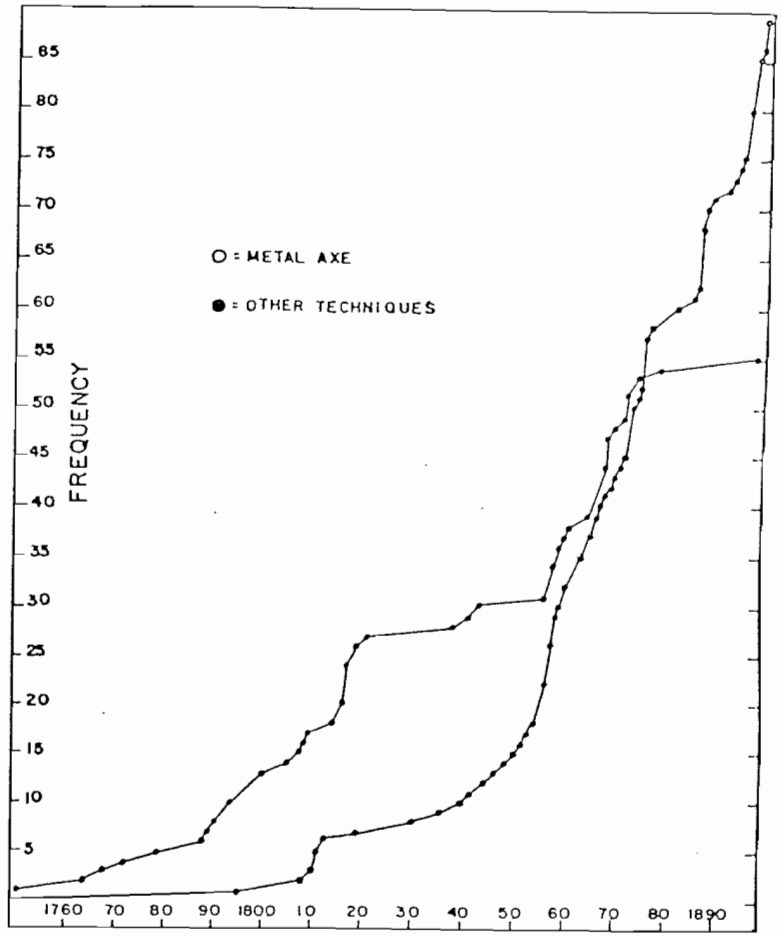

Fig. 4. Graphs of Cutting Methods on Dated Wood from Dwellings.

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The initial increase in metal axe use in the period A.D. 1808 to 1819 coincides temporally with the increase in specimens exhibiting galleries. Thus technological change, specifically the increased use of the metal axe through time, is related to the elimination of the short wood stockpiling period and the subsequent process of peeling bark from the wood to be used in domestic structures. Those groups using metal axes harvested live trees and incorporated the wood immediately into their domestic structures. Bark peeling activity was restricted to the wood surfaces facing the interior of the structure, and this procedure was performed with the metal axe. The untrimmed bark on the wood was then subject to massive bark beetle infestation while the material was in structural usage. The coincident shift to increased gallery occurrence in regions outside of the 1882 study area, presented in Table 12, is undoubtedly related to a similar, if not identical, set of behavioral changes that accompanied Navajo technological change.

Wood Re-Use and Repair Activities

The dated wood from domestic structures indicates the performance of periodic rebuilding and repair activities. Table 16 shows that, in those cases with only two dated tree-ring specimens from the same structure, the odds of the pair dating to the same year areapproximately 2:1 against such an occurrence. The tree-ring samples that exhibit no observed characteristics of a true exterior are not included in this estimate. The odds of two or more specimens from the same structure matching in all sample size classes are about 1:1. This is compatible with the notion that at least half of the wood in a given structure

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represents the initial wood harvesting and construction event. The rest of the wood dates the subsequent rebuilding or repair activities.

Table 16. Comparison of Outside Tree-Ring Dates within Multi-dated Hogans.

Specimens per structure	All same year	Same and different years				All different years	Total cases
		Cases	Same	Earlier	Later		
2	11	-	-	-	-	18	29
3	1	5	X	0	X	0	6
4	0	1	X	X	0	0	1
5	0	0	0	0	0	1	1
6	1	0	0	0	0	0	1
7	0	0	0	0	0	0	0
8	0	1	X	0	X	0	1
Total cases	13	7				19	39

Key: X = present
0 = absent

Other evidence supports this contention. First, the distributions of matched and nonmatched terminal dates in Table 16 show that, as the number of specimens per structure increases, it becomes increasingly probable that two or more specimens will date to the same year. Thus, a significant population of wood segments in the structure was harvested at the same time. Second, in six out of seven cases considered under the heading "Same and different years," the nonmatching dates are later than the matched specimens. It is highly likely, therefore, that the matched date population represents the initial construction event, and the later nonmatched date population specifies rebuilding or repair events.

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The periodicity of structural repair activity is designated in Table 17, where the number of years between cutting dates within each multidated domestic structure is presented as a distributional array. The distribution was generated on a case-by-case basis. A structure having two or more specimens dating to the same year is considered a single example of a "0" class case. A structure yielding three specimens dating to three different years produces three unique differences, and so on.

Table 17. Chronological Differences Between Cutting Dates in Dwellings.

No. years different	No. cases	No. years different	No. cases	No. years different	No. cases
0	20	10	1	51	2
1	4	11	1	70	1
2	2	14	2	94	1
3	1	15	1	100	1
4	2	18	4	141	1
5	1	20	1	155	1
7	2	25	3	159	1
8	1	28	1	166	1
9	2	31	1	182	1

Based upon the arguments concerning rebuilding and repair presented above, the data in Table 17 serve as an index of these activities in habitation structures through time. The most populous class, "0," represents the initial construction event. Most of the remaining differences cluster within 1 to 25 years, approximately one human generation,

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and may well record the incidence of repair activities performed by the inhabitants. The 20-year gap between 31 and 51 years probably separates rebuilding and repair activities from the use of previously cut or dead wood. The latter pair of alternatives is designated by the differences ranging from 51 through 182 years.

There is additional evidence for the use of old wood in the construction of hogans. In terms of dendrochronological information alone, there are six cases out of 39 where the disparity between outside dates in each structure is greater than or equal to 51 years. There are two single-dated structures where the informant dates are more than 50 years later than the tree-ring dates. In both of these cases, dated historic artifacts associated with the hogans independently confirm the informant estimates.

On the basis of the behavioral evidence, however, the extent to which wood was harvested from dead pinyon trees for use in domestic structures is minimal. The analyses of the growth condition (inc, c) and the gallery condition (G, non-G) indicate that wood was preferentially harvested from living trees. In addition, approximately 80% of the sample of tree-ring dates found in contexts where independent dating evidence was available are consistent with this evidence (see Table 4).

Wood reuse probably exceeded the use of dead trees in construction. Within approximately 100 sites where the observations were made, the NLC survey crews reported 12 cases in which more than one cutting technique was present on the wood from the same dwelling. In some of these, individual timbers exhibited more than one cutting technique. Additional information was available for six of these dwellings to

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support the notion of wood reuse. For example, the wood cut by the older methods was more severely weathered or cracked than the wood bearing metal axe marks. In other instances, trade items associated with the structure were consistent with the condition of the metal axe cut wood.

The use of wood with inconsistent dates or showing multiple cutting techniques in the same structure is highly patterned in both time and space. All of these cases are confined to regions where the length of Navajo occupation is greatest. In the areas where occupation time was relatively short, virtually all of the dates from a given structure are mutually consistent. Thus the probability of wood reuse increases with the increased availability of abandoned structures.

Another more direct line of evidence is consistent with this pattern of wood reuse activity. In approximately half of the sites where the dates derived from two or more dating methods are inconsistent or where more than one cutting method was used on the wood in a given structure, there are one or more dismantled hogans with most of the wood removed.

Environmental constraints may be related to this particular pattern of Navajo wood reuse. In Long House Valley I found that the likelihood of wood reuse increases with decreased wood supply. Parallel to the northern valley slope, in a zone defined by the valley floor and extending approximately ¼ mile above the valley, the ratio of axe cut stumps to living trees indicates that 70% to 80% of the wood resources have been exhausted over a period of 50 to 100 years. Abandoned domestic structures in this zone are now being dismantled and the wood stockpiled for reuse. An example of this activity is shown in Fig. 5.

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Fig. 5. Dismantled Hogan and Stockpiled Wood.

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In Long House Valley, the primary relationship between the environment and wood reuse is that the rate of Navajo wood harvesting has exceeded tree replacement. As discussed previously, tree growth is limited by water stress throughout the study area. Consequently the length of time required for trees to reach the appropriate diameter for use in domestic structures is considerable. The average age of tree segments used in domestic structures within the 1882 area is 180 years, within a total range of 60 to 400 years.

The wood related behaviors associated with the construction of livestock maintenance structures appear to be identical with those of domestic structures. Circular or subcircular corrals and lamb pens are built with horizontally stacked tree trunks and branches. The few horse corrals located during the survey are distinguished from sheep and goat pens by the height of the walls and the use of heavier timber. Horse corrals are generally 6 to 8 feet high whereas sheep and goat corrals are made of light timber, usually branches, with walls 3 to 4 feet in height. Lamb pens are miniature sheep corrals, ranging between 4 and 10 feet in diameter, and are constructed of smaller tree branches.

Although there are only 21 dated tree-ring specimens from corrals and lamb pens, the distributions of terminal ring condition subset outcomes are similar to those from hogans. Six out of seven specimens, for example, exhibit the inc growth condition, indicating that wood for livestock structures was preferentially harvested during the growing season. In terms of beetle gallery incidence, six out of 10 specimens are galleried. There are only two samples with intact exteriors that date prior to A.D. 1817, and both are nongalleried. This pattern,

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although based on a very small sample, is identical to that observed in domestic structures. Perhaps the wood was debarked, perhaps after a short stockpiling period prior to use in all structures in the period A.D. 1700-1817. The high incidence of galleries on the later corrals and lamb pens probably designates the use of unpeeled wood.

The tree-ring evidence from Navajo sweathouses conforms in most respects to that from domestic structures. Sweathouses are structurally defined as miniature interlocked forked-pole hogans. The mode of constructing the wooden superstructure can be seen in Fig. 6. The completed structures are then covered with earth. Features associated with sweathouses specify behaviors that pertain to their function. An exterior hearth is used to heat the small stones that are then placed inside the structure to one side of the doorway. The occupant is seated on the opposite side of the entrance absorbing the dry heat. Once heated and utilized, the stones are discarded in a pile adjacent to the sweathouse. Unused rock is stockpiled separately.

A total of 13 tree-ring specimens were datable from sweathouses. Three out of six samples exhibit the G condition, and all of these date after A.D. 1817. Moreover, the NLC survey crews recorded nine cases in sites dating after A.D. 1817 where bark was not peeled from the wood used in constructing sweathouses. These nine examples were scattered throughout the study area. The use of the metal axe to trim bark from the interior surfaces of wood used in sweathouses was recorded for approximately 20 sites. Thus the absence of a wood stockpiling phase and the use of bark-laden wood in domestic structures in post-A.D. 1817 sites is also reflected in the construction of sweathouses. Too few

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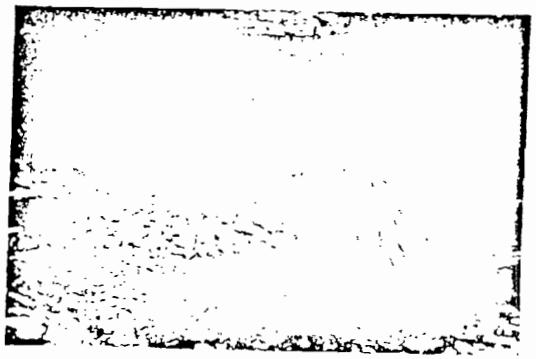

Fig. 6. A Sweathouse and Stone Discard Pile.

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specimens were available to specify any preferred season for harvesting wood for use in sweathouses. The distribution of sweathouse entry orientations is apparently not directly related to solar phenomena, and thus cannot specify the season of construction.

The number of dated tree-ring specimens from other types of structures is extremely small. Thus dendrochronological data cannot be employed separately or in combination with other information to specify wood-related behaviors used in the construction of these structures.

Wood Cutting Methods

When treated analytically as artifacts, wood from archaeological sites is a potentially rich source of information related to technological and other activity systems (Robinson, 1967). Structural features datable by dendrochronological and other methods produced a considerable amount of information concerning regularities in Navajo wood segmenting techniques. The modes of felling, reducing, and shaping trees (beam condition) was noted by the Navajo Land Claim staff for approximately 1,000 dated structures. More than 90% of these structures fell within the five categories listed in Table 18. These five types, moreover, are the most populous architectural feature classes recorded in the survey reports.

Table 18 illustrates the impact of technological change on wood cutting behavior. As the metal axe became increasingly available to Navajo groups, the proportional incidence of its use increased, and the relative occurrence of the other methods decreased through time.

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Table 18. Beam Conditions in Five Major Classes of Architecture.

Architectural type	Beam condition type: Stone axe	%	Burning	%	Breaking	%	Metal axe	%	Total
				A.D. 1750–1800					
Domestic structures	6	12%	9	18%	27	54%	8	16%	50
Game traps	1	33	1	33	0	0	1	33	3
Livestock structures	1	7	5	33	7	47	2	13	15
Windbreaks	0	0	0	0	0	0	0	0	0
Sweathouses	0	0	0	0	0	0	0	0	0
Totals	8	12%	15	22%	34	50%	11	16%	68
				A.D. 1801–1867					
Domestic structures	7	4%	29	16%	85	46%	64	34%	185
Game traps	7	29	4	17	7	29	6	25	24
Livestock structures	2	3	15	21	25	35	29	41	71
Windbreaks	0	0	1	17	3	50	2	33	6
Sweathouses	0	0	4	29	5	36	5	36	14
Totals	16	5%	53	18%	125	42%	106	35%	300
				A.D. 1868–1880					
Domestic structures	0	0%	20	9%	42	20%	149	71%	211
Game traps	0	0	0	0	0	0	0	0	0
Livestock structures	1	1	20	18	35	31	56	50	112
Windbreaks	1	3	3	9	11	31	20	57	35
Sweathouses	0	0	0	0	2	6	31	94	33
Totals	2	1%	43	11%	90	23%	256	65%	391
				A.D. 1881–1900					
Domestic structures	0	0%	4	3%	8	6%	121	91%	133
Game traps	0	0	0	0	0	0	0	0	0
Livestock structures	0	0	5	9	12	23	36	68	53
Windbreaks	0	0	0	0	4	19	17	81	21
Sweathouses	0	0	0	0	0	0	16	100	16
Totals	0	0%	9	4%	24	11%	190	85%	223

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Despite these general trends, variability exists in wood-cutting methods within each time period. The departures specify differential wood-use strategies that vary by architectural type. From A.D. 1868 to 1900, deviations from the total percentage within each beam condition class correspond to stem types generally selected for use in the various architectural classes. For example, sheep corrals, lamb pens, and windbreaks are usually composed of light untrimmed wood such as small branches. Domestic structures and game traps, however, are characteristically built with wood from the main stem or trunks of trees. Note in Table 18 that the proportional incidence of burning and breaking methods in livestock and windbreak structures from A.D. 1868-1900 significantly exceeds their occurrence in domestic structures.

This pattern was frequently observed within a given site, where wood from hogans was cut by a metal axe and the associated corrals or windbreaks were constructed of wood exhibiting mostly broken or burned beam conditions. I personally observed the same pattern in most Navajo sites I visited in Long House Valley.

A more refined analysis of the beam condition data indicates that a complex but consistent set of behaviors is responsible for these patterns. Additional wood trimming was undoubtedly required in the construction of domestic and sweathouse structures. The length of the beams and chinking material was probably adjusted to maximize structural stability and wood-to-wood contact. Both of these requirements are necessary to carry the weight and to maintain the integrity of the earthen covering that was always placed upon Navajo sweathouses and hogans. In contrast, little or no trimming and stem length adjustment are required

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in the construction of windbreaks and livestock structures. Thus the post-A.D. 1868 beam condition frequencies in habitation and sweathouse structures do not accurately reflect the incidence of changing tree felling techniques, but rather the increased availability of the metal axe to perform felling *and* secondary modification behaviors.

In summary, an analysis of populations of dated pinyon pine tree-ring samples exhibiting various element combinations of the exterior ring condition set has led to the identification of several regularities in Navajo wood use behavior. A number of the ring condition subsets can thus be transformed into behaviorally meaningful statements.

The growth condition subset, when specified by the elements inc or c, on tree-ring samples, is highly consistent with independent dating evidence. This would indicate that wood was preferentially cut from living trees. Although both elements, inc and c, are equally consistent with other dating evidence, a significantly high proportion of the samples exhibit the inc element. This indicates that wood harvesting for architectural use generally occurred in the late spring-early summer. This is also the preferred season for dwelling construction.

The gallery condition subset, when specified by the element G on dated wood samples, is also highly consistent with independent dating evidence. The high incidence of galleries is related to the use of freshly cut timber with the bark remaining on it for construction. This behavior is associated with the use of the metal axe in building dwellings. Instead of debarking the wood entirely, the interior-facing side of the timbers was frequently trimmed with the metal axe. The remainder of the wood surface was therefore subject to beetle infestation. Wood

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for many dewllings and other structures, however, was not partially debarked and was thus subject to beetle infestation. Prior to A.D. 1817, before the metal axe was available to more Navajo groups, wood for domestic structures was generally debarked, perhaps after a short stockpiling period.

All of the specimens possessing bark are consistent with independent dating evidence (see Table 4). The B dates fall within the post-A.D. 1817 period when wood was generally not debarked. The B outcome of the bark condition subset also specifies the harvesting and the immediate use of wood that was cut from live pinyon trees.

Wood use behaviors reconcile some of the apparent inconsistencies in the tree-ring dates from the same structure. Dwellings were frequently repaired, and after A.D. 1868, wood from previously built structures was re-used with greater frequency. The amount of dead wood used in architectural features appears to be minimal. On the basis of independent dating evidence alone, the proportion of dead wood exhibiting one or more of the ring condition elements presented above does not exceed 12% (see Table 4). Since a portion of the date inconsistencies is produced by repair and re-use activities, the amount of dead pinyon used in construction would probably be lower than the 12% estimate. In terms of wood use behavior, it can be stated with about 90% confidence that an isolated tree-ring date from a pinyon timber from a Navajo structure located within the study area possessing one or more of the outside ring conditions inc, c, G, or B represents a wood harvesting event.

The behavioral relationships presented in this section render the tree-ring dates partially interpretable. However, a more complete

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explication of the dates and the ring condition subsets must include relations with the physical environment. Those regularities most pertinent to interpreting the dates for use in settlement analyses will be presented and discussed in the following section.

Probability Dating

Dendrochronology and Navajo wood-use behaviors are highly interrelated. The dating properties of specimens from architectural features are significantly associated with the stem classes selected for use.

Based upon the relationships established in the previous section, a terminal tree-ring date followed by one or more of the observations inc, c, G, and B is highly related to the death date of the specimen. However, Table 4 shows that the absence of any observable details concerning the growth, gallery, or bark conditions on wood samples is less likely to be compatible with other kinds of dating information. This pattern is predictable, given erosion and decay processes operating upon the exterior surface of the specimen that would, in time, remove one or more outside rings and thus remove all traces of the terminal ring condition.

The question raised in the context of these statements was whether or not the thicker mainstem wood from game traps and domestic structures survived these corrosive forces at a higher rate through time than the smaller branches used in livestock, windbreak, and sweathouse structures. The answer to this query is apparent in Table 19. The percentage of dated specimens lacking any observable evidence of a true exterior collected from structures generally built with branch wood

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significantly exceeds that from features usually constructed with trunk segments.

The statement that the absence of terminal ring characteristics on the exterior surface of dated specimens is related to erosion is clearly supported in Table 19. The proportional incidence of samples lacking such evidence is markedly higher in the early period in both architectural wood composition classes.

Shorter time period categories are not warranted in Table 19. The number of exterior rings missing from any given specimen cannot be estimated without experimental data concerning wood erosion rates within the study region.

Table 19. Wood Samples Lacking Evidence of True Exteriors.

Architectural wood composition	Pre-1700 to 1850		1851 to post-1900		Total period	
	Number	%	Number	%	Number	%
Heavy wood structures[a]	47/126	37	3/144	2	50/270	18
Light wood structures[b]	18/20	90	0/22	0	18/42	43
Totals	65/146	44	3/166	2	68/312	22

[a]Domestic and game trap structures.
[b]Livestock, windbreak, and sweathouse structures.

Navajo wood selection strategies, combined with the environmental settings from which wood was harvested for construction purposes, are interrelated with the datability of the tree-ring samples. The probability of a tree-ring specimen cross dating with a master chronology is

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reduced by a number of conditions (Dean, Robinson, and Stokes, 1970), as follows:

(1) The annual growth rings on a specimen must be discernible. Thus, if a wood or charcoal fragment is crushed or decayed, the specimen is generally not datable.

(2) Altered growth conditions for a tree can affect datability. Ring series from trees that have been subjected to disease, insect, or fire damage often exhibit anomalous growth patterns that do not covary with the master chronology, and thus they cannot be dated.

(3) Cross dating is usually not obtainable from specimens that exhibit little ring-to-ring width variation. Trees growing under optimal conditions usually produce large annual rings, all of which are nearly identical in width, and thus are not datable. In contrast, trees growing on sites where climatic and nutritional input is perennially insufficient for normal growth generally produce small rings with little year-to-year variation, and are not datable.

The impact of these limiting conditions upon successful specimen cross dating varies inversely with the length of the ring series being examined and stem diameter. Total decomposition of small branches occurs within a shorter period of time than the main trunk. Moreover, smaller diameter wood or charcoal is probably less likely to survive crushing forces than thicker segments. If a tree survived a recent fire, insects, or disease, it is more probable that the mainstem section, containing a

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longer ring series, would be partially datable, and the erratic or suppressed growth in the shorter and younger series of rings in the branches would not cross date. Similarly, changing microenvironmental conditions such as an increase or decrease in arboreal plant competition might well affect the datability of the branches, but the trunk might partially cross date with a master chronology.

The diameter of a stem, however, does not directly determine age or datability. For example, two wood samples measuring 3 inches in width might well contain 30 and 300 annual rings, respectively, and both might be datable. Nonetheless, diameter, age, and growth characteristics are usually intercorrelated within the same tree, and among trees located within the same environment (Fritts, Smith, and Stokes, 1965; Fritts, 1966).

The interplay of these conditions on pinyon specimen datability within each major Navajo architectural type is illustrated in Table 20.

Table 20. Datability of Specimens from Five Architectural Classes.

Architectural type	Datable specimens		Undatable specimens		Total No. specimens
	Number	%	Number	%	
Domestic structures	254	32	552	68	806
Livestock structures	21	29	52	71	73
Sweathouses	13	25	39	75	52
Game traps	16	23	54	77	70
Windbreaks	8	18	36	82	44
Totals	312	30	733	70	1045

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Tree-ring specimens from domestic structures show the highest percentage of datability. The second and third highest datable percentages are obtained from livestock and sweathouse structures. The occurrences of these three architectural types are highly coincident on a site-to-site basis, and the environmental settings of these sites are generally in pinyon-juniper woodlands. The slight discrepancies in datability are therefore probably related to a decrease in datability with decreasing stem diameter.

Game trap catch pens are constructed of heavy mainstem wood. However, these structures contrast in their environmental setting with hogans, sweathouses, and livestock structures. Virtually all game corrals are located in relatively open grassland environments where soil and possibly other conditions are inimical to arboreal growth. The few scattered trees that probably served as construction material were growing under extreme stress conditions and thus were less likely to cross date.

The lowest yield of tree-ring dates is from windbreaks. Both environmental and diameter related conditions probably limited the datability of this sample. Windbreaks are usually constructed of small branches and are predominately located in environmental zones with low arboreal density.

The environment of the 1882 study area is significantly related to the problems encountered by dendrochronologists attempting to cross date the NLC archaeological tree-ring specimens. Out of 316 dated samples, 166, or 52%, were assigned the "+" symbol, indicating that the specimens were either partially cross dated, with a ring count made to

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the exterior, or the outermost rings fell within a period where small rings are known to occur and thus may be missing from the specimens. Most of the "+" dated samples from the study area are characterized by compact ring series exhibiting little ring-width variation (Stokes and Smiley, 1964a).

Since more than half of the dated specimens were not absolute outside dates, it was necessary to search for death-date estimation methods that could provide more refined dating controls. Dated samples showing the "+" condition and lacking any evidence of a true exterior could not be considered for death-date estimation without experimental data concerning wood surface erosion rates. Within the total population of tree-ring dates from the study area, 69, or 22%, fell into this category and were excluded from further analyses. Only those "+" specimens with one or more of the terminal ring conditions inc, c, G, and B could be considered for death-date estimation.

Based upon the relationships established in the preceding sections of this chapter, there are two principal sources of error in estimating the exact year in which a "+" dated specimen was harvested. Wood use behaviors such as remodeling and re-use activities could affect the dimensions of the death-date estimate range. Secondly, environmental conditions related to tree growth could affect the number of years discrepancy between the outside date of a "+" dated specimen and the actual year of tree death. The question raised in this context is which of these two sets of relations had the greatest impact upon the dating properties of the "+" specimens?

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The interpretations of the patterns in the data presented in Table 21 indicate that environmentally related sources of error significantly outweigh behavioral ones. Tree-ring dates from multiple-dated structures having a mixture of "+" and fully cross dated specimens were compared with each other to see whether "+" dates were consistently earlier or later than the true cutting dates. Only domestic structures were used in this analysis. Multiple dated game traps were not included in the sample, for it was apparent that these structures were repaired frequently (see Table 14). Data from structural types other than domestic structures were not available. In order to obtain a comparable and a larger sample of comparisons, multiple-dated domestic structures in the regions immediately adjacent to the 1882 study area were compiled and are included in Table 21.

Table 21. Comparison of "+" Dated with Fully Cross Dated Tree-Ring Samples.

	"+" date earlier[a]			"+" date later[a]		
Sample area	(1) No. samples	(2) No. of structures	Ratio (1):(2)	(3) No. samples	(4) No. of structures	Ratio (3):(4)
1882 study area	25	6	4.17	11	5	2.20
W-LLC, W-CH circum-study area	47	7	6.71	10	3	3.33
Total region	72	13	5.54	21	8	2.62

[a]In relation to cutting date.

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Extrapolating from the growth characteristics of pinyon in the study area and its immediate environs, "+" dated specimens should consistently date earlier than the cutting dates. Stokes and Smiley (1964a) indicate that specimens in this region rarely possess "double" rings, whereby a tree initiates growth more than once per year. Moreover, the NLC tree-ring specimen work notes do not list any occurrence of double rings in any dated sample collected from the 1882 study area. If a specimen was partially cross dated with a ring count made to the exterior, it is highly unlikely that the outside date would overestimate the actual death date of the sample. However, the specimens usually possessed small, compact ring series. Previous studies have shown that datable tree species showing these growth characteristics are likely to show a high incidence of locally absent rings (Fritts, Smith, Budelsky, and Cardis, 1965, pp. 7-14; Fritts, Smith, Cardis, and Budelsky, 1965, pp. 396-399; Fritts, 1966, pp. 973-974). It is probable, therefore, that the terminal date of a "+" dated sample would be an underestimate of the true death date. Thus if the wood in a given domestic structure was harvested in the same year or if repairs were made over a short period of time, "+" dates should be consistently earlier than the cutting date specimens.

Navajo wood-related behaviors could counterbalance environmentally related dating error and produce another kind of error pattern. If part of the wood in a hogan was re-used from a previous structure, or a series of repairs was made over a sufficiently long period of time, the underestimated "+" dates from the youngest wood might well be later than cutting dates from the re-used or initial construction material. If

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these kinds of behaviors predominated, there should be no significant difference between "+" dates being earlier or later than the cutting dates, or perhaps a tendency toward the "+" dates being later than the cutting dates could occur.

Table 21 shows that the frequency with which "+" dates from the same structure are earlier than the cutting dates is significantly higher than the frequency with which "+" dates from the same structure are later than the cutting dates. If the ratios presented in Table 21 are viewed as crude measures of rate, it would appear that the number of wood cutting events within a given structure fell within a short period of time, and the "rate" of such occurrences is consistently twice as high in all sample areas.

There are two separate sets of criteria by which the "+" symbol is assigned. Thus the environmentally related sources of error within each type might well be different. The first set of conditions states that a "+" is given to a specimen when the outermost rings fall into a period in which very small ring(s) are known to occur but the specimen does not possess enough additional rings to permit the presence or absence of the ring(s) to be verified. After examining the NLC archaeological specimen work notes, only one "+" date assigned on the basis of these criteria from a multiple-dated structure was found in the study area collection. This particular specimen dated two years earlier than the cutting date. The limited amount of information, however, prevented a separate evaluation of this class of "+" dates in death-date estimation analyses.

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The criteria for the second type of "+" condition are applicable when the outermost rings are either very small and/or complacent, and the sequence of ring-width variation in the outer part of the specimen cannot be cross dated with the known ring chronology for the period; therefore a ring count is made to the outside. The evidence from Table 21 would indicate that the principal source of error in this class of "+" dates is attributable to missing rings. If this is indeed true, then death-date approximation is possible if the number of missing rings can be estimated.

The odds that a ring will be locally absent from a specimen are not equally distributed through time. As dendrochronologists have discovered, the years that are signified by relatively small rings are more likely to be missing from a sample than those designated by relatively large rings (Dean, 1970). Thus, the amount of error in a "+" date is not a function of the length of a ring count but is directly related to the number of years in the ring-count period where locally absent rings are most likely to occur. One basic problem, therefore, is to discover what size range of rings that are locally absent in given years is most likely to occur in specimens from the study region.

On the assumption that the interpretation of Table 21 is correct, a series of Pearson's r correlation coefficients was obtained from two variable sets: the number of years difference between the cutting date and the "+" date from a given structure, and, within the ring-count period of the "+" date, the number of rings falling within a series of increasing ring-width index ranges. Only those cases where the "+" dated specimen was earlier than the cutting date were included in the sample.

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Specimens were excluded when no information as to the exact ring-count period was available. A total of 22 cases was suitable for analysis. The ring-width index for a given year was obtained from the 1882 area regional chronology (Stokes and Smiley, 1964b, pp. 24-25).

Tree-ring indices are produced by measuring the ring widths in each sample. As trees increase in age, the amount of radial growth decreases. Since the specimens vary considerably in age, a curve is fit to the sequence of ring-width values of each specimen to remove the age trend. The line of the growth curve corresponds to the mean and is assigned a value of unity. Annual ring-width values greater than or less than 1.00 signify above or below normal growth, respectively. The curve-fitting and numerical assignment to the mean renders the index values comparable between specimens for any given time period (Stokes and Smiley, 1968). The indices from the measured specimens collected throughout the study area were then averaged to produce a regional chronology of index values (Stokes and Smiley, 1964b, pp. 24-25).

The results of these correlational analyses are presented in Table 22. All of the Pearson's r correlation coefficients are significant within the 95% confidence level for a sample population of 22 (Young and Veldman, 1965, p. 420). The threshold for maximum covariation appears to fall within the ring-width index range of 0 to .59. The erratic fluctuations in the coefficients up to the 0 to .59 range are empirically justifiable. The index ranges are cumulative and the population of indices for each sample was unique by virtue of the fact that the ring-count period fell within different time spans and covered unique sets of indices within two centuries. Thus in a ring-count period, one

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specimen dating five or six years earlier than the cutting date may have five rings falling within the 0 to .29 range, and another "+" dated specimen from another structure dating five years earlier than the cutting date may have two rings within the 0 to .29 range and three within the .30 to .59 range. After the 0 to .59 threshold is reached, increasing the range of ring-width indices does not increase covariation. Instead, error accumulates and the correlation coefficients drop smoothly in the .60 to .99 range.

Table 22. Correlations Between Date Differences and Index Ranges.

Ring-width index range	Correlation coefficient
0 - .09	0.616
0 - .19	0.510
0 - .29	0.673
0 - .39	0.578
0 - .49	0.464
0 - .59	0.847
0 - .69	0.750
0 - .79	0.689
0 - .89	0.630
0 - .99	0.578

Death-date estimation for "+" dated specimens is warranted based on the findings presented in Table 22. The acceptable ring-width index range in which annual growth events are most likely not to be present in

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a sample is 0 to .59, and is specified by the correlation coefficient of 0.847. The characteristics of this presumed straight-line curve relationship are given by

$$Y_c = a + bX,$$

where Y_c is the computed Y value, a is the Y intercept, and b is the slope of the line (Croxton, 1953, pp. 115-117). In this case, $Y_c = 2.30 + 0.8666X$. A visual inspection of the data array plotted against the line of this equation indicated that the relationship between X and Y was indeed linear. The error of the estimating equation is given by

$$S_{Y,X} = \sqrt{\frac{Y^2 - (aY + bXY)}{N}} = \pm 2.39 \text{ years.}$$

The dispersion characteristics of the data around the axis of the estimating equation show that 95% of the cases ($2S_{X,Y}$) will fall within a range of ±4.78 years of the actual death date (Croxton, 1953, pp. 119-120).

The dating controls provided by this death-date estimation method were greatly enhanced. There is some evidence to show that the estimated death dates are reasonably accurate. In eight sites out of a total of 14 where "+" dated specimens were previously incompatible with independent dating evidence, the death-date estimates were now compatible. Moreover, there was no change in the compatibility status of those "+" dated specimens that were previously assessed to be consistent with other kinds of dating information. Out of 69 "+" dates exhibiting evidence of a true extreior, sufficient information was available for estimating the outside date in 51. In all, 16% more confidently dated specimens were

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added to those that were fully cross dated and exhibiting some evidence of a true exterior, raising the total percentage from 48% to 64%.

The Structure of Navajo Local Groups

The Navajo Land Claim archaeological survey crews located more than 1,000 sites within the 1882 study area. The reports from 453 sites were made available for this study through the Navajo Tribal Museum, Window Rock, Arizona (Correll, 1961). Roughly 85% of the sites in the sample were located through the use of local Navajo residents as guides and informants, and the remainder of the sites were found through reconnaissance.

The remains of 1,598 architectural features attributable to the Navajo are described in the NLC site reports. The number of structures recorded within a given site varied between one and 23 features. A series of interrelated questions arose in the context of the survey information that are relevant to my basic problem interests:

(1) What Navajo activities are represented in these architectural remains, and how are they distributed in both time and space?

(2) In behaviorally meaningful terms, what constitutes a "site"?

(3) What is the nature of variability within Navajo settlement systems in the study area from A.D. 1750 to 1900?

The answer to the first question was available through the criteria that the Land Claim archaeologists employed to categorize the structural remains. Characteristics related to modes of construction,

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form, and function of the features were obtained through Navajo informants, archaeological evidence, and historical documentation (Van Valkenburgh, 1956a, pp. 4-41; Littell, 1967, pp. 733-883). Independent lines of evidence found in the field usually supported the assignment of function to a particular class of structures. In the 1882 area there are 12 basic types of architectural features noted in the NLC reports. The criteria used to identify each of these types and the supportive functional evidence are listed as follows:

Domestic structures (hogans) are walled, roofed architectural features, generally possessing a single entrance or doorway. The walls and roof may be constructed of interlocking forked poles, horizontally stacked wooden log cribbing, or a combination of the two. Walls may also be partially or entirely constructed with dry-laid or mortared stone slab masonry, with a wooden cribbed or beamed roof. Occasionally the walls are constructed by closely spaced vertical wooden posts socketed into the ground. The stone or wooden superstructure is usually covered with moist earth. The ground plans of hogans are either subcircular or quadrilateral. The floors of the structures are often excavated 6 to 12 inches below the ground surface. Hogan diameters range between 6 and 20 feet. A stone slab is often placed under one of the doorposts. Independent evidence supporting the domestic function of hogans includes spatially associated features such as interior or exterior hearths, stoves or ovens, ash and trash dumps, and wood-chopping areas.

Livestock structures (corrals) are walled but unroofed structures possessing one entrance that is opened or sealed by one or more wooden poles that serve as sliding or removable bolts, or more rarely, by a

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hinged wooden gate. The fence consists of horiziontally stacked wooden logs or branches, dry-laid stone slab masonry, or a combination of wood and masonry. The later corrals are occasionally constructed of vertically socketed wooden posts with barbed wire strung between them. Corral diameters range between 10 and 250 feet; they are mostly subcircular in shape, and more rarely are quadrilateral. Evidence that supports livestock maintenance and containment includes sheep, goat, horse, and more rarely cattle manure, or differential plant growth in the interior of these structures that is related to the presence of this fertilizer.

Sweathouses are small interlocked forked-pole hogans possessing a single entrance. As with most hogans, the floor is excavated 6 to 12 inches into the ground, the wooden structure is covered with moist earth, and the floor plan is subcircular. The diameters are smaller than those of hogans, ranging between 4 and 6 feet. Associated artifacts and features that support the function of dry heat bathing include exterior hearths and associated but discrete piles of heat-altered and unheated stones, the presence of heat-altered stones inside the structure, and occasionally a partially charred forked stick that apparently was used to manipulate the hot stones.

In *Lamb pens*, the modes of fence construction are essentially identical to those of corrals. Often, however, there is no entrance or gate. Lamb pens are usually subcircular in shape, with diameters ranging from 4 to 10 feet. The evidence to support the use of these structures to impound and protect newborn lambs is only indirect. Usually they are adjacent to or contiguous with the larger corrals and contain only sheep droppings.

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Windbreaks are walled, unroofed structures generally constructed of cribbed wooden poles or branches. Occasionally the walls are constructed with dry-laid stone slab masonry. There is usually one entrance, with a few lacking any entry. The ground plan is usually subcircular, with diameters ranging between 6 and 12 feet. The use of these structures as temporary shelters or warm-weather activity areas is supported by the presence of hearths and occasionally trash and ash heaps, manos and metates, and other activity-related artifacts.

Game traps (deer or antelope corrals) are designated by cribbed wooden circular or subcircular walls up to 8 feet in height, with diameters ranging between 25 and 250 feet. Attached to each side of the 25 to 50 foot entrance is a horizontally stacked wooden fence extending ¼ to 1 mile in length that served as the drive chute. Occasionally there is a smaller 3 to 5 foot wide entrance located opposite the main entrance. Evidence supporting the function of these structures as game traps is only indirect. Unlike livestock corrals, there is no surviving mechanism for sealing the main entrance, and they do not contain domestic animal dung.

There are several types of summer structures, called *lean-tos and ramadas (shelters, shades)*. Lean-tos are constructed with a wooden crosspiece socketed in the forks of two vertical wooden posts. Beams are then laid side by side on the crosspiece with their opposite ends at an angle to the ground. The roof is then covered with moist earth. The ground plan is quadrilateral, and the dimensions range between 8 and 12 feet on each side. Ramadas are constructed with four vertical forked posts that form a rectangular space. Wooden crosspieces are then placed

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from corner to corner in the forks of the posts. Poles and brush are laid on top of the crosspieces and the sides. Ramadas are rectangular in floor plan, measuring between 8 and 12 feet on a side. The use of these structures as warm-weather shelters or dwellings is supported by the presence of exterior hearths, ash and trash dumps, and wood-chopping areas.

The construction characteristics of the *ceremonial structures (Yei hogans)* are identical with the interlocked forked pole hogan. The diameters of ceremonial hogans, however, are significantly larger, ranging between 18 and 25 feet. Evidence supporting the ceremonial function of these structures is indirect. Associated features not usually found in most sites include a ramadalike structure (Yei Baghan) and clusters of associated windbreaks.

Storage caches are bounded spaces usually with limited access and highly variable in form. Storage space may be a natural feature such as a rock shelter, cave, or fissure that is at times modified by bounding off a space within the feature with wooden or stone slab masonry. Storage space is irregular, subcircular, or quadrilateral in shape, with the sides 2 to 5 feet in length. Other storage spaces are produced in the form of subterranean pits excavated into the ground, often lined with wood or stone slabs. Storage features are generally recognized on the basis of associated materials such as corn cobs and other vegetal material, or ceramic vessels.

Weaving looms are recognized by a horizontal wooden crosspiece, 4 to 5 feet from the ground, supported by two vertical forked wooden posts. This apparatus is often located within a windbreak structure.

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Independent evidence consistent with the designated use of this type of feature is only indirect and often absent. Occasionally artifacts such as wool carding instruments or loom shuttles are found in association.

Iron- or silversmithing (smithies) are activities usually performed within a hogan or windbreak structure. The location of a smithy is identified by the presence of associated materials such as hearths containing metallic slag, anvil rests, and stone molds.

Ovens are dome-shaped subcircular structures, measuring 2 to 4 feet in diameter and 2 to 4 feet in height, constructed of stone slab masonry and covered with moist earth or mortar. A small 1- to 2-foot doorway is located 12 to 18 inches above the ground. The function of these structures as ovens is supported by the presence of associated ash dumps and ash in the interior.

The 12 classes of architectural features specify distinctively different sets of activities. The phrase "behaviorally meaningful terms" in the second question stated above can therefore be refined to ask whether or not these particular activities are interrelated and do they relate to each other in both time and space.

The Land Claim survey reports and their analyses of the material were not directed toward the answer to this question. Essentially the Navajo Land Claim problem was to demonstrate Navajo use and occupancy of the study area through time. The survey information examined in detail by the NLC staff was related to showing that a given feature possessed a set of characteristics attributable to the Navajo, that the date or dates assigned to the feature specified the time of construction or use, and that the location of the feature at that place specified Navajo use

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of that locale. The role of archaeology in the claims case is stated explicitly in the Navajo docket (Littell, 1967, pp. 738-740):

> On-the-ground examination of archaeological remains is clearly the best method of determining the ethnic origin of sites, and architectural features are by far the most significant criteria for determining ethnic affiliation of structures. A site complex of various component structures, ground plans, and the characteristic placement of associated features such as the hogan hearth, or the sweathouse heating stones, also are valuable aids in ethnic identification. [Informants] and cultural associations such as pottery sherds and artifacts, also aid in corroborating the ethnic affiliation of sites. The amount of debris accumulation gives some indication of length of occupancy, dependent upon environmental factors, but the presence of ash dumps *per se* is not a valid criterion for tribal identification, as all tribes discarded ashes and refuse. Similarly, although a large aggregate of structural components within a site is indicative of a lengthy occupancy, size of a site is not a valid criterion for determining ethnic affiliation.... Structures such as windbreaks, shelters, and ramadas by themselves are not usually diagnostic of any particular group, but when found associated with identifiable hogans, or other characteristic Navajo structures, or when located within an area of extensive Navajo occupation, they are identifiable with reasonable certainty as part of the overall complex of Navajo occupancy within that geographical locality.

Notice, however, that the term "site" is not explicitly defined, but is implied to be any set of architectural elements which, if they clustered in space, were labeled "typical Navajo complexes" in the NLC site reports (Correll, 1961). One major problem, therefore, was to transform site survey information into behaviorally significant Navajo settlement components.

If the implied Land Claim definition is initially accepted, a site may be viewed in a behavioral sense as a space containing any combination of activities specified by the types of architectural elements. The number of possible kinds of sites is therefore given by $2N^2 + (N-1) = 229$, where $N = 12$, the number of architectural classes. The formula

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designates the number of unique architectural combinations that can occur, such as sites containing one or more hogans only (a single element combination), one or more hogans and one or more corrals (a two element combination), and so on. In the 450-site sample, however, only 59 unique combinations occur. Table 23 illustrates that Navajo architectural diversity within the NLC-designated sites is low, and the actual distribution departs significantly from the expected array. The expected distribution is derived from the frequencies in the "Kinds of combinations" column, where, for example, the 12 single element combinations represent 4% of the total number (299) of combinations. Thus 4% of the 450-site sample (18 sites) should be single element combinations.

Table 23. Architectural Combinations in the Land Claim Site Reports.

No. of elements in combination	Kinds of combinations	No. of sites in each combination class	
		Expected	Observed
1	12	18	160
2	66	99	152
3	55	83	98
4	45	68	33
5	36	54	6
6	28	42	1
7	21	32	0
8	15	28	0
9	10	15	0
10	7	10	0
11	3	5	0
12	1	1	0

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A number of conditions limited the element combination range; some are Land Claim survey related, and others probably are related to Navajo settlement behavior. The kinds of architectural associations and the frequency within each class are listed in Table 24. The principal source of error in the distribution is the disproportionate availability of each architectural type. To some extent this is attributable to NLC sampling error. As noted in the quotation presented above, windbreaks, ramadas, and shelters are not ethnically restricted to the Navajo. Thus during the first three years of the survey, sites that contained only these structural types were not generally sought and recorded. As Van Valkenburgh (1956a, pp. 4-5) states:

> Two distinct classes of Navajo homes were located in the survey of the Navajo-Hopi contact area--the summer and winter residences. Summer homes were located near farms, while winter homes were located at points which offered facilities for fuel as well as range for their stock.
>
> For purposes of archaeology, the remains of Navajo winter homes are more productive. They were, and are to this day, the fixed home of the family consisting of substantial hogans, corrals, and other auxiliary structures. The summer home, with some exceptions, was in the past usually a ramada, a brush and log circle, or windbreak. Sometimes it was a more substantial *chacha'o*, or shade. Practically all Navajo groups reported in our survey are of the permanent winter home description.

Emphasis was therefore placed on occupation zones that contained hogans, producing proportionately high frequencies of this architectural type. From 1957 to 1960, however, more survey time was devoted to recording sites with windbreaks, ramadas, and shelters, but not sufficiently to rectify the sampling bias.

The relatively low incidence of such structural types as ceremonial hogans, looms, smithies, storage facilities, and ovens cannot be explained in terms of explicitly stated NLC sampling methods. Therefore

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Table 24. Architectural Element Associations in NLC Sites and Spatial Clusters.

Structural element combination[a]	NLC site frequency	Spatial cluster frequency	Structural element combination	NLC site frequency	Spatial cluster frequency
A	107	115	A-C-H	1	2
A-B	94	121	B	1	1
F	34	34	A-K	1	1
A-B-C	33	42	A-E-H	1	1
A-B-D	32	29	A-B-K	1	1
A-C	27	33	A-C-I	1	1
C	10	10	B-C-E	1	1
A-E	9	11	A-B-D-K	1	1
A-G	7	8	A-B-C-K	1	1
A-B-G	6	6	A-B-C-H	1	1
A-B-C-D	6	3	A-B-C-J	1	1
E	6	9	A-B-H-J	1	1
A-B-E	5	10	A-B-C-G	1	1
A-B-D-I	5	4	A-B-D-G	1	1
A-H	4	6	A-B-D-H	1	1
A-B-C-E	4	4	A-B-E-H	1	1
B-E	4	3	A-B-C-E-H	1	1
A-B-I	3	3	A-B-C-D-J	1	1
A-B-H	3	3	A-B-C-D-G-L	1	1
A-J	3	1	C-E	1	0
A-C-J	3	1	B-D	1	0
A-B-D-E	2	3	A-B-C-I	1	0
A-B-J	2	2	A-B-E-G	1	0
A-B-C-D-E	2	2	A-B-C-L	1	0
A-C-E	2	2	A-B-D-J	1	0
A-E-I	2	1	B-D-E-J	1	0
A-B-L	2	1	A-B-C-D-I	1	0
G	2	1	A-E-L	0	1
A-I	1	6	A-G-I	0	1
A-B-G-J	1	2	B-G	0	1
A-B-C-D-G	1	2	B-C-G	0	1
A-B-D-E-J	1	2			

[a]Key: A = Hogan, B = Corral, C = Sweathouse, D = Lamb pen, E = Windbreak, F = Game trap, G = Shade, H = Ceremonial, I = Storage, J = Loom, K = Smithy, L = Oven

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the low occurrence of these types of activities may be related to Navajo behavior.

During the process of compiling information from the Land Claim reports, it became apparent that some sites represented more than one occupation. Moreover, the possibility arose that more than one behaviorally discrete settlement was included within one site. These problems in survey behavior were evaluated through the analysis of site maps.

The distance and compass direction between architectural and other associated features was available in most of the site reports. These data were compiled on computer punch cards for each structural type within each NLC-designated site. A CALCOMP plotter program was devised to generate site maps (Adam, 1971).

A number of striking patterns emerged from the analysis of the maps. One or more spatially discrete clusters of architectural features were clearly discernible within sites that contained one or more hogans. Examples of two spatially defined clusters are presented in Fig. 7.

A comparison of the architectural element combinations within spatial aggregates and within NLC sites in Table 24 shows that both are in relatively close agreement. Out of a total of 65 combinations, 50, or 77%, are shared by the NLC sites and the clusters. There is evidence to show that many of the NLC sites are in fact composed of more than one set of activity clusters. The site maps and Table 24 illustrate that many of the NLC sites were composed of multiple sets of identical combinations. Notice in Table 24 that the spatial cluster frequencies are consistently higher than the NLC frequencies in classes that contain the elements A, B, and C. In those element combinations *not* shared by both

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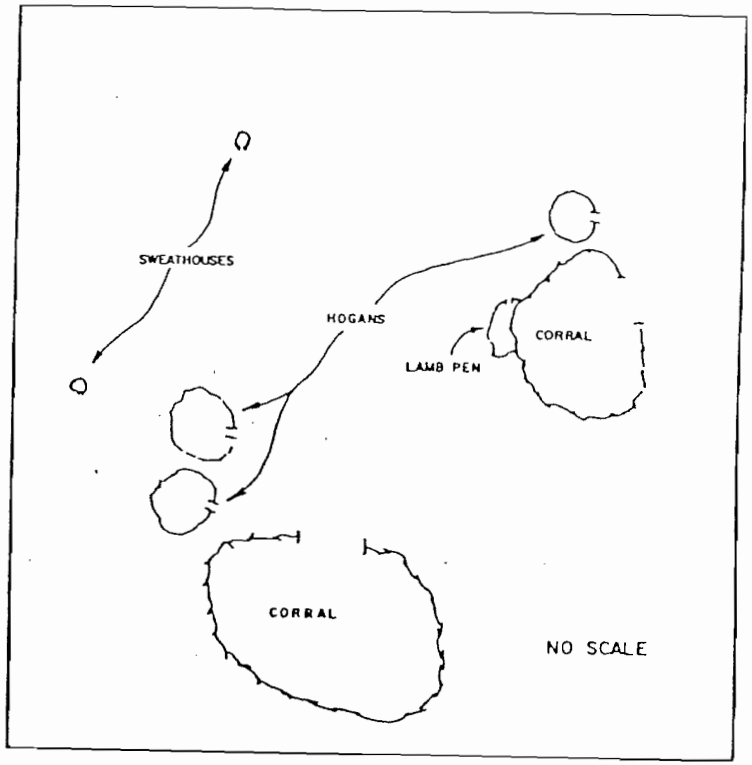

Fig. 7. Two Architectural Aggregates.

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sets of data, the areas of disagreement are patterned. The NLC sites have more four- and five-element sets, and the clusters contain more kinds of two- and three-element sets than the NLC sites. Thus, by reducing sites into spatial clusters, architectural complexity and diversity are further decreased.

The problem remains, however, whether the NLC designation of site or the spatial aggregates of architecture more appropriately signify important components of the Navajo settlement system. Another possibility that must be considered is that neither of these constructs accurately specifies any significant segment of settlement and thus both are artifacts of NLC survey behavior.

In the course of the analyses presented below it became increasingly clear that understanding the temporal structure of activities represented by the architectural array is an important step in developing settlement models. Each activity is performed within a *general* time frame (daily, seasonally, annually, and so on). Within the general time frame some set of actors performs an activity within a *specific* temporal framework that may include one or more time-related conditions (cooperatively or independently, simultaneously or at different times, redundantly or nonredundantly, and so on). Archaeologists must define the boundaries of the temporal and spatial distributions of the activity products and byproducts to define the behavioral organization of the actors (Krause and Thorne, 1971). To do this, the investigator must eventually delineate behaviorally meaningful occupations. In behavioral terms, an occupation is that space defined by the boundary of a temporal discontinuity that crosscuts a set of activity-related general and

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specific time frames represented in that space. The archaeological content of this space, moreover, defines a site.

An analysis of construction activity within each NLC-designated site shows that the spatial cluster of architecture has temporal/occupational significance. Sites containing two or more tree-ring dated structures were initially compiled. Structures, and in some cases sites, were eliminated from the sample if the tree-ring dates were not actual or estimable cutting dates. The dates included in the sample were those specimens exhibiting a true exterior and were either fully cross dated to the outside or the death date could be estimated according to the equation presented in the previous section. The sample was further refined by eliminating those dates in multi-dated structures that were attributable to repair and wood re-use activities. The recognition of these wood-related behaviors is based upon the evidence presented in Tables 16 and 17. The final sample was thus designed to maximize the likelihood of comparing initial construction activities within the classes of architecture indicated in Table 25. From an inspection of the site maps, hogans within the same cluster tended to be the same style (forked pole, cribbed log, and so on). The data were appropriately classified to evaluate whether or not this pattern was related to the timing of construction events within and between spatial clusters.

Although the frequency of well-dated sites is low, a number of patterns in the timing of construction events can be seen in Table 25. Hogans of the same type located within the same cluster tend to be absolutely or very nearly contemporary with each other. The spread of dates between one and 11 years, in all but three cases, came from clusters

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where each structure had only one tree-ring date. Therefore it is possible that the [illegible]tures were initially constructed in the same year, and the differences are generated by remodeling or repair activities. The case of the 36-year difference is from well-dated hogans that are spatially associated and clearly represents a departure from the remainder of this class.

The sample of hogans of different types within the same cluster is too small for statements to be made with confidence. The 38- and the 63-year differences, however, came from multiple-dated hogans that were apparently built at different times.

The greatest range of date differences is produced in the comparison of hogans of different styles between spatial clusters. In two sites the differences are minimal, and in three sites the magnitudes of the differences exceed those from any other comparisons. The fact that two thirds of the cases are 15 years or older would support the notion that each cluster generally represents a different occupation.

Table 25. Date Differences Between Structures Within and Between Clusters.

Cluster affiliation	Hogan style	Frequencies of tree-ring date differences (years)												
		0	1	2	3	4	5	6	7	8	9	10	11	Other
		Hogan-hogan comparison												
Same	Same	8	2	1	2	1	1	1	1	-	-	-	1	36
Same	Different	-	-	-	-	-	-	1	-	-	-	-	-	38,63
Different	Same	-	-	-	-	-	-	-	-	-	-	-	-	-
Different	Different	1	1	-	-	-	-	-	-	-	-	1	-	15,21,36, 71,86,105
		Hogan-nonhogan comparison												
Same	-	4	-	2	4	-	1	3	-	-	-	-	-	-
Different	-	1	-	-	-	-	-	-	-	-	-	-	-	34

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Tree-ring dated hogans compared with nonhogan structures within the same cluster produce a distribution of differences almost identical to hogan-hogan comparisons. The kinds of structures that fall within the occupational range of a cluster include lamb pens, sweathouses, corrals, ramadas, and one example of a ceremonial hogan. Thus a number of spatially aggregated activities were designed to be performed, by virtue of construction, absolutely or relatively contemporaneously.

Dated nonhogan structures compared with hogan dates between clusters produce two widely separated differences, similar to the hogan-hogan comparisons between clusters. Thus all between-cluster construction events either were contemporary or represented distinctively different occupations.

On the basis of the tree-ring evidence alone, the spatial cluster of hogans and other structures can be tentatively accepted as a fundamental unit of Navajo settlement. The time period represented in the within-cluster analyses shown in Table 25 ranges from A.D. 1766 to 1900. The three cases where between-cluster hogans and nonhogan structures are essentially contemporary all date within the period A.C. 1868 to 1878. The spatial distributional system of contemporary Navajo local groups may have changed after their release from Fort Sumner in 1868. An examination of the calendrical years specified in the cases where the "contemporaneity of the spatial cluster" rule is violated also involves the post-Fort Sumner period. The case where the tree-ring dates from hogans of the same type within the same cluster are separated by 36 years is specified by the dates A.D. 1856 and 1892, respectively. This might well represent an instance of cluster reoccupation. There is independent

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evidence that supports this possibility. Some of the undated wood in the later structure was felled by the earlier technique of burning (see Table 18), and the 1892-dated specimen exhibited only metal axe marks.

The two cases where hogans of differing types located within the same cluster are separated in time by 38 and 63 years are attributable to the post-1868 period. In one case, Anglo trade goods were found in association with the later hogan but not with the pre-Fort Sumner structure. In the second case, a mixture of tree-ring dates ranging from A.D. 1846 to 1871 would indicate that wood might well have been re-used, and the contrast in hogan typology is the product of rebuilding activity in A.D. 1871.

There is no evidence to show that the tree-ring dates are not fully indicative of initial construction activity in the between-cluster analyses. The dates in these comparisons range between A.D. 1772 and 1900.

An independent body of information was available to assess the temporal significance of hogan aggregates. Previous analyses of hogan entry orientations presented in Fig. 2 and Tables 6 and 7 show the sensitive relationship between orientation and the season of hogan construction. Therefore, if two or more dwellings were built simultaneously, the doorway orientations should be identical. It is possible, however, that two or more hogans could be constructed in different years or seasons within the same year, accurately oriented toward the sunrise at the time of construction, and both could have identical orientations. The odds of this coincidence in sites that usually contain two to four dwellings are probably low but nonetheless required independent testing.

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A matrix was devised to gauge the relative incidence of identical doorway orientations in hogan pairs within and between clusters and within and between architectural styles. Those entrance orientations directly constrained by the physical environment were not included in the sample presented in Table 26. The rate of identical orientations produced by independent construction events was evaluated by drawing a random sample of orientations. Again, those orientations from hogans directly constrained by the physical environment were removed from the sample universe. Since physiographic setting influences the time of day that the sun rises, and thus entry orientation (see Table 7), the sample was stratified by landform class. Orientation pairs were selected at random within each stratum. Each member of the sample pair was selected from different NLC-designated sites. The randomly drawn pairs were classified within Table 26 in terms of identical or different hogan styles.

Table 26. Hogan Pairs with Identical Entry Orientations.

Spatial designation	Same style		Different		Total	
	No.	%	No.	%	No.	%
Within cluster	18/52	35	2/22	9	20/74	27
Between clusters	0/7	0	0/8	0	0/15	0
Between sites	1/40	3	5/60	8	6/100	6

The results of these comparisons, shown in Table 26, are compatible with the interpretation of the tree-ring data. More than a third of the hogan pairs within the same cluster of identical architectural

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style have the same orientation, and significantly exceed the occurrence from any of the other combinations. The proportion of hogans of different types within the same cluster with identical orientations is not appreciably higher than the outcomes from the random sample. The cluster as a viable unit of Navajo settlement is further supported by the fact that no hogan pairs between clusters within the same site have identical orientations.

A comparison of orientations from pairs of tree-ring dated hogans is consistent with the above interpretations. The amount of such data, however, is severely restricted. The few cases available are presented in Table 27.

Table 27. Hogan Dates and Orientations Within and Between Clusters.

NLC designation	Hogan type	Cluster	T-R date	Orientation
W-LLC-DZ-M	Stone and wood	C-1	1852	East
	Stone and wood	C-1	1858	N78°E
W-LLC-HT-C1	Forked pole	C-1	1866	S65°E
	Forked pole	C-1	1869	East
	Forked pole	C-1	1869	East
W-LLC-UD-G	Forked pole	C-1	1873	S85°E
	Forked pole	C-1	1879	S75°E
W-LLC-MJ-X4	Forked pole	C-1	1878	S85°E
	Forked pole	C-1	1885	N85°E
W-LLC-MJ-A3	Forked pole	C-1	1856	East
	Forked pole	C-1	1892	S73°E
W-LLC-MJ-S3	Cribbed log	C-1	1811	East
	Forked pole	C-2	1879	N65°E
W-LLC-MJ-Z3	Forked pole	C-1	1866	N70°E
	Cribbed log	C-2	1887	S74°E

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Only one case of hogan pairs of the same type within the same cluster dating to the same year was present in the NLC data, and their orientations are identical. Hogans built in different years within the same or different clusters have different orientations.

The architectural composition of the spatial aggregates was examined further to interpret the information presented in Table 24. In the analysis, paired associations within and between each type of structure within clusters were compared in terms of random and nonrandom co-occurrence weighted by the actual frequencies of each architectural type. The observed and the expected frequencies are given in Table 28. The significance of disproportionately high and low frequencies of association was obtained through chi-square analyses. The most striking of these significantly high or low frequencies are game traps, which are described and designated in the Land Claim reports as separate sites. What little independent evidence is available is consistent with the NLC inference. No reports were available to indicate the presence of Navajo dwelling sites within 5 to 10 miles of any game trap that were contemporary with the use of these structures from the early 1700's through 1870. Since this period was critical to the Land Claim case, it is most probable that such sites would have been included in the archaeological documentary exhibit. The environmental setting of game corrals in predominately grassland plant zones contrasts with the locational criteria for dwellings and most of the other structural feature types in the period A.D. 1750-1867. Thus, antelope and deer drives, using the game trap, constituted an activity that was spatially separated from other settlement elements.

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Table 28. Architectural Association Pairs Within Clusters.

Structural type	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)
Observed matrix												
(A) Hogans	115	-	-	-	-	-	-	-	-	-	-	-
(B) Corrals	255	1[a]	-	-	-	-	-	-	-	-	-	-
(C) Sweathouses	99	63	10[b]	-	-	-	-	-	-	-	-	-
(D) Lamb pens	50	50[a]	9	0[b]	-	-	-	-	-	-	-	-
(E) Windbreaks	40	25	10	5	9[a]	-	-	-	-	-	-	-
(F) Game traps	0[a]	0[a]	0[a]	0	0	34[a]	-	-	-	-	-	-
(G) Ramadas/shelters	23	16	5	4	0[a]	0	1	-	-	-	-	-
(H) Ceremonial	17	8	4	1	3	0	1	0	-	-	-	-
(I) Storage	11	7	1	4	1	0	1	0	5[a]	-	-	-
(J) Looms	9	8	3	3	2	0	3	0	0	0	-	-
(K) Smithies	7	6	1	1	0	0	0	0	0	0	0	-
(L) Ovens	4	3	1	1	1	0	1	1	0	0	0	0
Expected matrix												
(A) Hogans	110	-	-	-	-	-	-	-	-	-	-	-
(B) Corrals	226	17	-	-	-	-	-	-	-	-	-	-
(C) Sweathouses	94	56	5	-	-	-	-	-	-	-	-	-
(D) Lamb pens	43	26	11	2	-	-	-	-	-	-	-	-
(E) Windbreaks	45	27	11	5	2	-	-	-	-	-	-	-
(F) Game traps	29	17	7	3	3	1	-	-	-	-	-	-
(G) Ramadas/shelters	26	15	6	3	3	2	1	-	-	-	-	-
(H) Ceremonial	15	9	4	2	2	1	1	1	-	-	-	-
(I) Storage	15	9	4	2	2	1	1	1	1	-	-	-
(J) Looms	9	5	4	1	1	1	1	0	0	0	-	-
(K) Smithies	6	3	1	1	1	0	0	0	0	0	0	-
(L) Ovens	3	1	1	0	0	0	0	0	0	0	0	0

[a] x^2 = p <.01
[b] x^2 = p <.05

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Livestock corrals are found in association with all lamb pens and do not occur by themselves or with game traps. The single case of an isolated corral was one that had been used by a Navajo informant aiding the Land Claim survey team; his former dwellings, mentioned briefly in the report, were not recorded (Correll, 1961, pp. 205-206). All corrals are associated with habitation structures, either warm-season dwellings or hogans.

The pattern of association with sweathouses is distorted in this analysis by survey sampling error. In the 1970 Long House Valley survey I found that the criteria for locating sweathouses did not coincide with those for the rest of the cluster. If limestone or other stone suitable for heating is available within 200 to 300 yards of a community, the sweathouse is spatially associated with the cluster and the quarried stone is transported to the sweathouse site. On the other hand, if stone resources are not available within this radius, the sweathouse is located adjacent to the resource, which might be up to a mile from the dwellings. The variability in distance between the cluster and the sweathouse on the NLC site maps was compatible with my findings in Long House Valley. The Land Claim archaeologists were aware of the problem of locating associated sweathouses, for Van Valkenburgh (1956a, p. 23) states:

> Failure to locate sweathouses with every hogan group and windbreak processed in our survey is explicable. While a functional part of the group, rarely are they found close to a group, some being located as far distant as a mile or more from the other units in the group.

Thus the considerable number of isolated sweathouses in Table 28 are not separate occupational entities but were probably associated with a habitation cluster somewhere nearby.

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Storage facilities stand in the same relation to the cluster as sweathouses. Underground pits, shelves in trees, and storage cellars are always spatially associated with habitation clusters. Those storage spaces produced in caves, rock shelters, and fissures, however, exhibit a wide range of variation in their distance from the remainder of the community. As in sweathouses, therefore, the significantly high number of storage spaces recorded as isolated sites are probably related to a nearby cluster, and again represent survey sampling error.

Other than the negative association with game traps, hogans are not significantly related to any other structural type. In the case of this ubiquitous dwelling type, however, the weighting of frequencies has overshadowed some important facts. There are no ovens, smithies, ceremonial hogans, or lamb pens that occur outside of a cluster containing hogans. Thus, baking, iron or silverworking, ceremonies, and lamb care are behaviors that absolutely do not take place outside of the context of hogan-related domestic activities.

Survey sampling error might be involved again with single, isolated hogans. There are a total of 32 such occurrences that are designated as separate sites in the NLC reports. In this sample, 28 are datable, with 23 falling within the post-Fort Sumner period (A.D. 1868 to present). After 1868, the spatial distances between the architectural components of the cluster sharply increase. A more detailed discussion of this and related patterns is presented in the next chapter. It is therefore quite likely that these isolated structures are part of a larger aggregate.

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Table 28 shows that a significant portion of the windbreaks were located as isolated aggregates or single structures. Interestingly, however, they do not occur with ramadas or lean-tos, the other types of warm-weather domestic structures. Windbreaks, ramadas, and lean-tos can replace hogans in their association with corrals, sweathouses, looms, and storage. Moreover, if the sampling error argument for sweathouses and storage is correct, the incidence of hogan association with these warm-weather types of structures is considerably lower than any of the other architectural types.

To summarize the findings thus far, the analyses of tree-ring data, the Land Claim site reports, the site maps, and information from the Long House Valley survey indicate that three behaviorally distinct types of sites were produced by Navajo occupying the 1882 study area. The first type, game traps, represents an activity that was performed at least once a year, in the late spring-early summer period (see Table 14). All of these structures were used repetitively, although perhaps not continuously, for various periods ranging from at least two to 40 years. Game drives were conducted from at least the eighteenth century through 1870, when the deer and antelope populations were virtually eliminated from the region (local informant data, Correll, 1961, p. 1077). These structures are spatially and behaviorally isolated from Navajo habitation sites. The number of personnel required to perform a game drive probably exceeds the populations of local groups (Hill, 1938, pp. 145 to 156). This activity, therefore, may specify a supra-community level of Navajo organization.

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The second type of site is the summer or warm-weather settlement. It is composed of windbreaks or lean-tos and ramadas that were the loci of such domestic activities as cooking, wood-chopping, trash and ash dumping, and so on. The habitation structures occur as single or multiple spatially associated units without other types of architecture. Subsistence activites such as farming or food collection may well have been conducted in the vicinity of these sites. This speculation is supported by informant data from two such sites (Correll, 1961, pp. 712, 1008). The presence of corrals associated with clusters of windbreaks or shades and shelters in some summer sites indicates the performance of herding activities. Other activities represented by associated architecture include weaving, storage, and sweat bathing. The low frequency of strictly summer sites in the Land Claim reports reduces the strength of any statements made as to the total range of activities that were performed. The degree to which summer and winter sites with corrals were architecturally distinctive prior to 1868 is in doubt, for all such sites date to the late nineteenth and early twentieth centuries. There is one summer site represented by two lean-tos with a tree-ring date of A.D. 1866, which was used as a base for farming activities (local informant data, Correll, 1961, p. 1236).

Most of the data contained in the survey reports describe the third type of Navajo settlement, defined by the presence of one or more hogans. These dwellings were, for the most part, built within the late spring-early summer period (see Table 3 and Fig. 2). This pattern holds true from the 18th through the 20th centuries. Groups of Navajo occupying two or more spatially associated hogans of the same style often

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built their homes simultaneously (see Tables 25, 26, and 27). Within one to 10 years, additional domestic structures were added to the cluster (Tables 25 and 27). Although this pattern persists from the 18th to the 20th century *within* each hogan cluster, after A.D. 1868 sets of at least two spatially associated hogan aggregates were constructed simultaneously (Table 25).

The pattern of repair activity indicates that hogan clusters were occupied intermittently or continuously for at least one to 25 years (Table 17). After A.D. 1868, abandoned hogan clusters were occasionally reoccupied, or, more plausibly, the odds that a given hogan cluster would be reoccupied were increased. The fact that remodeled hogan styles often contrasted with those of the original group, and the time gap between abandonment and reoccupation spanned up to five human generations, indicates that the cluster reoccupants were probably different groups (Tables 25 and 26). All of the architectural feature types, with the exception of game traps, can be found in association with hogans. The presence of warm-weather structures indicates that hogans do not specify strictly cooler seasonal occupation.

The arguments presented above define the three behaviorally distinct units of Navajo settlement and the kinds of activities that took place within them. The problem remains as to the organizational structure of the actors within these units. Insofar as information was available, the human organizational aspect in relation to the use of game traps has been discussed above. The rest of this section is devoted to the behavioral structure of habitation sites.

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The sites containing dwellings, particularly hogan sites, exhibit a wide range of variation in terms of size and architectural complexity. A set of analyses was devised to evaluate the spatial structure of activity performance within the cluster. One question that arose was whether or not relative group size within the cluster was related to activity patterns. In this analysis, relative hogan diameters were assumed to covary with the number of inhabitants. Absolute dimensions were not used, for the NLC archaeologists found that hogan styles and diameters change with time (Littell, 1967, pp. 812-836). Thus relative dwelling dimensions were used within clusters containing two or more habitation structures, but no comparisons were made between aggregates.

Only two activity loci appeared to coincide with hogan size. All looms, where the data were available, were spatially associated with the largest hogans within the cluster. Other activities such as iron or silverworking, sweatbathing, storage, and warm-season outdoor activity areas were equally associated with all relative hogan sizes. Livestock corrals tended to be related to hogan size. Within 115 multiple-hogan clusters, 58, or 50%, of the hogans associated with the corral were the smallest hogan within the cluster; 19, or 17%, were the same size; and 38, or 33%, were larger than one or more other dwellings. One striking pattern, however, is that domestic-related activities (dwelling construction, wood chopping, cooking, ash and trash dumping) are the only behaviors that are associated with each habitation structure in every cluster. Within 296 multidwelling clusters, there are only two cases where other architecturally specified activities that occur more than once are spatially related to two or more habitation structures. One aggregate with

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four hogans has two ovens, each associated with a separate dwelling, and another site contains two windbreaks, each adjacent to a different hogan.

The activities that are recognized in the survey reports can therefore be separated into two contrasting behavioral sets:

(1) Those activities that are associated with each dwelling, with the number of loci varying directly with the number of dwellings.

(2) Those activities that vary independently of all dwellings, with any given activity type associated with one and only one dwelling.

The social organizational structure of Navajo local groups probably generated these contrastive behavioral sets. The first set may be labeled *autonomous behavioral units*. The social organizational correlate of these units is probably the domestic group structural component (or components) of the cluster. The second set of activities, or the *cooperative behavioral units*, probably reflects the corporate structure that existed between the household groups. The patterned distributions of looms and livestock corrals may specify those activities that are delegated on the basis of group size or number of generations within each domestic group. The other nonhousehold activities can be performed by any domestic group, the products of which are directly or indirectly shared, or the activities are shared directly by all domestic groups within the cluster.

There is some evidence that is consistent with the social organizational constructs presented above. Navajo habitation clusters are

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not infinitely large. They are restricted to aggregates containing, usually, no more than five or six dwellings. Some set of limiting conditions must restrict the size of any cluster and give rise to the production of others. The single habitation unit as a domestic group is supported by the fact that the smallest cluster that can be defined with confidence consists of a single dwelling and one or more ancillary activity structures. This minimal cluster persists from the 18th to the 20th century.

The size and age composition of a domestic group is socially regulated (Goody, 1962). One problem was to define, if possible, the number and age ranges of the occupants of dwellings in the context of the cluster. As mentioned previously, relative hogan size tended to be spatially patterned in terms of the corral. In multiple hogan clusters, the smaller hogans tended to be closer to the corral. Where corrals were lacking, the same relation obtains, with the larger dwellings more distant relative to the others. The tree-ring and hogan measurement data necessary for analyzing domestic group fission within the community are insufficient to make any statements about this process.

Another means of measuring domestic group composition within the aggregate was by analysis of burial location. Burials are highly associated with domestic structures, being either within the dwelling or immediately adjacent to it. Table 29 shows that the locations of burials are not equally distributed within multiple hogan clusters. This pattern may be related to differential age composition of domestic groups within the cluster. If the burials represent mature adults (an assumption that cannot be justified here, with the lack of osteological information), the

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oldest members of the multidwelling cluster community may be located in the larger dwellings and farther from the corral than at least one other hogan. The delegation of herd maintenance duties may fall to the younger members of the cluster.

Table 29. Burial Distributions in Relation to Hogan Size.

Site type	Relative hogan size			
	Smaller	Larger	Unknown	Total
1. Two or more hogans and corral				
Hogan nearest corral	0	0	0	0
Hogan far from corral	2	10	2	14
2. Two or more hogans only	0	2	3	5
3. Isolated hogan and corral	-	-	6	6
4. Isolated hogan only	-	-	6	6

The single isolated hogan sites containing burials all date to the post-A.D. 1868 period when the clusters become physically dispersed. This class of burials may therefore represent the oldest adults in the community and are spatially distant from the other architectural components of the cluster. The rest of the burials are found in minimal clusters with corrals. These particular aggregates date to both before and after A.D. 1868. If the minimal cluster represents a newly established community immediately after fission from a larger aggregate, the bud group may not be the youngest domestic group to leave. Additional archaeological information that could support or deny these social organizational possibilities, however, could not be found.

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Ethnographic information from the study area and its immediate environs is compatible in most respects to the statements generated from the archaeological data. The spatially defined cluster of dwellings and other architecture is still the basic unit of western Navajo settlement. Adams (1963, pp. 52-65) in the Shonto Plateau area, immediately adjacent to the study area to the northwest, documents summer and winter habitation cluster communities. Within the 1882 area on Black Mesa, Downs (1964, 1965, 1972) documents the lifeway of the inhabitants of a cluster, which he terms a "homestead group," and argues for the social and economic autonomy of this settlement unit. Levy (1962, p. 782) addresses himself directly to western Navajo community organization:

> Navajo tend to settle in clusters of hogans. Depending upon a variety of factors, these clusters may range from one to ten dwellings. They consist of one or more nuclear families, most related by consanguineal ties.

Levy (1962, p. 783) discusses briefly the relationship between architectural manifestations and community fission:

> Neolocal residence of a single nuclear family, though frequently observed, is often the result of a single observation in time. In the pastoral areas, for instance, there will, at any given moment, be a certain number of nuclear families splitting off from the parent camps.

The relatively tenuous inferences concerning age distributions within the cluster and the age of the domestic group at the time of fission from the established community is consistent with a single case documented by Downs (1965, 1972). In this instance, the size of the Navajo local group was regulated by subsistence potential. A drought reduced the water supply to the point that the community herd could not be maintained. The first domestic group to leave the cluster with their

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portion of the livestock was the youngest member of the oldest generation in the community. This group established an autonomous single dwelling cluster of architecture several miles distant. The bod group was perhaps the only candidate for leaving the community based on the size of the herd they had accumulated. Given the time required for a given domestic group to acquire a herd of sufficient size fer independent survival, fission may well be, and may have been in the past, performed by generationally older groups.

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CHAPTER 3

NAVAJO SITE SELECTION STRATEGIES

The previous chapter was primarily devoted to developing time controls and to the definition of Navajo settlement units. The rest of the research, reported here, concentrates on the site units in relation to the physical environment in which they were found. In keeping with my interests in human behavioral organization, I have chosen to answer those questions framed with the intent to understand Navajo settlement location in terms of their use of the 1882 study area. The sections that follow are both direct and indirect attempts to answer these queries:

(1) When and under what set(s) of conditions was the study area occupied by groups of Navajo?

(2) What were their site selection strategies?

(3) How did the Navajo make use of the study area environment?

Changing Political Relations and Navajo Settlement

Previous studies show that the greatest concentration of Navajo settlements in the 17th and 18th centuries fell within northwestern New Mexico (Keur, 1941; Hall, 1944; Vivian, 1960; Hester, 1962; Bannister, 1965). In this demographic sense, my study area was marginal to the major occupancy zone in the 18th century. To this day, Navajo groups located in southeastern Utah and in Arizona west of Canyon de Chelly are

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labeled "western Navajos" by many ethnographers. The question that arose, therefore, was how did the 1882 study area become intensively settled by Navajo groups?

The earliest tree-ring dates from the study area (1622+incG, 1666inc) indicate that there may have been some Navajo use in the 17th century. The region was occupied with some regularity in the early 18th century as a series of cutting dates illustrates (1703inc, 1710inc, 1711inc, 1720inc, 1723incG, 1728inc, 1729inc).

Construction activity ceases or is limited within the study area from A.D. 1730 to 1750. This time gap may be related to survey sampling error although this appears to be unlikely. The Land Claim survey was designed to be extensive but was not a thoroughly intensive investigation of the region (Van Valkenburgh, 1956a, p. 3). This kind of sampling strategy is not amenable to site density analyses or for measuring connectivity between sites. However, there is evidence to show that the survey was spatially and chronologically representative of Navajo settlement within the 1882 Executive Order Hopi Reservation. The 1882 Reservation was a disputed claim area between the Hopi and the Navajo. The NLC survey thus covered the entire region with approximately equal intensity. Second, the claim case was designed to show Navajo use and occupancy of the area both before and after the A.D. 1846 to 1868 legal test period. All sites located by the survey teams, particularly those dating prior to A.D. 1846, were useful for this argument. Moreover, all sites datable by any method were included as documentary exhibits and constitute the reports made available for my study (Correll, 1961). Finally, the spatial distribution of sites dating from A.D. 1750 to 1800

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in Fig. 6 shows a continuously expanding zone of Navajo occupation. By A.D. 1900, the entire region exhibited some evidence of Navajo occupation.

The time periods shown in Figs. 8 through 10 were designed to maximize the use of all dating methods employed by the NLC staff, including ceramics, dated trade goods, informants, and dendrochronology. On the basis of tree-ring evidence there appear to have been a few early Navajo settlements immediately west of the study area, on the Coconino Plateau, beginning in the second half of the 18th century (Stokes and Smiley, 1964b, pp. 16-17). The maps in Figs. 8 through 10 reflect increasingly extensive and intensive use of the region.

The temporal distribution of construction activity shows that the periods of intensive use of the study area by Navajo groups fluctuated considerably. In this analysis, the terminal cutting dates estimated by the equation presented in the previous chapter (page 93) or from fully cross dated specimens were plotted as a frequency distribution through time. The dates of habitation clusters or game traps were regarded to be analytically and behaviorally discrete units. Identical dates from each site were removed from the sample. All cutting dates, including those attributable to repair or rebuilding activities, were included to signify that a given site was at least occupied in those years specified by tree-ring dates.

A number of discrete clusters of construction events can be seen in Fig. 11. Relatively few sites were occupied or established from A.D. 1750 to 1787. A surge of construction activity occurred from A.D. 1807 to 1812, and again from A.D. 1815 to 1816. The area appears to have been occupied on a relatively continuous basis from A.D. 1818 to 1855.

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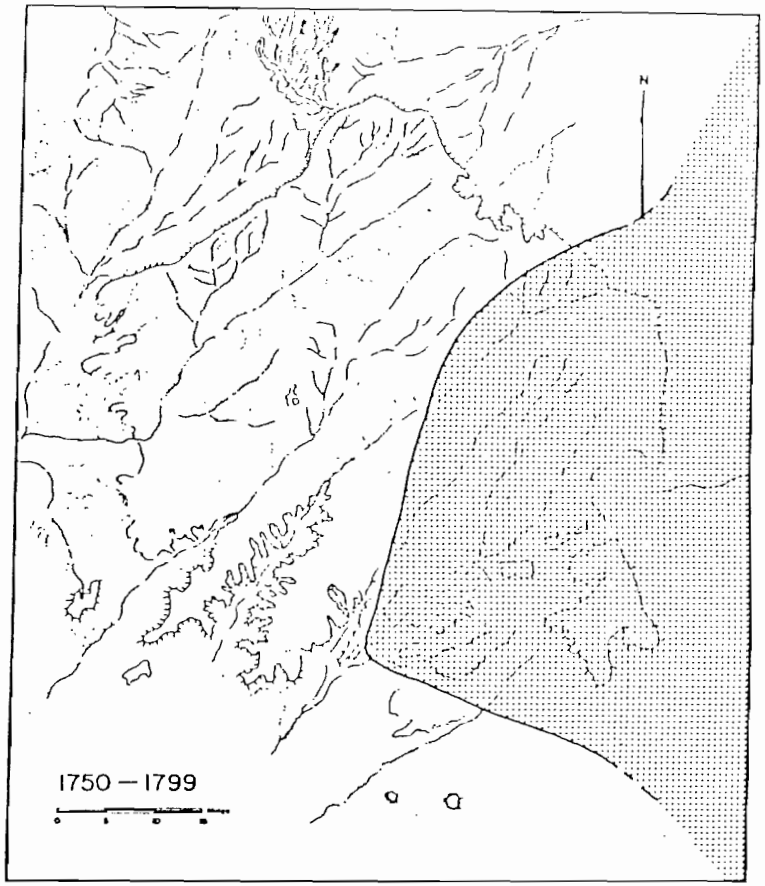

Fig. 8. Navajo Use Area, A.D. 1750-1799.

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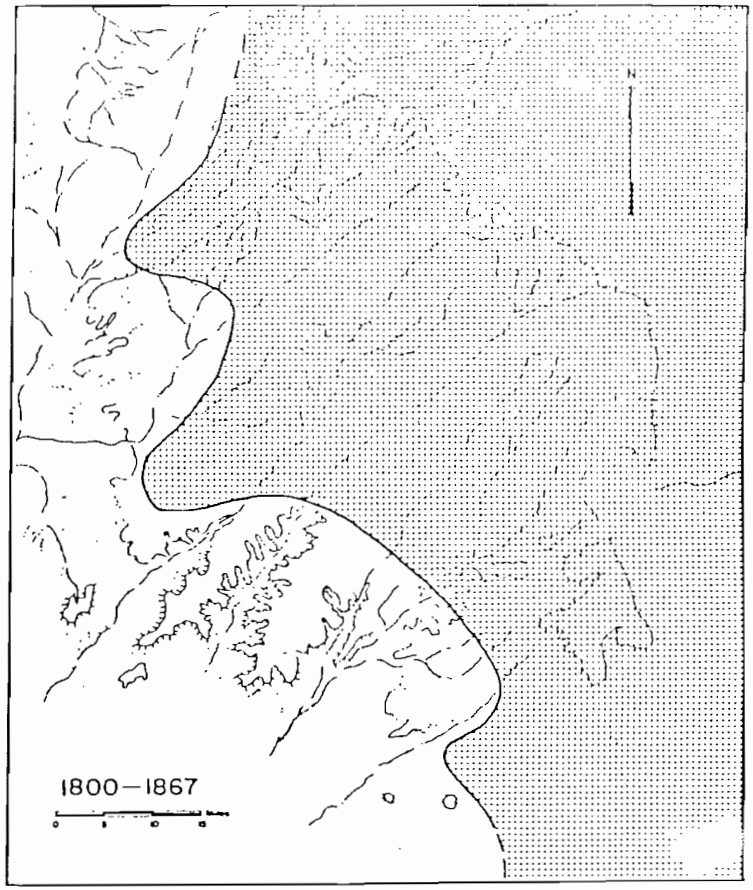

Fig. 9. Navajo Use Area, A.D. 1800-1867.

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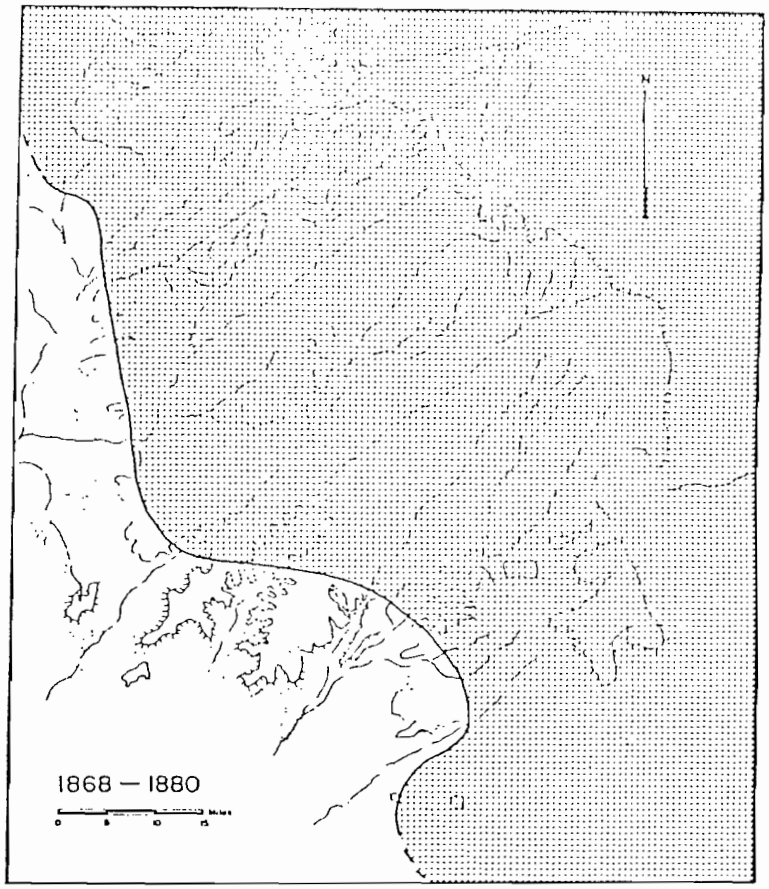

Fig. 10. Navajo Use Area, A.D. 1868-1880.

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Fig. 11. Construction Activity Frequency from A.D. 1750-1900.

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However, the rate of construction from A.D. 1856 to 1861 equals, and in A.D. 1858 surpasses, that for the rest of the study period. A lull in wood cutting took place from A.D. 1862 to 1867, but increased sharply in A.D. 1868 through 1871. The rate of continuous construction increased from A.D. 1868 to 1900, with several peaks appearing in A.D. 1877 to 1879 and A.D. 1897 to 1898.

Sampling error prevents a literal interpretation of Fig. 11. Wood decay and erosion processes undoubtedly reduced the frequency of cutting dates in the period A.D. 1750 to 1850 (see Table 19). The number of years with no recorded construction sharply decreases through time. From A.D. 1750 to 1799, there are no cutting dates for 36, or 72%, of the years. In the A.D. 1800 to 1849 period, 23, or 46%, of the years lack evidence of construction. Finally, from A.D. 1850 to 1900, there are only six, or 12%, of the years that do not have any cutting dates. Although this trend is at least partially related to wood decomposition, it is also probable that the rate of continuous Navajo occupation increased through time and has inflated this trend. There is no evidence for tree-ring sampling bias that would produce the surges in construction activity. The fact that these peaks can occur in the early and mid 19th century despite the increased odds for specimen decomposition must mean that these periods have real demographic significance.

It is likely that the major periods of increased wood harvesting activity are related to a successive series of Navajo migrations into the study area. Documentary evidence is consistent with this interpretation. All of the major peaks in construction, from A.D. 1750 to 1861, are associated with events that immediately precede or follow political

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changes in the Southwest. Hester (1962, pp. 76-86) has shown that a general westward shift in Navajo settlement began in A.D. 1750. Although his study terminates at A.D. 1800, the warfare-related conditions that generated this trend continued to intensify.

The Navajo pattern of warfare, from A.D. 1750 to 1864, was clearly related to their economy (Reeve, 1959, 1960; Brugge, 1964; Littell, 1967, pp. 885-1215). Raids by less than 20 to several hundred individuals were designed primarily to capture livestock and humans, rather than for killing and destruction. Similarly, retaliatory raids against the Navajo by the Spanish, Mexicans, and Indian groups resulted in relatively few deaths but the capture of Navajos and considerable quantities of agricultural produce and livestock (Littell, 1967, pp. 85-116, 885-1215). The human, plant, and animal booty from these raids was an economic asset to be bought, sold, or exchanged within and between virtually all ethnic groups occupying the Southwest. In this economic sense, the Navajo were active or *de facto* participants in a system of consumption and exchange that was predicated upon raiding. Success within this system can be measured by acquiring goods directly or indirectly from raiding and being able to consume or exchange them without the loss of one's life or losing any other human, agricultural, or livestock capital through counterraids. Thus movement westward into the study area may be partially related to an attempt to reduce economic loss.

The probability that a given Navajo group could be involved in a raid and counterraid event cycle sharply increased in the 1770's to 1821. The Utes to the north were raiding Navajo communities both prior to and

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during this period (Reeve, 1959). Moreover, a relative truce in raiding activity between the Spanish and the Navajo was broken, and attacks resumed on a widespread scale from A.D. 1770 to 1821 (Reeve, 1959, 1960). The frequency of Spanish retaliatory raids increased in this period until they relinquished the territory to the Mexican government in A.D. 1821. Mexican campaigns against the Navajo were intensive between A.D. 1821 and 1823 but appear to drop in frequency after this period (Littell, 1967, pp. 85-95). The increase in Navajo construction activity within the study area between A.D. 1807 and 1820 corresponds to these documented events and may represent groups attempting to avoid attack during this politically unstable period.

The second major influx of Navajo groups into the region, as reflected in construction activity, follows American political control of the Southwest in A.D. 1846. Although Navajo raiding continued, retaliations by American forces did not commence until A.D. 1849 and increased in frequency until A.D. 1863 (Littell, 1967, pp. 97-102). The larger Navajo migration into the study area in the A.D. 1856 to 1861 period might be related to a change in military tactics. Similar to the Spanish and Mexican raids, American punitive expeditions against the Navajo resulted in the capture of humans, agrarian produce, and livestock. However, the general American military policy against hostile Indian groups was essentially exterminationist, and resulted in the deaths of significantly more Navajos than the Spanish and Mexican raids (Littell, 1967, pp. 76-83, 96-103). The massive Carson campaign of A.D. 1863-1864 successfully destroyed the agrarian and livestock subsistence base for thousands of Navajo groups. By A.D. 1864, more than 8,000 Navajos had

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surrendered to Carson's forces and were incarcerated at Fort Sumner for a period of four years (Brugge, 1964; Johnston, 1966). The lower frequency of cutting dates in the A.D. 1863 to 1868 period may reflect the drop in Navajo population during the Fort Sumner confinement.

In A.D. 1868, the Navajo were released from Fort Sumner and a lasting treaty was signed. From A.D. 1750 to 1868, former Navajo use areas were occupied successively by Spanish, Mexican, and American settlers (Littell, 1967, pp. 73-79). The reduction of use area in New Mexico during the Fort Sumner period probably forced more Navajo groups to move west into the study area (Littell, 1967, pp. 177-258). The sharp increase in wood cutting activity in A.D. 1868 to 1870 probably reflects this post-Fort Sumner migration. Later in the 1870's, Navajo groups continued to move westward as their population dramatically increased. These demographic shifts were accommodated, belatedly, by a series of Executive Order reservation extensions (Johnston, 1966, pp. 24, 76-80). The remainder of the peaks in Fig. 11 are probably related to the continuation of Navajo westward expansion and population growth from A.D. 1868 to 1900.

There is additional support for some of the interpretations of Fig. 11. Navajo site selection strategies were, in part, related to retaliatory raiding. The landforms selected for settlement in the A.D. 1750 to 1868 period provided community seclusion or seclusion with high visibility of the surrounding terrain. Table 30 shows that, after Fort Sumner, the Navajo located sites in settings that would have been harder to defend and were more easily discernible. The data for Table 30 are from Kemrer and Graybill (1970, p. 208).

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Table 30. Site Location and Defense.

Landforms of high defensive potential	1750 to 1868	1869 to 1900	Landforms of low defensive potential	1750 to 1868	1869 to 1900
Mesa top	8	9	Base of hill	0	1
Canyon bottom	16	15	Valley edge	12	19
Hilltop	3	0	Open flatlands	1	27
Ridge top	8	13	Rolling country	5	48
Hill slope	3	0	Valley bottom	0	10
Wash bottom	11	1	Valley bench	1	2
Base of cliff	13	3	Rincon bottom	0	4
Cliff top	7	1			
Mesa bench	7	3			
Heavy woodlands	1	0			
Ridge slope	4	3			
Canyon side	16	15			
Mesa slope	1	6			
Totals	98	69	Totals	19	111

Several Navajo informant statements confirm that these landform criteria were indeed related to seclusion and defense:

> Hastiin Yazhi Bina'aten ("Shorty Blind Man") of the Ma'iidesh-gizhhnii Clan lived here after the return from Fort Sumner. They had cornfields in the canyon bottom between Hogans #3 & #4. After living here for ca. 5 years after returning from Fort Sumner they moved out into a more open location (Correll, 1961, p. 1199).

> [The informant] says that this site was occupied before Fort Sumner. Once before Ft. Sumner some Spanish soldiers came to attack the people here, but Hastiin Etsitty "did a sing" that prevented the Spaniards from finding the hogans and attacking and they turned back (Correll, 1961, p. 1174).

> There were about 37 families around here and Navajo Mountain who did not go to Fort Sumner, but did move into good hiding places. Col. Carson's troops did not penetrate this area, but his Ute allies did raid here, during the Carson campaign. This family did not go to Fort Sumner (Correll, 1961, p. 1010).

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Documentary accounts of Spanish and Mexican raids on Navajo settlements are consistent with the location of sites with seclusion but often high visibility. Mesa, ridge, and mountain tops were frequently used for defensive purposes (Littell, 1967, pp. 103-114).

Despite the use of landforms that would provide seclusion for sites located in the study area prior to A.D. 1868, from Table 30 it appears that 19, or 15%, of the sites do not conform to this set of criteria. During the process of examining the sites that departed from this pattern, it became apparent that dwellings may have been purposely camouflaged. Some hogans were incorporated architecturally into living trees, and others were built against or between boulders and other geological outcrop forms. A tabulation of sites with dwellings exhibiting these camouflage characteristics and cross classified with time is presented in Table 31. The A.D. 1750-1867 sites contrast significantly with the post-A.D. 1868 sites in terms of construction modes that would reduce the visibility of domestic structures. Moreover, all of the sites dating to the pre-Fort Sumner period located in low defensive potential landforms show these characteristics.

Table 31. Sites with Evidence of Camouflage.

Time period	Camouflage characteristics				
	Present	%	Absent	%	Total
1750-1800	22	69	10	31	32
1801-1867	60	69	27	31	87
1868-1880	16	17	76	83	92
1881-1900	16	17	78	83	94

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There is one bit of informant data that supports the fact that the Navajo purposely camouflaged their structures during the pre-Fort Sumner period (Correll, 1961, p. 1184):

> [The informant] says the structures on this crag were built before Ft. Sumner for defensive purposes and were plastered over with mud over the outside for camoflage [*sic*].

Informant statements contained in the Land Claim site reports support the inferred drop in population during the A.D. 1864 to 1868 Fort Sumner confinement period. Although a number of informants and the tree-ring evidence testify to the fact that some groups did not leave the study area, most of the informant statements, in a ratio of approximately 2:1, indicate that the majority of the inhabitants went to Fort Sumner. The informant and tree-ring data from the same site are consistent. Sites that were reported by informants to have been built immediately prior to A.D. 1864, or abandoned when the occupants went to Fort Sumner, and reoccupied in A.D. 1868, are fully supported by the tree-ring dates. The post-Fort Sumner reoccupation of and new groups migrating into the study area are supported by informants and by sites dated independently by informants and the tree-ring method.

Navajo movement into less physiographically restrictive landform settings in the post-A.D. 1868 period is related to the spatial expansion of the community. Table 32 illustrates the contrast in areal dispersion between the pre- and the post-Fort Sumner periods. These measurements do not include sweathouses or storage structures, for their spatial association with the remainder of the cluster is highly variable in all time periods.

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Table 32. Mean Areas[a] of Sites, A.D. 1750-1900.

Time period	Number of structures per site				
	2	3	4	5	6
1750-1867	180	739	7,420	9,912	9,274
1868-1900	536	8,825	18,704	56,841	425,104

[a]In square feet.

Approximately 69 of the post-Fort Sumner sites share the same type of landform setting as those built in the earlier period (see Table 30). Most of this portion of the later sites are more spatially expanded than those constructed in the pre-1868 period but not nearly as dispersed as those located in the more open settings. Thus landform setting does restrict site area, but the earlier clusters apparently are areally condensed to a greater degree than would be expected in terms of physiographic boundaries alone. The spatial compaction of the pre-Fort Sumner community is probably related to defense, where the proximity of neighboring households would ensure mutual aid and protection during an attack.

There appear to be no changes in the spatial organization within the Navajo habitation cluster. The distance within and between all architectural types increases in the post-Fort Sumner period. Similarly, associated features such as ash and trash dumps are located at a greater distance from dwellings in the later period.

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Navajo Environmental Exploitation Strategies

On the basis of the evidence just presented, it is clear that certain aspects of Navajo site selection accommodated changing relations with neighboring groups in the Southwest. The following question now must be answered: How did the Navajo make use of the selected environmental settings to maintain themselves?

Site selection criteria were not restricted to changing warfare and politically tranquil conditions. Other criteria appear to have been considered as well. Habitation site settings nearly always fulfilled certain requirements for human comfort and survival. All sites, for example, are within several miles of a permanent or semipermanent source of water. Also, sites on landforms with considerable topographic relief are situated on south-facing exposures that provide maximum access to solar heat.

Virtually all of the sites are located in environments that are conducive to the successful performance of at least one subsistence activity. As discussed in the first chapter, the Land Claim staff prepared a rudimentary map of vegetation zones that was sufficiently sensitive to physiographic, geological, and soil variations to be useful for analytic purposes. Within the study area, three plant zones are defined:

(1) Southern Desert Shrub: desertic shrubs, yucca, cacti, winter annuals.

(2) Grasslands: grama grasses, Mormon tea, salt grasses, creosote, saltbushes, weedy plants.

(3) Pinyon-Juniper Woodlands: blue grama, sagebrush, weedy plants, pinyon, juniper.

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Some types of Navajo sites are restricted to particular sets of plant, topographic, and geological zones and specify the kinds of subsistence activities that were conducted. Game traps are located in flat or rolling country, within grassland or grassland-desert shrub zones with sparse tree cover. The location of game traps in this open setting that were in use within the pre-1868 period contrasts with the secluded habitation sites. The criteria for locating game traps are directly related to the resources exploited and to the methods used to exploit these resources. The setting is the habitat of antelope and to a lesser degree deer. In addition, the open setting is amenable to the successful performance of game drives. Since the low plant cover permits high visibility of the surrounding terrain, the animals cannot easily elude the hunters by using plant cover or the topography for refuge or slipping through the line of drivers.

Other subsistence-related sites can be recognized on the basis of feature composition within certain environmental settings. Single isolated or clusters of windbreaks in pinyon forests with associated threshing floors or roasting pits specify pinyon nut collecting and processing stations. Warm-weather communities or hogan clusters lacking corrals are usually located in desertic shrub plant zones. These plants thrive on alluvial soils associated with washes and alluvial fans. This setting is suitable for agricultural activities. Such associated features as wells, water control devices, storage facilities, and plant food processing equipment support this inferred relationship. Many of these sites, however, exhibit little direct evidence for farming. Dry land farming techniques in this area do not usually involve any major

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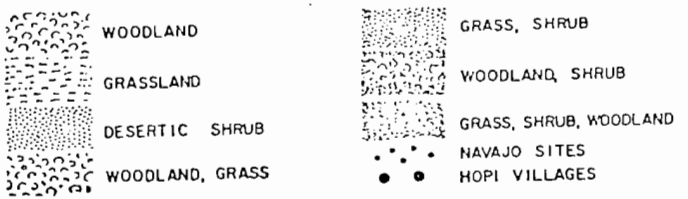
Figs. 12-15. Site Location by Vegetation Zone.



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modification of the environment. Consequently, the evidence of this activity disappears shortly after abandonment. Other settings appear to have been used exclusively for pastoralist activities. Dwelling sites with corrals located in open grasslands or in the wooded uplands with little or no available arable land would indicate that herding was the primary subsistence activity performed in these settings.

Pastoralism appears to have been the most widespread subsistence activity performed within the region by Navajo groups from A.D. 1750 to 1900. From 307 datable sites, 247, or 80%, contained sheep corrals. The stability of a pastoralist economy in the context of raiding and warfare may have been greater than any other economic activity (Brugge, 1964). Livestock as a mobile food supply is not as restricted in terms of seasonal availability as plant and nondomesticated animal supplies. Similarly sheep and goat resources may not fluctuate as dramatically with environmental change as plants and hunted animals. The question that arose in this context was whether or not herd-owning Navajo groups had a hierarchically structured subsistence economy whereby site selection and environmental use decisions were based primarily upon successful herding and secondarily in terms of supplemental economic activities. In addition, did threat of attack in the pre-1868 period affect these decisions?

To answer these questions, the location of sites containing corrals with respect to accessible plant zones and through time is shown in Figs. 12 through 15. In this analysis, the Land Claim plant distribution map (Correll, 1958) was translated in terms of pastoralist access. The map was found to be reasonably accurate. The types of vegetation present in the vicinity of each site were generally recorded in the

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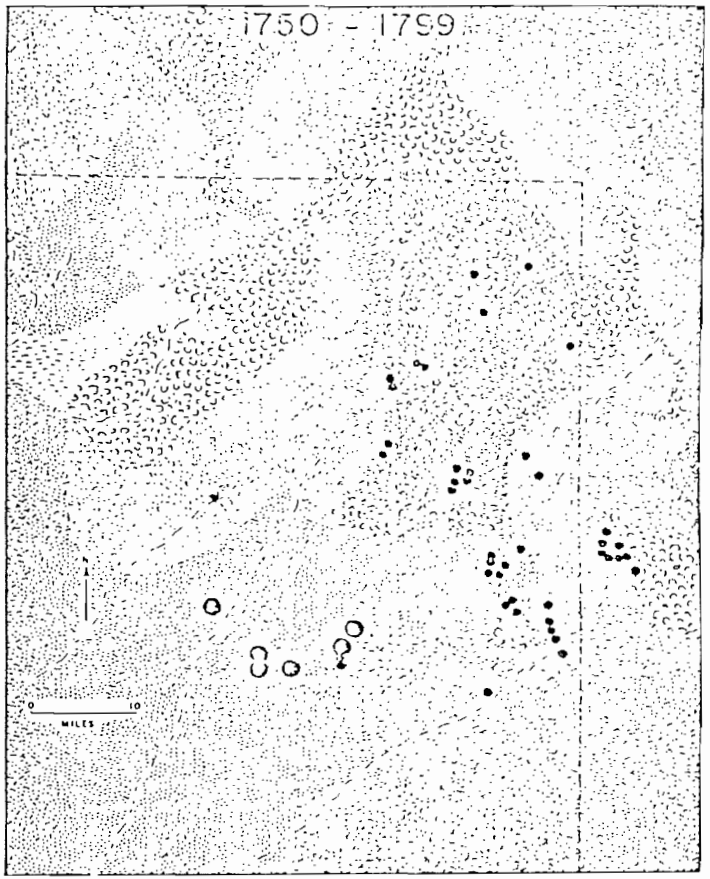

Fig. 12. Site Location by Vegetation Zone, A.D. 1750-1799.

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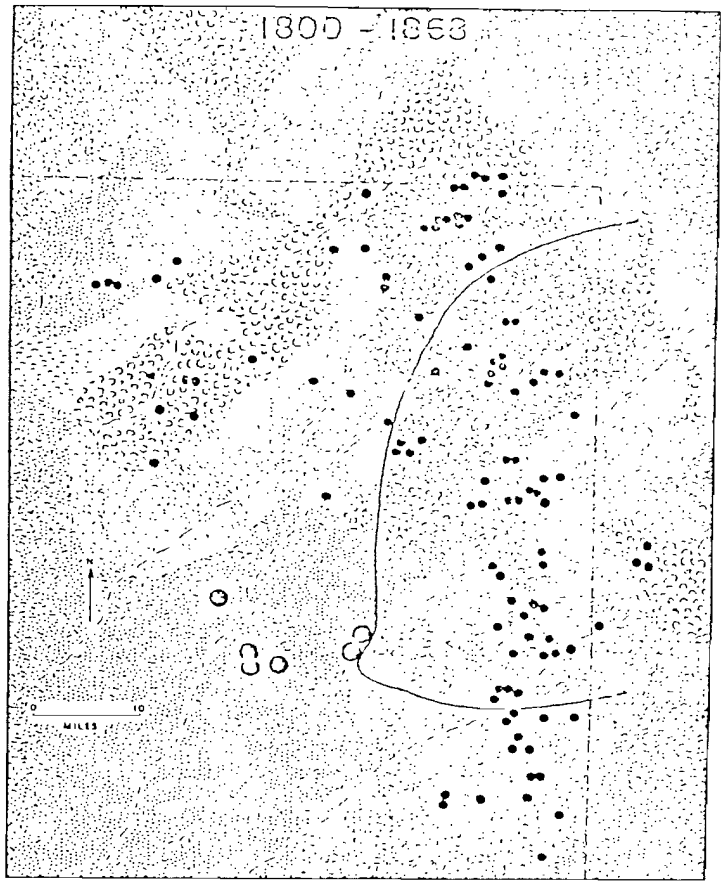

Fig. 13. Site Location by Vegetation Zone, A.D. 1800-1868.

The heavy line shows the extent of occupation in the previous period.

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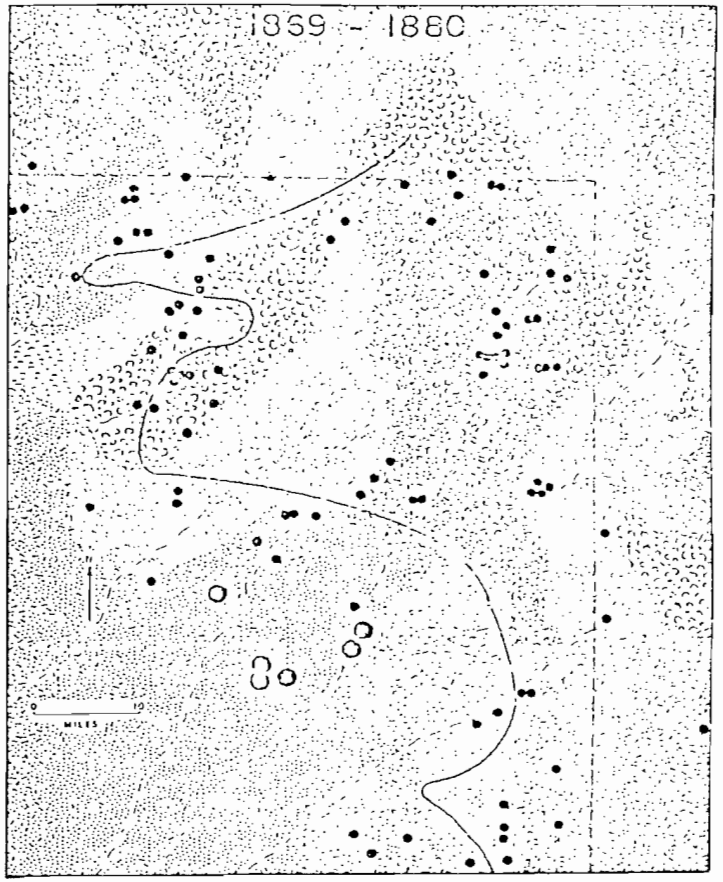

Fig. 14. Site Location by Vegetation Zone, A.D. 1869-1880.

The heavy line shows the extent of occupation in the previous period.

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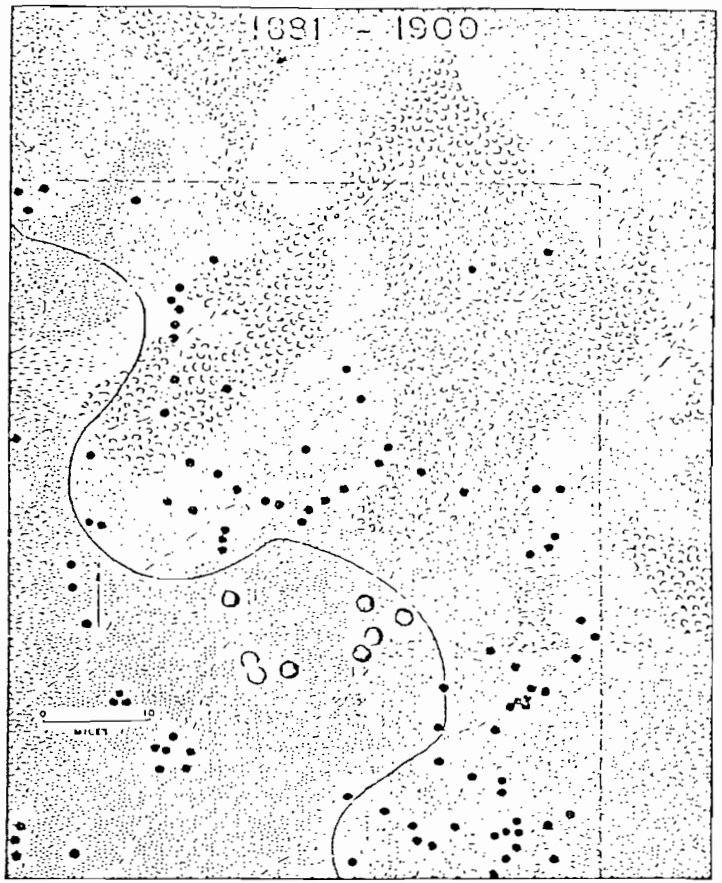

Fig. 15. Site Location by Vegetation Zone, A.D. 1881-1900.

The heavy line shows the extent of occupation in the previous period.

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field. There is a 93% correspondence between the mapped plant distributions and the field data. Pastoralist access distance was derived from Downs (1964, p. 83), who found that contemporary Navajo herdsmen on Black Mesa can drive their sheep 10 miles per day within a radius of 5 miles from the habitation cluster. The plant communities used regularly for grazing may therefore differ significantly from those in the immediate vicinity of the corral. Thus, to restrict the designation of the vegetation class exploited to that of the site would likely be an underestimate of the zones used on a daily basis by Navajo herdsmen.

Based upon Downs' (1964, p. 83) estimate, a 5-mile extension of every vegetation class boundary was drawn such that a set of zones containing two, and in some areas all three, vegetation classes was generated. The base map used in Figs. 12 through 15 reflects the outcomes of this transformation and specifies the distribution of accessible plant communities for grazing for sites located throughout the study area.

Despite the transformation of plant zones in terms of herding access, the map in Figures 12 through 15 illustrates the relationship between vegetation and topography (see also Fig. 1). Pinyon-juniper forests predominate in the uplands of Black Mesa and Balakai Mesa. The major source of grasslands is on the northwestern flatlands of Black Mesa, where soils derived from the Mancos shales inhibit arboreal growth. The areal percentage of desertic shrub increases to the south along the major washes and in the flatlands below Black Mesa.

The threat of raids appears to have restricted maximum utilization of plant resources for grazing in the A.D. 1750 to 1867 period. The vegetation access zones in Table 33 are listed in terms of decreasing

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grazing potential. Note that 95% of the sites in the A.D. 1750 to 1867 period are located within or adjacent to woodlands. Although pinyon-juniper woodlands contain sufficient plant species for browsing and grazing, ranking second to grasslands, the zones offering little cover were avoided. It is probable that herding was preferentially performed in vegetative settings that would reduce the odds of detection by attackers. After A.D. 1868, these open zones containing grasslands were exploited more fully. In both periods the location of sites containing corrals was b[illegible] primarily upon grazing potential. Relatively few communities were located in desertic shrub zones that would be more suitable for farming.

Table 33. Distribution of Sites by Vegetation Zone.

Vegetation access zone	Site frequency			
	A.D. 1750-1867		A.D. 1868-1900	
	Number	%	Number	%
Grasslands	2	3	18	17
Grass and woodlands	26	38	41	39
Woodlands	33	49	23	22
Shrub and grass	1	1	8	8
Shrub and woodlands	6	8	10	9
Shrub	1	1	5	5
Totals	69		105	

Environmental change probably does not affect the inferences made above to any significant degree. As discussed in the first chapter, arroyo-cutting and the lowering of the water table, which began in

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the 1880's, undoubtedly affected plant growth. Desertic shrub zones probably expanded, replacing the areas once occupied by woodlands and grasslands. If anything, the relations presented in Table 33 are stronger than the current vegetation array indicates.

The number of sheep and goats available to Navajo groups apparently changed through time. On the assumption that corral area is a reasonably sensitive indicator of herd size, Table 34 shows that pre-Fort Sumner herds were, on the average, smaller than those in the post-A.D. 1868 period.

Table 34. Mean Corral Area.

Time period	Mean corral area, sq. ft.
1750-1800	279
1801-1867	1291
1868-1880	1691
1881-1900	1463

Mean corral area appears to be the most interpretable method for describing changing herd size. The number of livestock maintained by a community varied considerably. There is no significant correlation between the number of dwellings in a cluster and the size of the corral in any time period. Moreover, the distributions of the size of the cluster did not change appreciably through time. The range and the mean, mode, and median sizes of sheep corrals do change with time.

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The greatest rate of increase in herd size, between the periods A.D. 1750-1800 and A.D. 1801-1867, may reflect the products of Navajo raiding and livestock reproduction rates. Herd sizes appear to peak in the period A.D. 1868-1880 and decline somewhat in A.D. 1881-1900. The slight decrease might be related to a number of changing conditions. First, overgrazing, arroyo-cutting, and the concomitant decrease in available pasturage began in the 1880's (Gregory, 1917, pp. 130-131). Second, increasing dependence upon trading sheep and sheep products occurred between A.D. 1880 and 1900, which may have increased livestock consumption rates. The incidence of trade goods in Navajo sites increases dramatically after Fort Sumner. After A.D. 1880, more than 90% of the sites contain trade goods.

Navajo Mobility and Climatic Change from A.D. 1750 to 1900

Although Navajo groups preferentially selected those vegetation zones most suitable for pastoralist activities, the question remains to what degree new communities were established in relation to environmental change. Two critical resources, water and plant supplies, fluctuate directly with rainfall in this semiarid environment (Thornthwaite, Sharpe, and Dosch, 1942; Cooley and others, 1969). Climatic outcomes over space are highly variable on a year-to-year basis in this region. Contemporary Navajo groups relocate herding sites in response to climatically related grazing potential and water supply within the study area (Downs, 1964, pp. 25-34). The problem, therefore, is to evaluate site location in terms of climatic variation.

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Dendrochronological information was used in these analyses. A dendroclimatic network was established over the entire Navajo Land Claim area, using the method devised by Fritts (1965). The method is based on the demonstrated relationship among ring widths from trees located on sites with limited water supply and fluctuating amounts of annual rainfall (Douglass, 1914; Schulman, 1956). In the Southwest, temperature varies inversely with precipitation, and ring widths vary directly with this relationship (Fritts, Smith, Cardis, and Budelsky, 1965; Fritts, 1965). Cool, wet conditions generally produce wide rings, and warm, dry years result in narrow rings. Since pasturage in the study area also varies directly with moisture supplied directly or indirectly by rainfall (Thornthwaite, Sharpe, and Dosch, 1942, pp. 2-35; Downs, 1964, pp. 30-31), dendroclimatic values should be significantly related to grazing potential. The question to be answered therefore is: Given a range of pasturage outcomes produced by climatic variation in space, to what degree are Navajo herdsmen aware of these options and to what degree do they make use of them to locate or reoccupy sites?

Dendroclimatic stations are defined by collections of tree-ring samples from a given locality. In this network, the samples from each station clustered within an area of 10 square miles. Locations of the stations are shown in Fig. 16. The stations peripheral to the study area were included to evaluate areal climatic fluctuation in a broader perspective and to reduce areal distortion. The decision to locate a station was made on the basis of providing spatial controls and on the availability of tree-ring samples. Thus the array of the stations within the study area is related to the distribution of specimens suitable for

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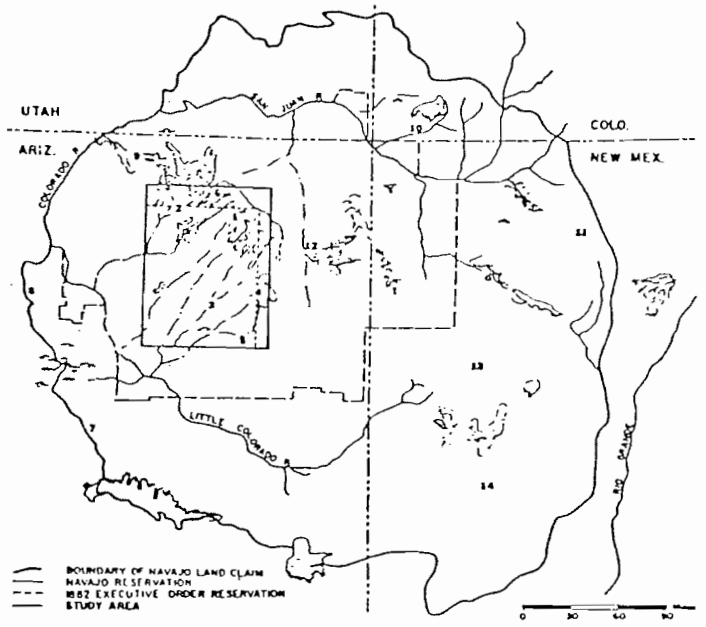

DENDROCLIMATIC STATIONS

1 CENTRAL BLACK MESA	8 LOWER HANBILI CANYON
3 BLETHLA VALLEY	9 NAVAJO CANYON
3 WEPO WASH	10 UPPER SAN JUAN RIVER
4 BALAKAI MESA	11 GOBERNADOR AREA
5 JEDDITO WASH	12 CANYON DE CHELLY
6 NORTH BLACK MESA	13 CIBOLA AREA
7 CANYON DIABLO	14 CEBOLLETA MESA

Fig. 16. Map of the Navajo Dendroclimatic Network.

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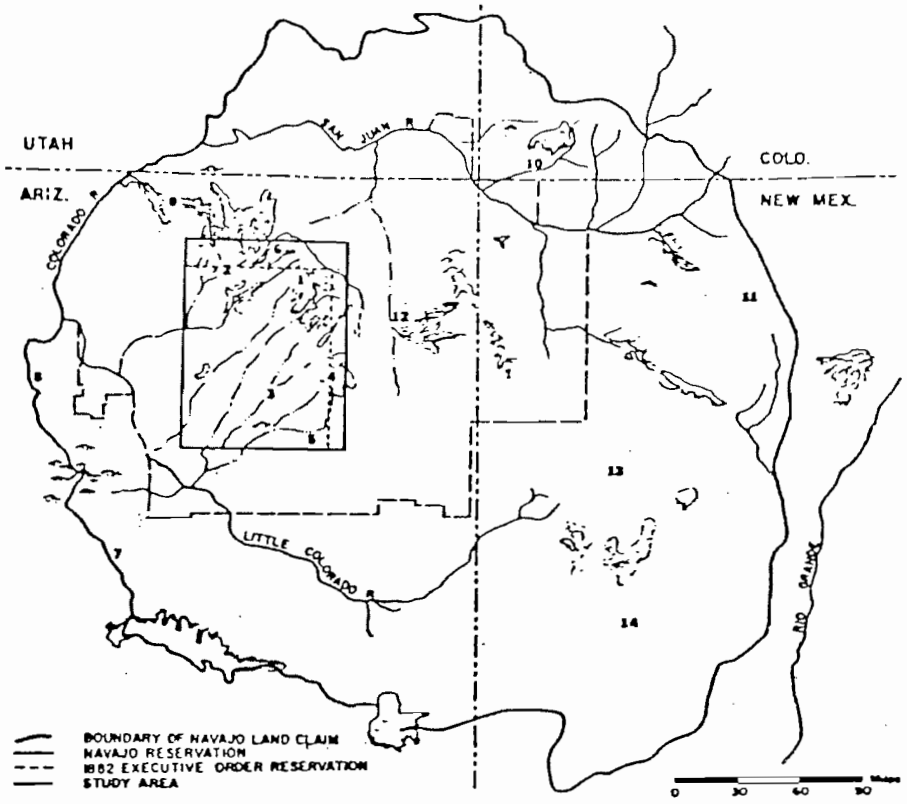

Fig. 16. Map of the Navajo Dendroclimatic Network.

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analysis. No specimens were available from the southwestern part of the region, which is largely a desert shrub-grassland plant zone (see Figs. 12 through 15). All of the specimens, from all stations, were pinyon pine (*Pinus edulis*). Cores from living trees and from archaeological specimens from Navajo sites were used. All but two of the stations were collected by the Land Claim staff. The station on North Black Mesa was collected as modern cores by William J. Robinson and Jeffrey S. Dean of the Laboratory of Tree-Ring Research, and I collected a portion of the Gobernador sample.

The specimens from all of the stations were reanalyzed and measured under the direction of Jeffrey S. Dean. Specimens or portions of the ring series showing anomalous growth were eliminated from the sample. The ring-width values for each specimen were evaluated, and specimens showing extremely high or low ring-to-ring variation (sensitivity), and not cohering with the others from the station, were eliminated. The ring-width values for each specimen were then plotted. The appropriate curve expressing the growth trend was selected (Fritts, 1963), and the curve was fit to the ring-width sequence. The ring-width values were then standardized by assigning a mean of unity (1.00) and converting ring widths to indices, thereby removing the age trend.

A cross correlation analysis was performed to remove those specimens, or segments, that did not cohere with the remainder of the sample from each station. Indices from each specimen were correlated with the others in the sample within the same 20-year time period. Specimens consistently exhibiting low r values relative to the others were eliminated from the sample. The 20-year time periods overlapped 15 years so that

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more discrete erratic growth segments could be removed. The outcome of these analyses was sets of specimens from each station that have nearly identical growth characteristics and thus, presumably, the same response to climate in the vicinity of the station. Although these analyses were designed to eliminate error in the form of atypical growth that would skew the dendroclimatic values at that station, it is possible that the station is not regionally representative. This type of error can be evaluated in terms of the outcomes from the other stations, and illustrates more precisely the need for a supra-study area perspective.

The indices from the trees of each station were averaged into a single chronology. The number of specimens suitable for analysis from each station and the total length of the chronology are given in Table 35. A minimum of four specimens is represented for every year in each station chronology.

Table 35. Summary Chronologies for the Navajo Dendroclimatic Network.

Station	Samples	Time range
1. Central Black Mesa	6	1660-1895
2. Klethla Valley	8	1630-1949
3. Wepo Wash	7	1750-1929
4. Balakai Mesa	20	1620-1949
5. Jeddito Wash	9	1690-1889
6. North Black Mesa	8	1620-1959
7. Canyon Diablo	6	1750-1949
8. Lower Navasu	11	1650-1949
9. Navajo Mountain	13	1600-1949
10. Middle San Juan	13	1610-1949
11. Gobernador	8	1670-1969
12. Canyon de Chelly	8	1640-1949
13. Cibola	10	1720-1919
14. Cebolleta Mesa	9	1720-1919

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The test period for evaluating climate and Navajo settlement location is A.D. 1750-1899. This 150-year span is the interval whereby the mean and standard deviation of the indices for the interval are calculated separately for each station. The mean is subtracted from each index and divided by the standard deviation to produce a series of positive and negative departure values that render all of the stations comparable. Each normalized departure is then multiplied by the square root of *N* (5 years). This step corrects for variability and converts the normalized departures into standard deviation units. For example, a departure value of -2.00 at one or more stations indicates that the departure for that year is two standard deviation units below the chronology mean and lies outside of 95% of the variation around that mean.

The dendroclimatic values for a sequence of five-year periods are presented in Appendix I. Each value in the maps represents a five year normalized departure average. Five-year intervals were selected to maximize the sensitivity to fluctuating grazing potential. In this region, periods of drought result in the destruction of mature grasses and browse, and the inhibition of seed and vegetative production. Range recovery following a drought may take up to seven years (Thornthwaite and others, 1942, pp. 46-129). Conversely, periods of optimum plant growth conditions may not be fully expressed in terms of plant density for several years.

A map of the stations was constructed for the computer by William J. Robinson. The departure data for each five-year interval were analyzed and contoured throughout the network using the SYMAP program. The maps in Appendix I show the index departure contours within

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the study region. Positive departures represent cooler, wetter conditions; negative values represent warmer, drier conditions.

Two stations, Number 1 in Klethla Valley and Number 5 below Black Mesa, frequently depart from the others within the study area but usually conform with each other. Although the two stations covary with regional climatic change, the intraregional variation reflects differences in microclimatic setting. Summer storms usually develop in the higher altitudes with less rainfall deposited in the valleys or off-mesa areas (Thornthwaite and others, 1942, pp. 47-53). Both of these stations are probably accurately documenting this meteorological pattern and contrast with the mesa-top stations.

The dots in Appendix 1 represent tree-ring cutting dates and the location of the sites from which they were derived. The sample is the same as that used in Fig. 11, except for some trees. This sample includes only habitation sites. All cutting dates, including repair and re-used wood, are included to indicate that a site was at least occupied in the year designated by the date.

Table 36 shows that there is a slight tendency for construction activity not to take place within the extreme negative departure zones. The frequency of departures was obtained by counting the number of times a zone with a given departure value occurred within the study area. This distribution was used as a measure of the range of climatic and pasturage variation available to the inhabitants of the area. The frequency of sites within each of these classes generally covaries with the number of times a given zone is available, with fewer sites than expected located within the extreme negative departure classes.

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Table 36. Comparative Distributions of Construction and Departures.

Departure value	Departure frequency	Wood cutting frequency
-5.00 - -5.99	0	0
-4.00 - -4.99	2	0
-3.00 - -3.99	7	1
-2.00 - -2.99	16	19
-1.00 - -1.99	25	39
0.00	30	64
+1.00 - +1.99	24	18
+2.00 - +2.99	15	7
+3.00 - +3.99	7	5
+4.00 - +4.99	3	5
+5.00 - +5.99	2	4
+6.00 - +6.99	1	1

The amount of construction activity does not correlate with climatic change. The major construction periods can occur in almost any set of climatic conditions. This is consistent with the argument presented in the first section of this chapter that peaks in wood cutting activity are more likely related to migration into the study area than internal movement.

It is clear, however, that site location is related to climatic change. The types of climatic outcomes that can occur in a given 5-year period are presented in Table 37. A cool, wet period is a map containing a set of departures that are greater than or equal to +2.00. An

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average period is a map that contains departures less than ±2.00. A highly variable period is one where the departures are equal to or exceed +2.00 and -2.00 on the same map. A warm, dry period is a map where the departure values are greater than or equal to -2.00. In Table 37, site location is viewed as a decision-making process that takes place within the context of each climatic type. A "most optimum" decision is one where a site is located in the most positive departure zone available within a 5-year period. An "optimum" decision is one where a site is found within the next most positive in the available array, with at least three less positive levels present in the map. A "neutral" decision is one that falls in the centermost value in the map. A "below optimum" decision is one that falls below neutral, but above the most negative departure zone. Finally, a "least optimum" decision is one where a site is located within the most negative departure value zone on the map.

Table 37. Construction Location Decisions by Climatic Outcomes.

Climatic type	Most optimum	Optimum	Neutral	Below optimum	Least optimum	Total occurrences
Cool, wet	8	6	23	7	30	74
Average	0	0	8	0	3	11
Highly variable	0	3	9	1	0	13
Warm, dry	15	5	43	2	12	77

The high frequencies in the most, neutral, and least optimum columns are related to the fact that there are 14 maps exhibiting only

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three different index-departure values and thus precluding the availability of the optimum and below optimum categories. There are 10 cool, wet periods, four average periods, five highly variable periods, and 11 warm, dry periods. Note that there are more occupations in the most optimum zones in the dry periods than in the cool, wet ones. Moreover, there are fewer construction events in the least optimum zones in the dry periods than the wet periods.

The Navajo did not always optimize site location. In the context of cool, wet conditions, location decisions are variable. Once drought conditions occurred, however, Navajo groups tended to optimize the climatic and pasturage options. This is cross-cut, however, by stress conditions related to personal security and relations with other groups, which apparently take priority over optimizing subsistence potential. During periods when immigrant groups moved west, in A.D. 1805 to 1819 and A.D. 1855 to 1864, site location decisions were not the most optimum available within the region. Approximately 45% of the sites in the neutral category are attributable to these periods. Similarly, 36% of the sites within the least optimum category were occupied during these periods. Only 22% of these fall within the most optimum category despite the fact that the number of construction events within these periods is 51, or 31%, of the total sample.

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CHAPTER 4

SUMMARY AND CONCLUSIONS

Most of the arguments I have made in the preceding chapters are founded wholly or in part upon my interpretations of the archaeological tree-ring dates. I have attempted to show how an understanding of Navajo settlement in behavioral terms was obtained through a detailed explication of the dated specimens in their behavioral and environmental contexts. I could find little to indicate that wood harvested from dead pinyon trees was used in Navajo architecture. Independent dating evidence was available for 265, or 83%, of the tree-ring dates. In this sample, roughly 90% of the tree-ring dates were consistent with this evidence. Each date, however, was recognized to be consistent or inconsistent with independent date information as a product of one or more of the following behavioral and environmental relations:

(1) Pinyon was preferentially harvested for wood in the late spring-early summer and used in all types of Navajo architectural features that were dated by the tree-ring method. This season coincides with scheduling of (at least) dwelling and game trap construction, and probably windbreaks, livestock corrals, and sweathouses.

(2) From A.D. 1700 to 1817, the bark was generally peeled from the wood and the wood was used immediately or stockpiled for a period that probably did not exceed one year prior to use in (at least) hogan and livestock corral construction.

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(3) After A.D. 1817, bark was not totally removed from the wood or stockpiled, but the wood was used immediately in the construction of (at least) hogans, corrals, and sweathouses. This change in activity performance is related to technological change, namely the increasingly popular use of the metal axe.

(4) Trees were harvested and used immediately without debarking in the construction of game traps. These structures were in use during the 18th through the mid 19th centuries.

(5) Hogans and game traps (at least) were frequently repaired one to 25 years after initial construction, with game traps usually having longer repair histories. The wood harvesting and preparation behaviors conform to those listed above.

(6) After A.D. 1868, the incidence of wood re-use sharply increased. This is probably related, in part, to decreased wood supply, increasingly higher population levels in the area, and increased availability of abandoned structures.

(7) Main trunk segments were selected for use in the construction of hogans and game traps. Smaller branches were preferred for use in building livestock corrals, sweathouses, and windbreaks. The extent of wood decomposition and erosion is inversely related to stem diameter.

(8) Wood that was harvested and used in architecture located in high stress environments is less likely to cross date. Larger stem segments are more likely to at least partially cross date than smaller sections.

The above relations permitted the recognition and separation of behavioral from environmental sources of "error" in date discrepancies

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between partially and fully cross dated specimens from the same structure. The environmentally produced error was quantifiable in partially cross dated samples. Tree-ring dates derived from ring counts consistently fell short of those that were fully cross dated from the same structure. This error is produced in the ring-count method, where rings are absent from the sample and therefore are not counted. The range of relative ring widths in which annual tree growth would least likely be expressed was obtained through a series of correlational analyses. The number of missing rings was thus estimable. The true cutting dates were calculated within a probabilistic range of error. The re-estimated dates were added to the sample of more confidently dated specimens in the analyses of Navajo settlement.

A series of analyses was conducted to assess the relationship between the archaeological content of the survey report units and site units defined in temporal, occupational, and behavioral terms. Maps of all of the reports and chronological analyses of features within them were used to generate the following statements:

(1) Most of the report-based maps contained one or more discrete sets of architectural aggregates.

(2) Each cluster was composed of at least one habitation structure.

(3) The aggregate is, in general, a temporally, occupationally distinct unit. The archaeological content of survey units dating after A.D. 1868 was occasionally contemporary and included more than one cluster.

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(4) Cluster reoccupation designated by re-using wood and the construction of new hogans was more likely to occur after A.D. 1868.

(5) The aggregates can be subdivided into two classes in terms of seasonally related architecture: sites containing only warm-weather dwellings (shades, lean-tos, or windbreaks), and sites containing all-weather dwellings (hogans).

(6) In terms of activity performance, the cluster stands as the basic unit of Navajo settlement. Household maintenance activities (wood chopping, trash and ash dumping) were performed near each dwelling. Each of the rest of the architecturally specified activities is *not*, except for two cases, at or near each habitation structure but is associated with only one of the dwellings. These activities include storage, ovens, sweatbathing, outdoor activities, weaving, herd and lamb protection, and ceremonies. The household activities specify the domestic unit component, and the pattern of other activity associations specifies the corporate component of the cluster as a structurally autonomous unit of Navajo settlement.

(7) Isolated structures, particularly sweathouses and storage structures, reported in the survey as separate units, are part of a nearby aggregate community. The high variability in distance is related to the locus of the appropriate environmental resource.

(8) The isolated game trap represents an activity that is performed outside of the context of the cluster community. The number of persons required to perform game drives might have exceeded those available within a single cluster, and thus might be a multicluster activity.

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(9) Another multicommunity activity is probably represented by ceremonial structures and the associated collection of windbreaks.

Changing relations with other Southwestern groups had a profound impact upon the Navajo that occupied the 1882 study area. The area may have been inhabited at least since the 17th century by the Navajo. However, successive waves of immigrants moved west and settled in the area immediately preceding or following the major political turnovers in the Southwest. Prior to the signing of the permanent treaty with the United States government in A.D. 1868, the Navajo groups occupying the area were under continuous threat of raids. The following set of contrastive relational statements illustrates the changed limiting conditions on Navajo settlement:

(1) *Pre-A.D. 1868:* The landforms selected for community location provide seclusion or seclusion plus high visibility of the surrounding terrain.

Post-A.D. 1868: Navajo communities are located on all types of landforms, particularly in open flatlands, valleys, and rolling country.

(2) *Pre-A.D. 1868:* Community structures are camouflaged.

Post-A.D. 1868: There is a significant reduction in camouflaging activity.

(3) *Pre-A.D. 1868:* Pastoralist activities are conducted in forested zones, probably to reduce herd visibility.

Post-A.D. 1868: Herding is performed in all types of plant zones, with a significant shift to the exploitation of grassland environments.

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(4) *Pre-A.D. 1868:* The above site selection criteria precluded the maximum utilization of pasturage resources. This is particularly true of immigrant groups who sought refuge in the region.

Post-A.D. 1868: There are fewer constraints on site selection. Thus communities are located within zones that would provide relatively optimum grazing potential.

In conclusion, the detailed examination of the dendrochronological information and its use in this study illustrates the wealth of behaviorally relevant information available to the archaeologist. Although I am not the first to make this point, I have attempted to show how inextricably involved archaeology and dendrochronology can become with one another to the mutual benefit of both disciplines. It has become increasingly clear to me, at least, that interdisciplinary research must give way to multidisciplinary cooperative efforts if archaeologists continue to pursue their present interest in the past from a behavioralist perspective. A few examples from this study may be used to illustrate this point. It might have been possible to estimate more cutting dates within a specifiable range of error if wood surface erosion rates within the region could have been calculated. Experimental studies might aid in establishing a series of erosion curves. Tree-ring samples from dead trees in the region would have been helpful in establishing a more rigorous empirical base for accepting or rejecting the notion of using dead wood in the architecture.

Most archaeological problems today require refined chronological controls. In this study I have tried to demonstrate that wood decomposition, the stem diameters selected for use, and the environment from

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which wood was harvested are related to the odds that a tree-ring sample will cross date to the true exterior. Carefully controlled pilot studies designed to understand how the archaeological wood is related to the behavioral and environmental context in which it is found could provide the archaeologist with sufficient information to sample less arbitrarily on a larger scale. The development of more flexible research strategies with the dendrochronologist could reduce the amount of time spent in processing samples with low interpretive potential and thus would reduce information feedback time.

This study may be of some heuristic and methodological value for the study of small sites. The architectural features in Navajo communities are usually not contiguous. Nonetheless, chronologically and behaviorally significant settlement units could be derived and separated from others in the vicinity. Many of the statements I made gave rise to questions I could not answer without excavation and systematically collected surface material. However, the questions I now find myself asking are probably more directly pertinent to understanding Navajo settlement than those I initially entertained. In this sense there is more to be done than this study has accomplished.

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APPENDIX I

DENDROCLIMATIC MAPS

The illustrations in the pages that follow are dendroclimatic maps for the interval A.D. 1750 to 1899. The numbered contours identify the departure values. The crosses indicate significantly warm, dry zones. The hachured lines identify the significantly cool, wet zones. The dots on the maps specify the locations of wood harvesting events that took place within the interval indicated on each map.

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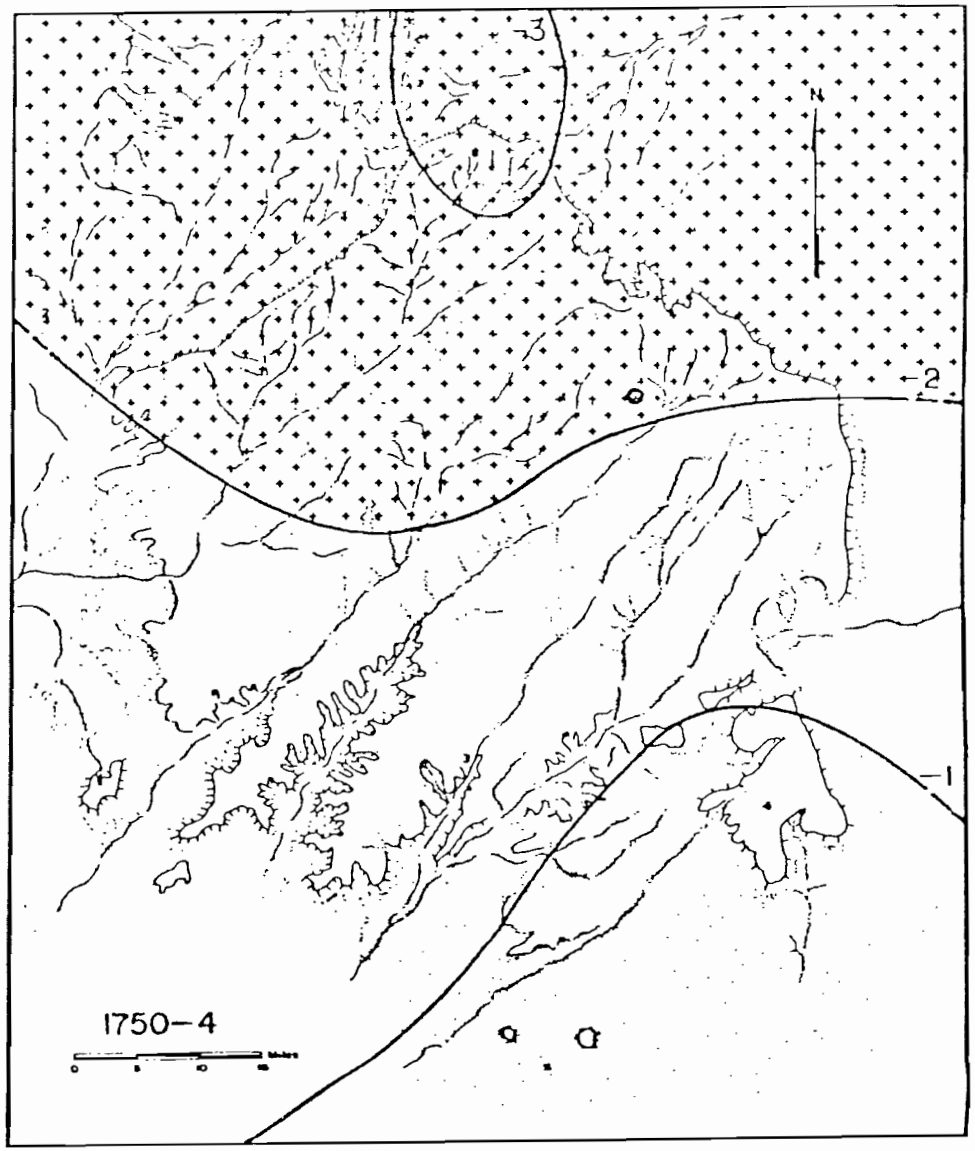

Dendroclimatic Interval, 1750-1754.

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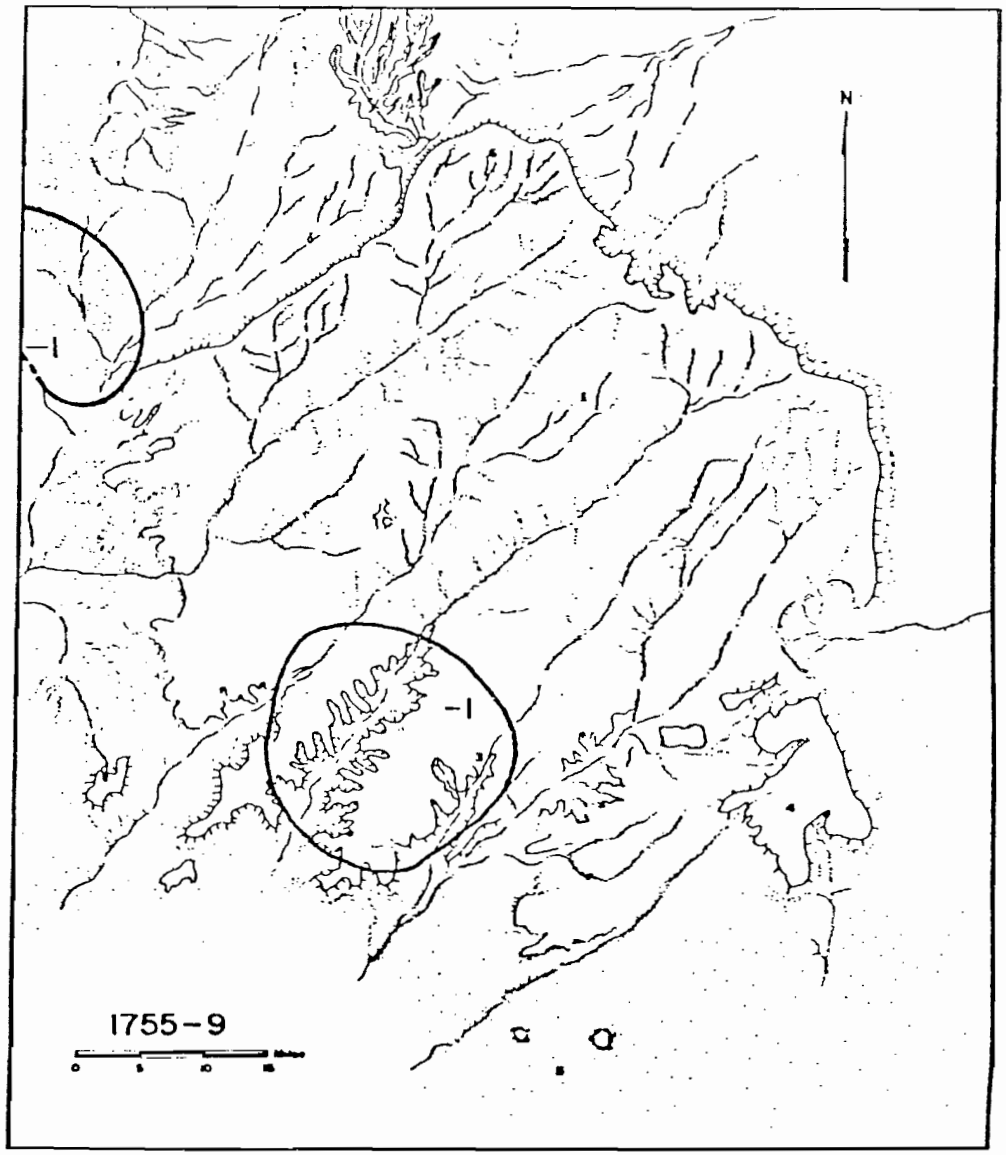

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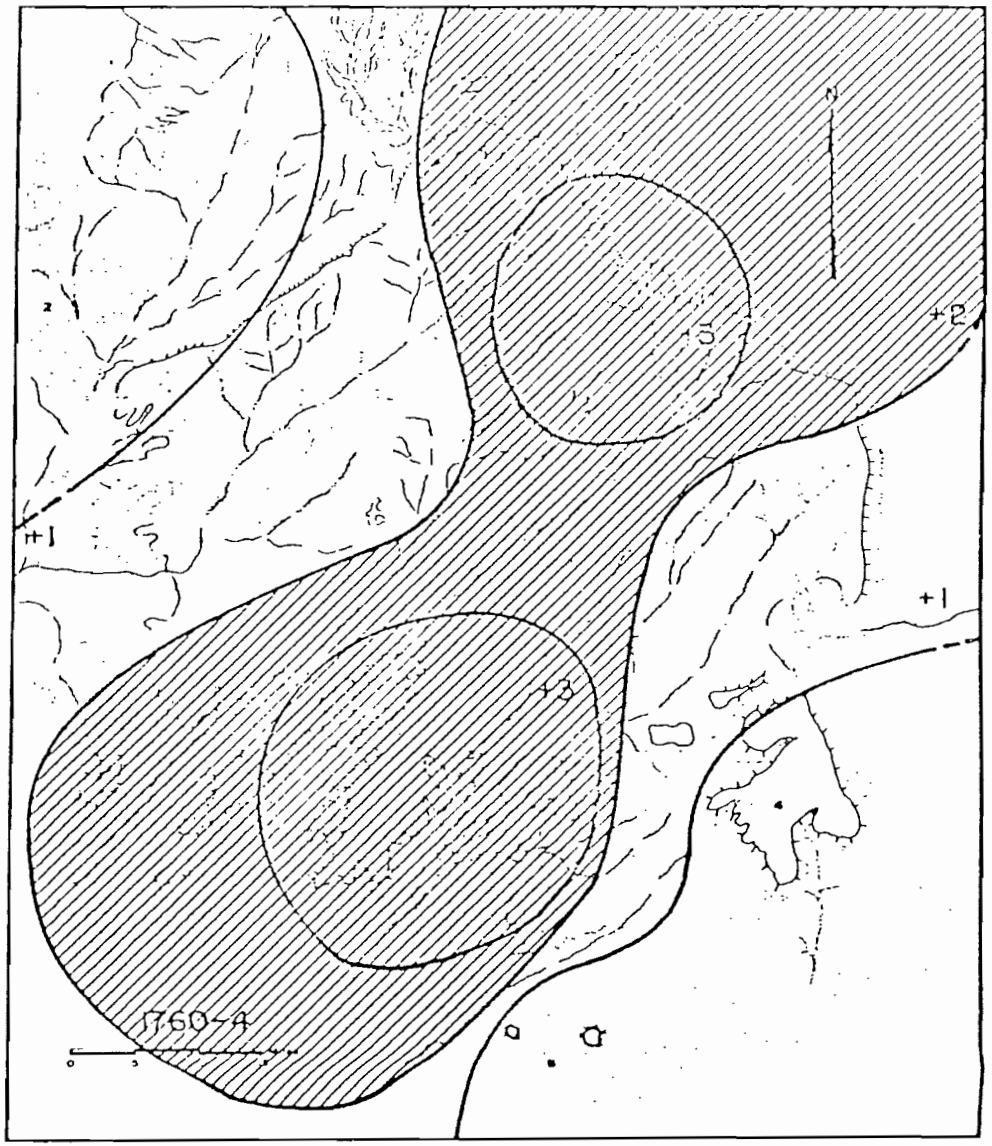

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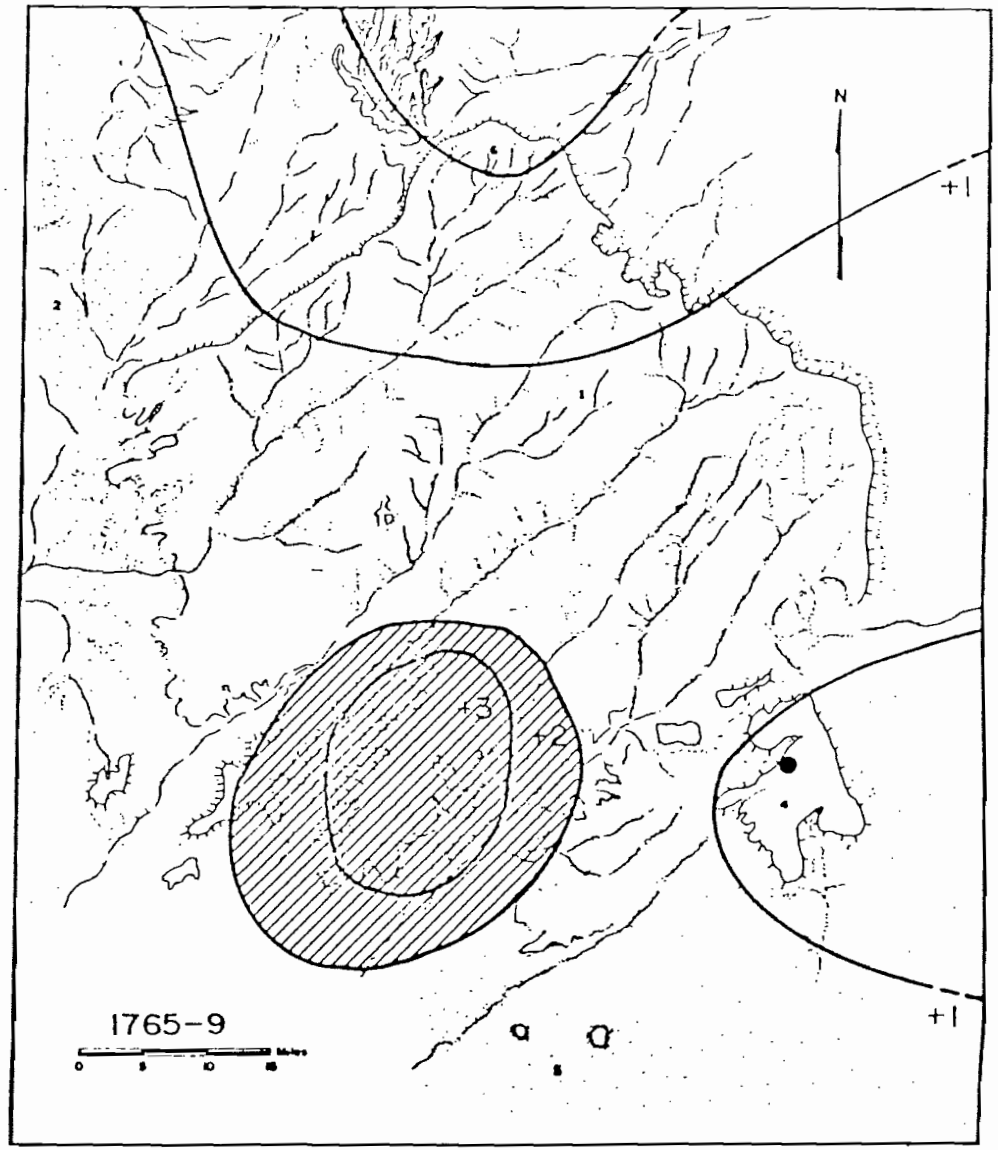

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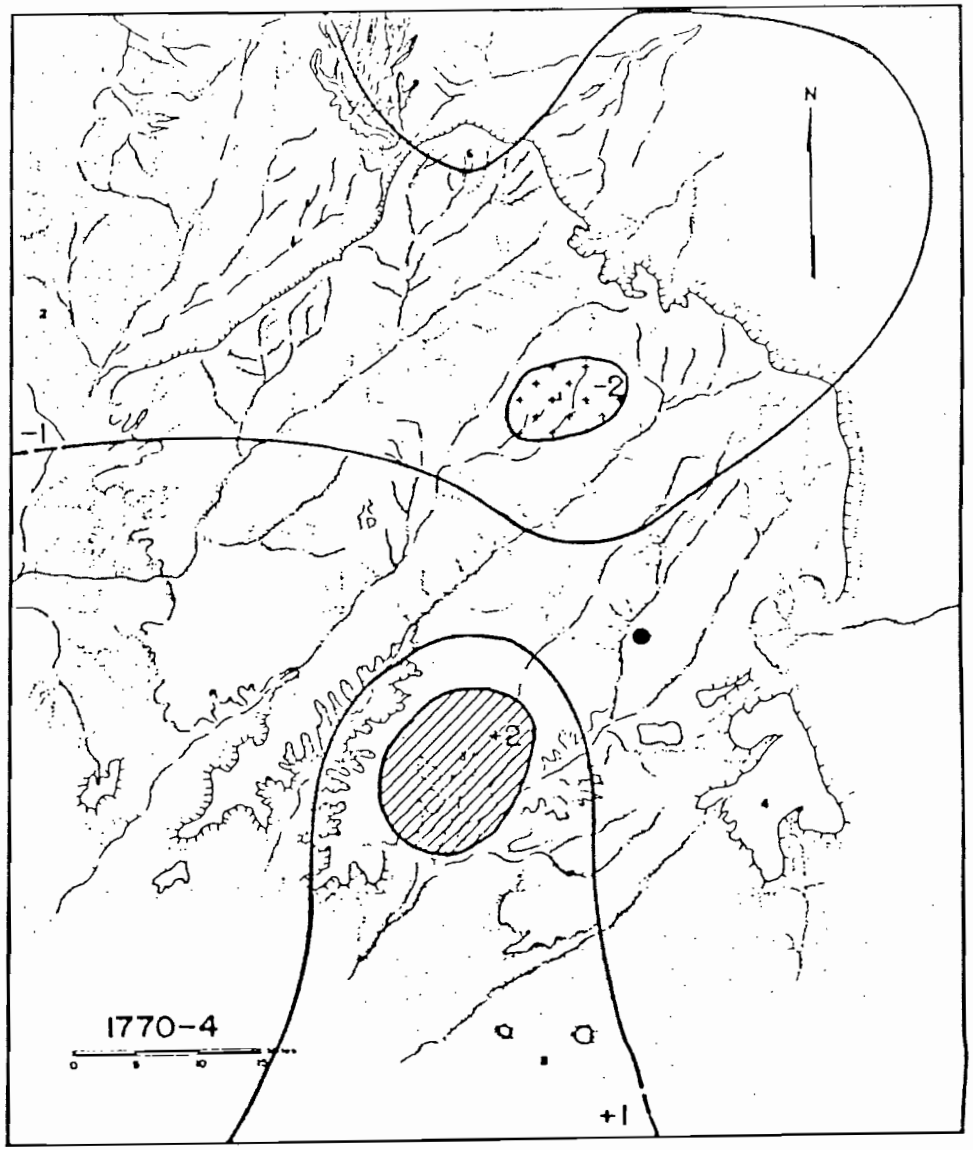

Dendroclimatic Interval 1770-1774

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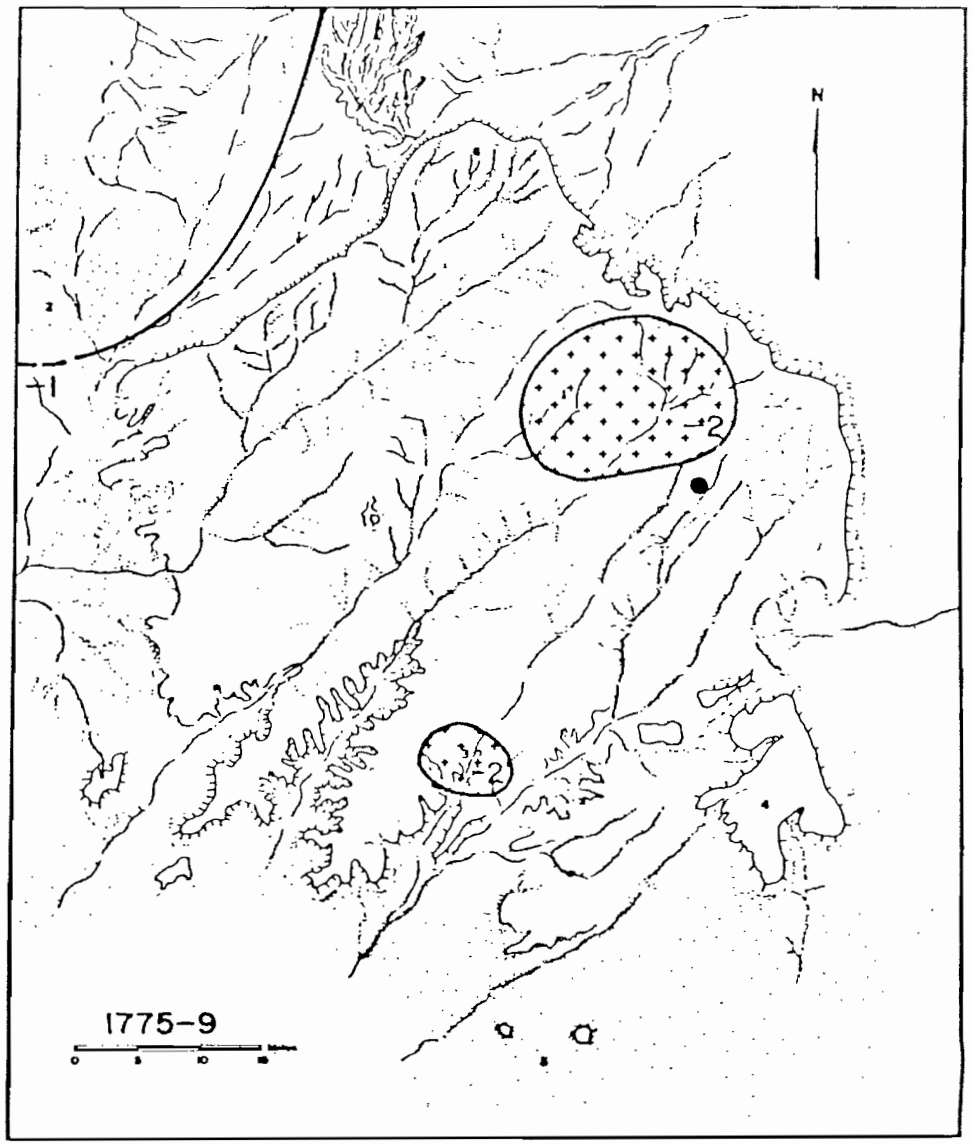

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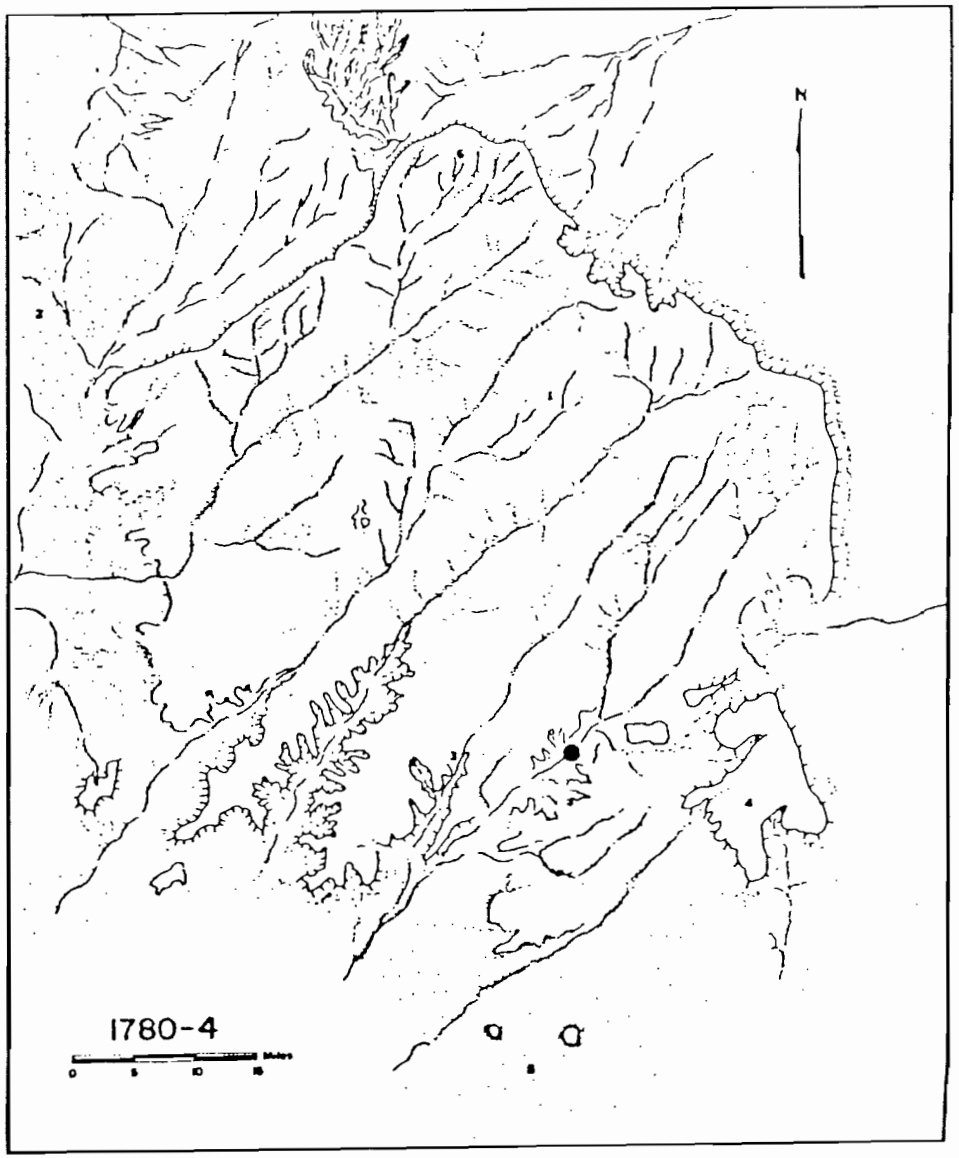

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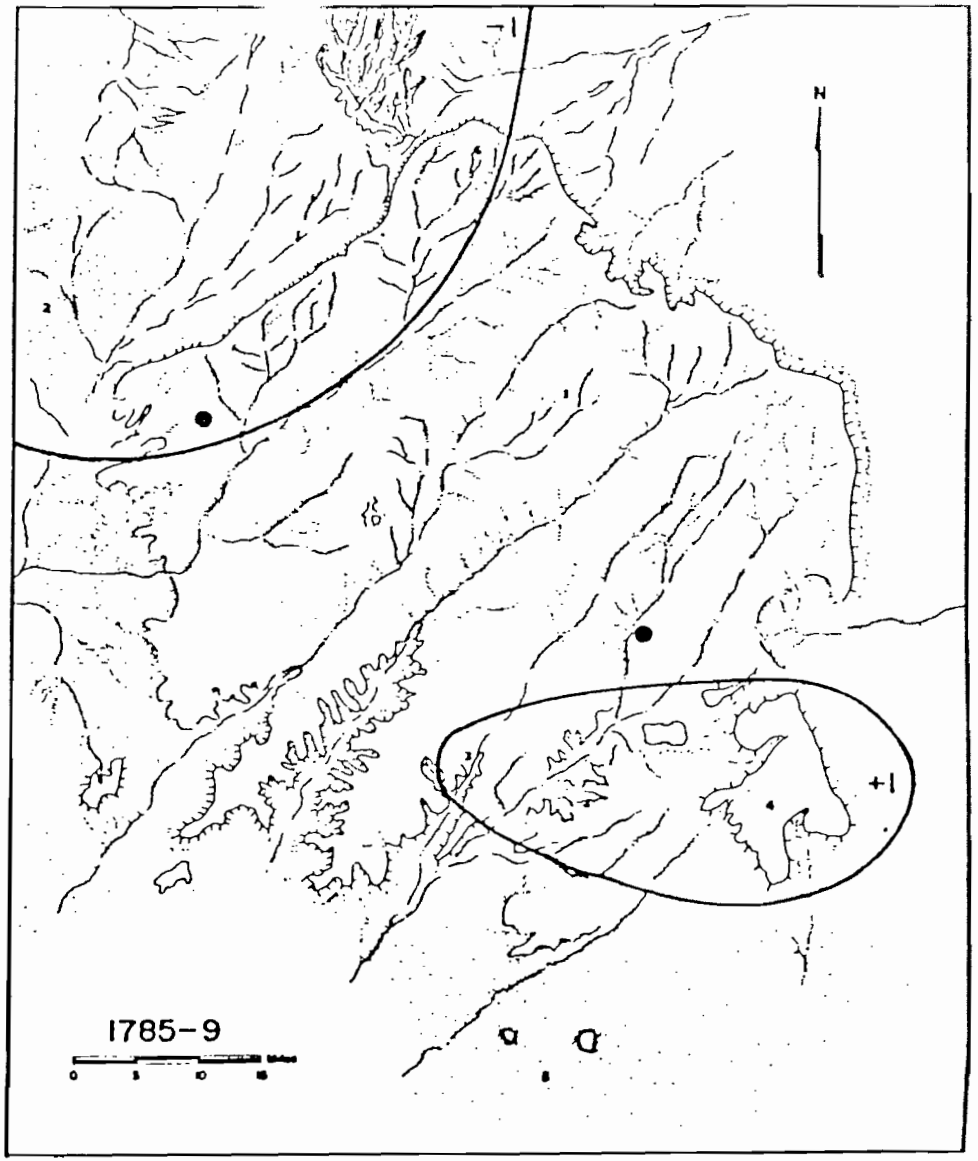

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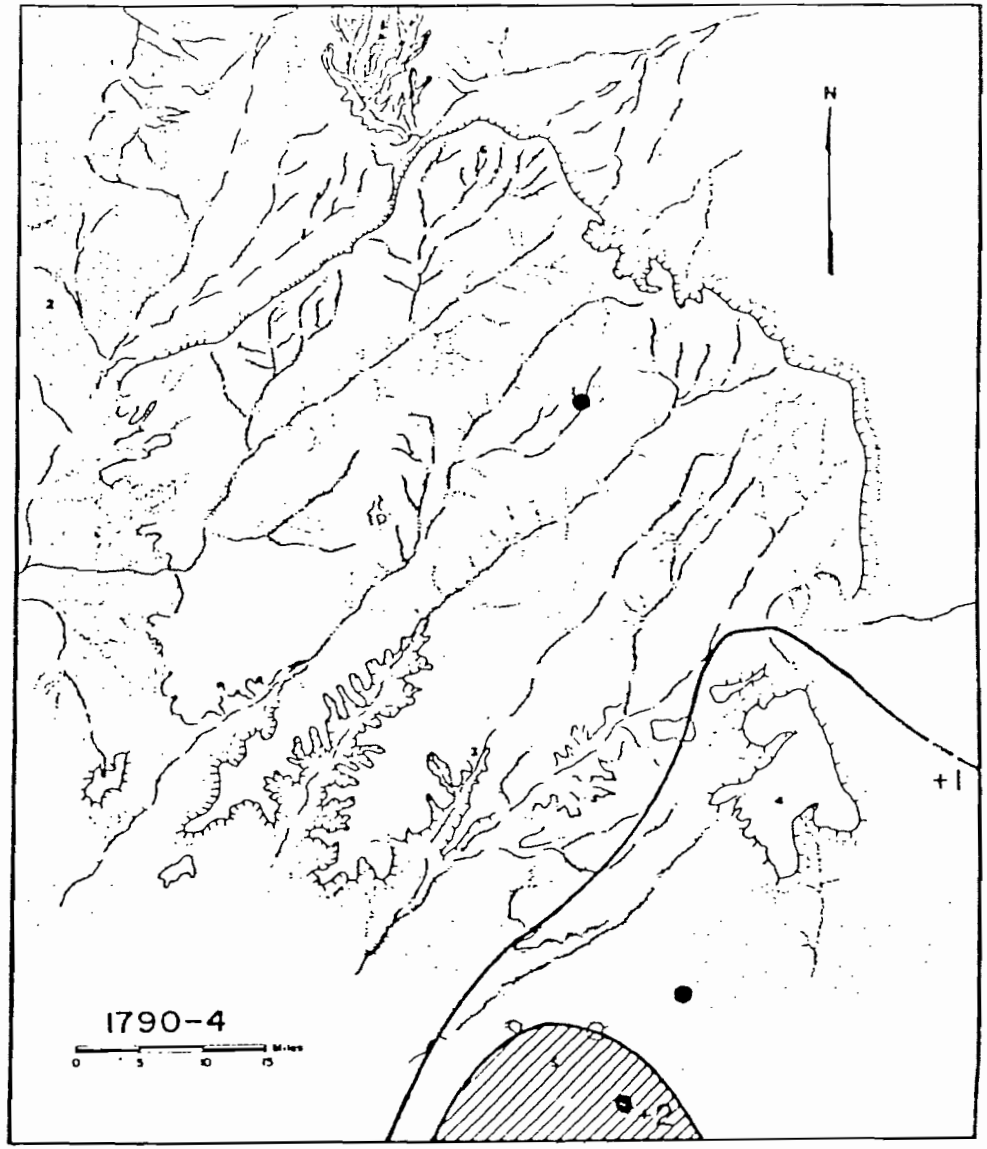

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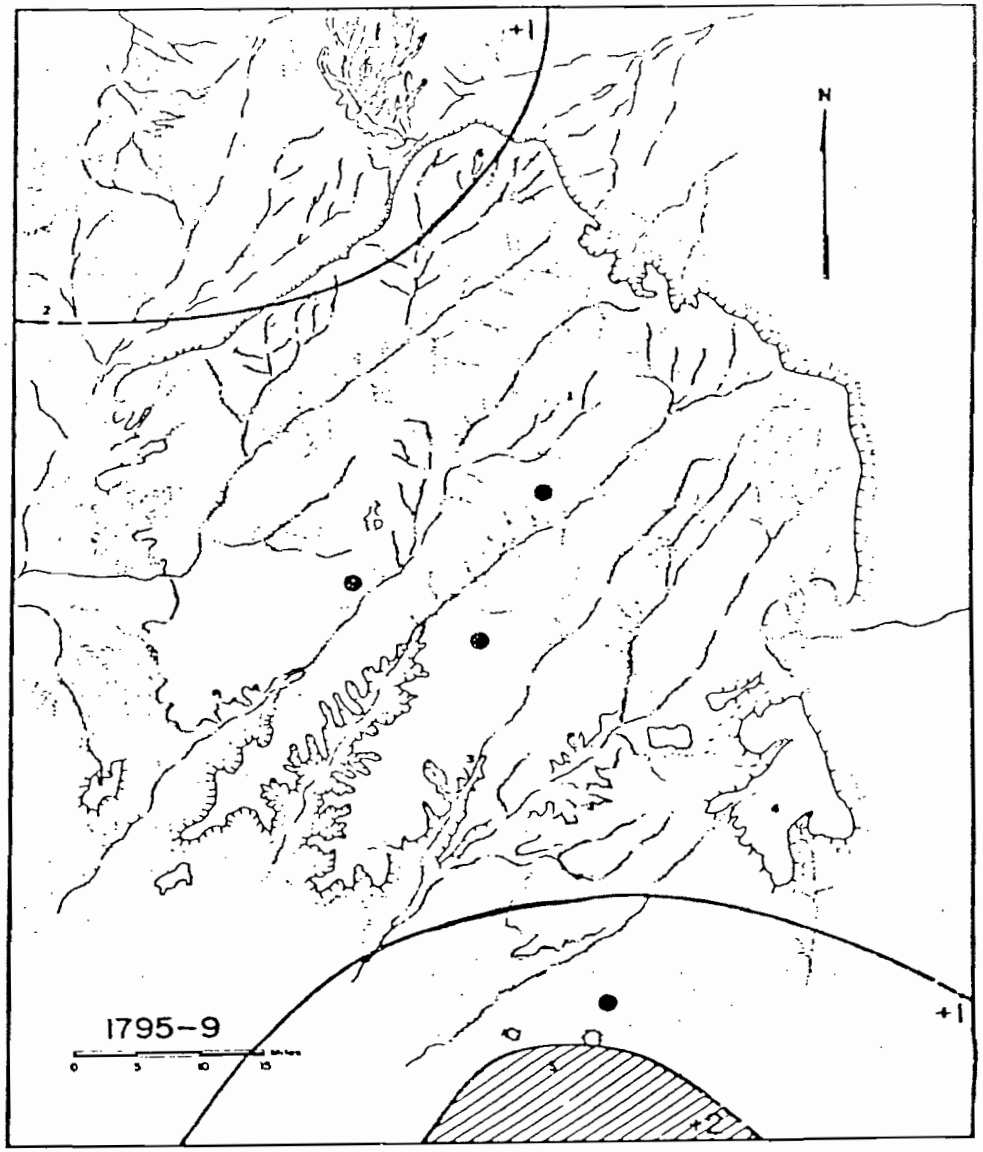

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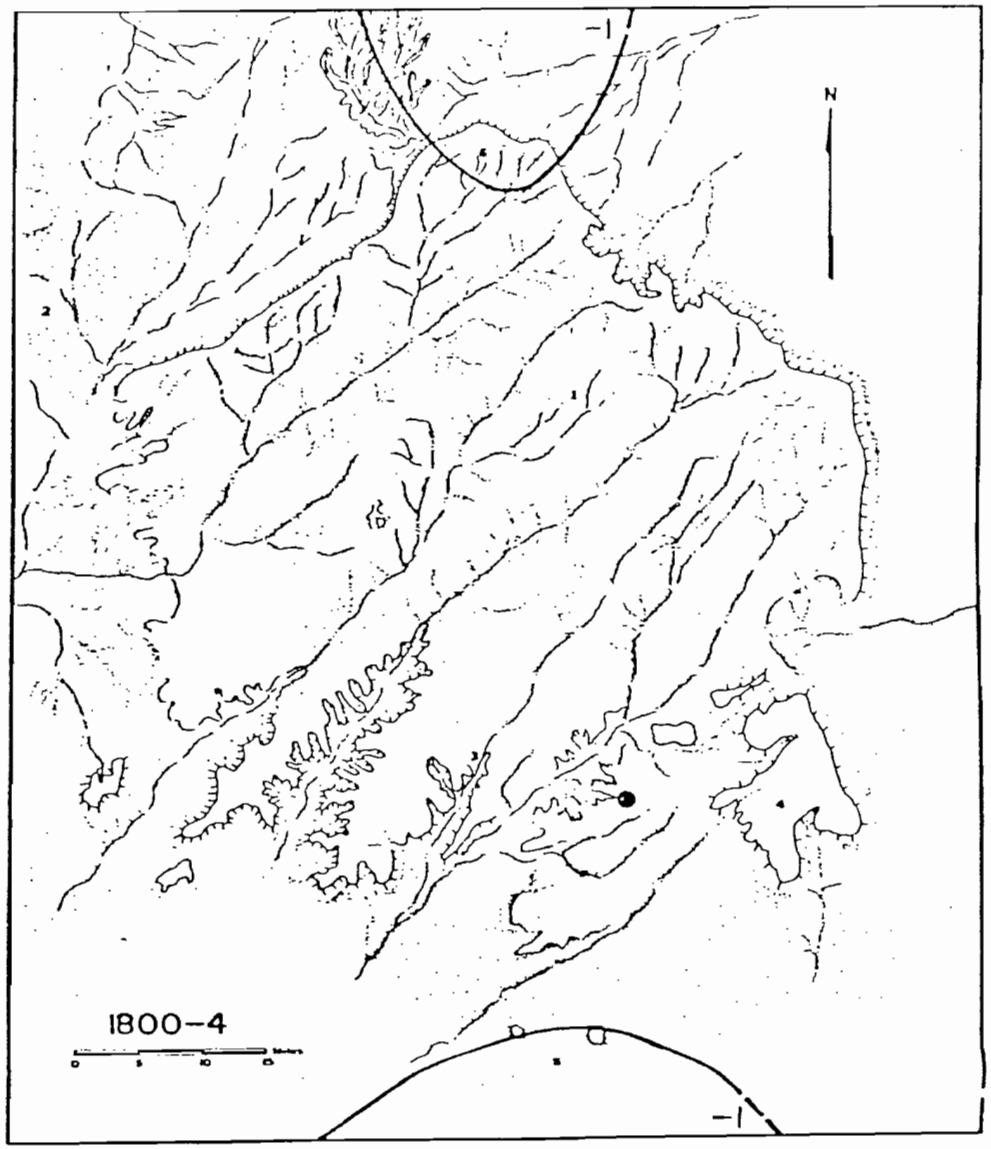

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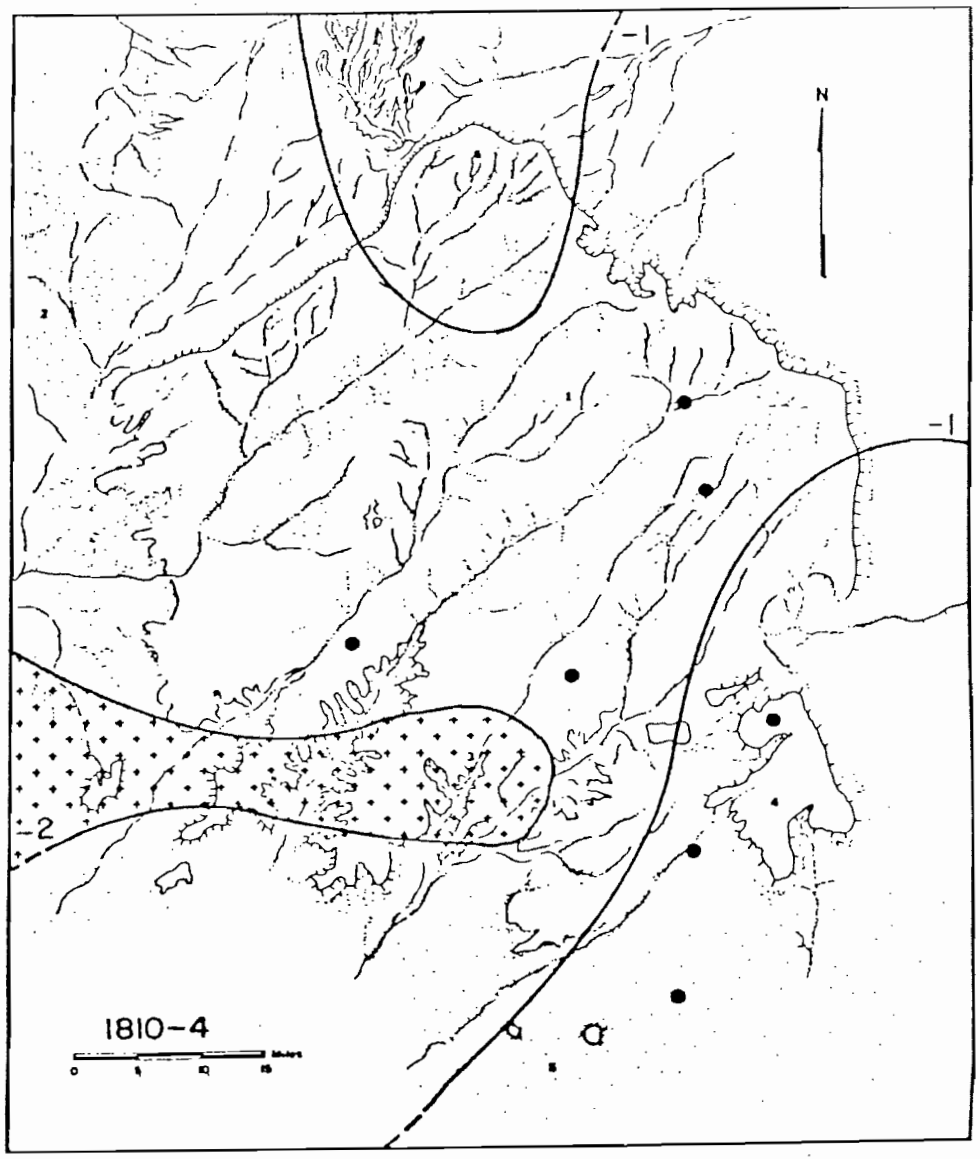

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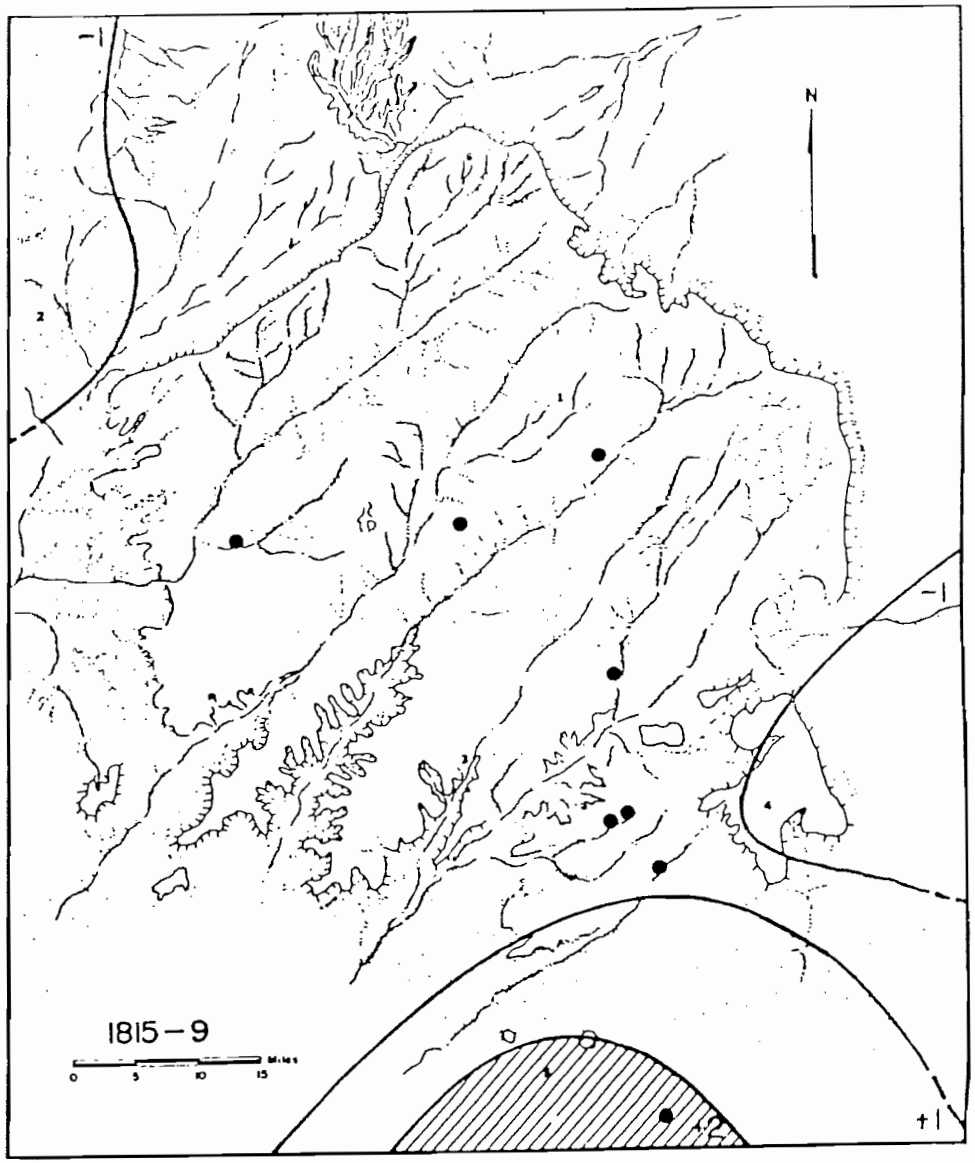

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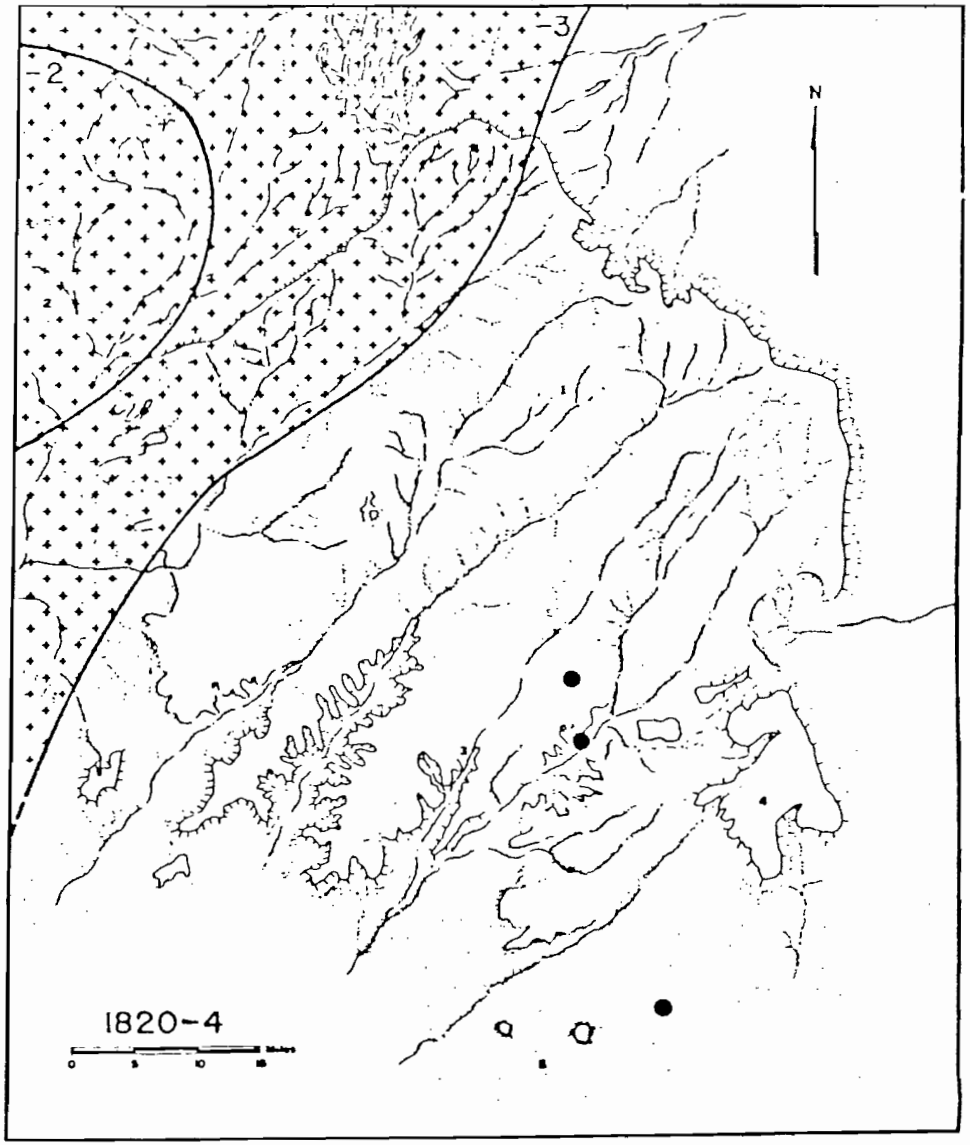

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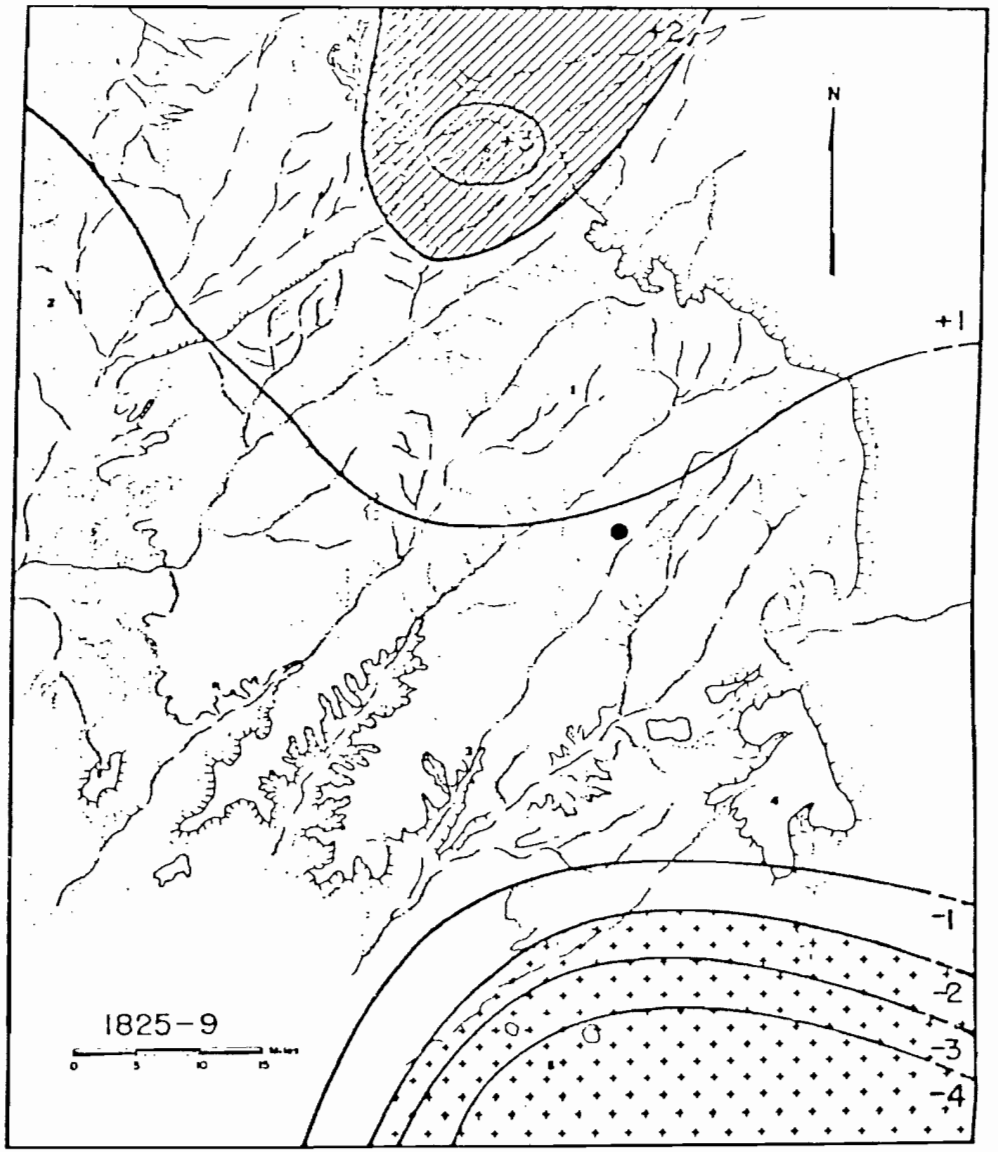

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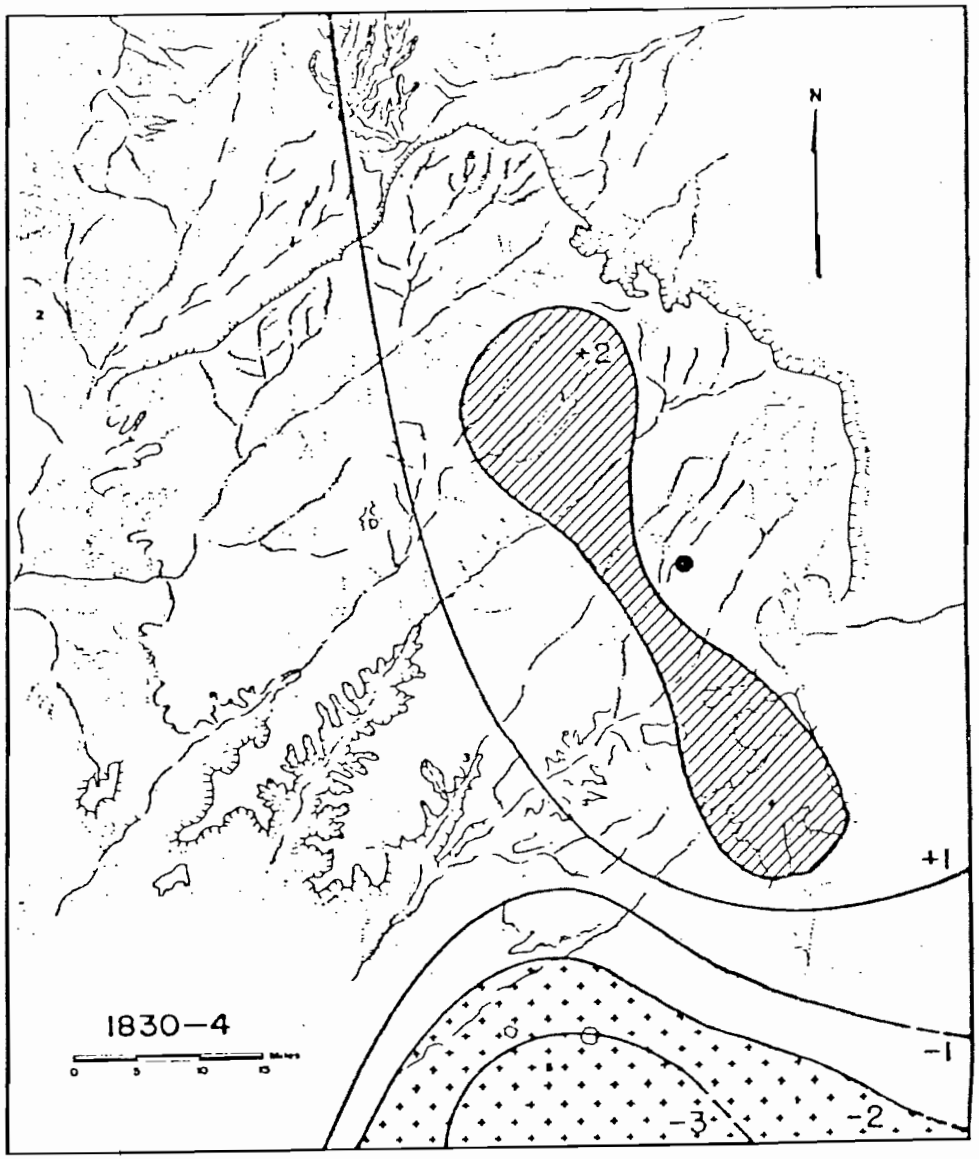

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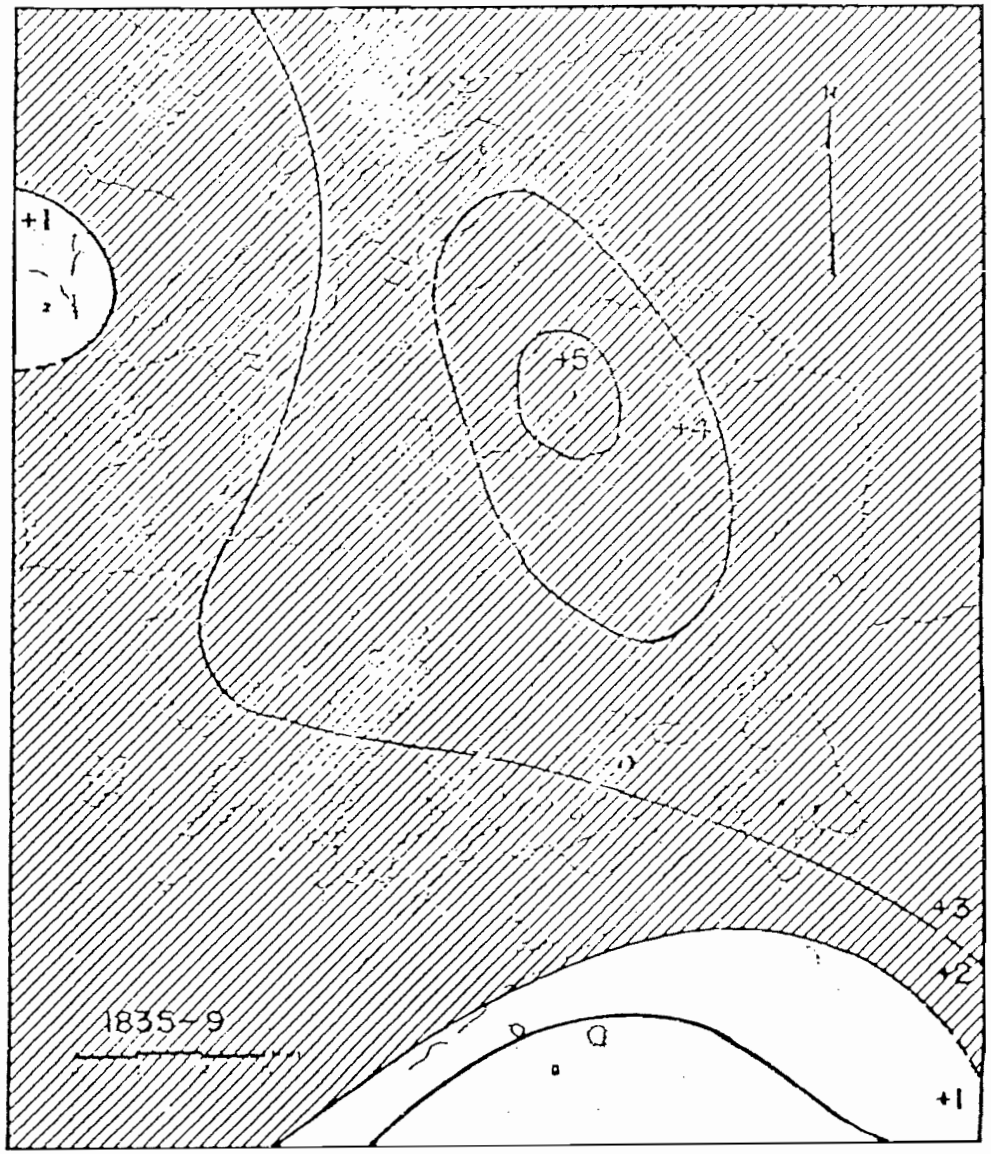

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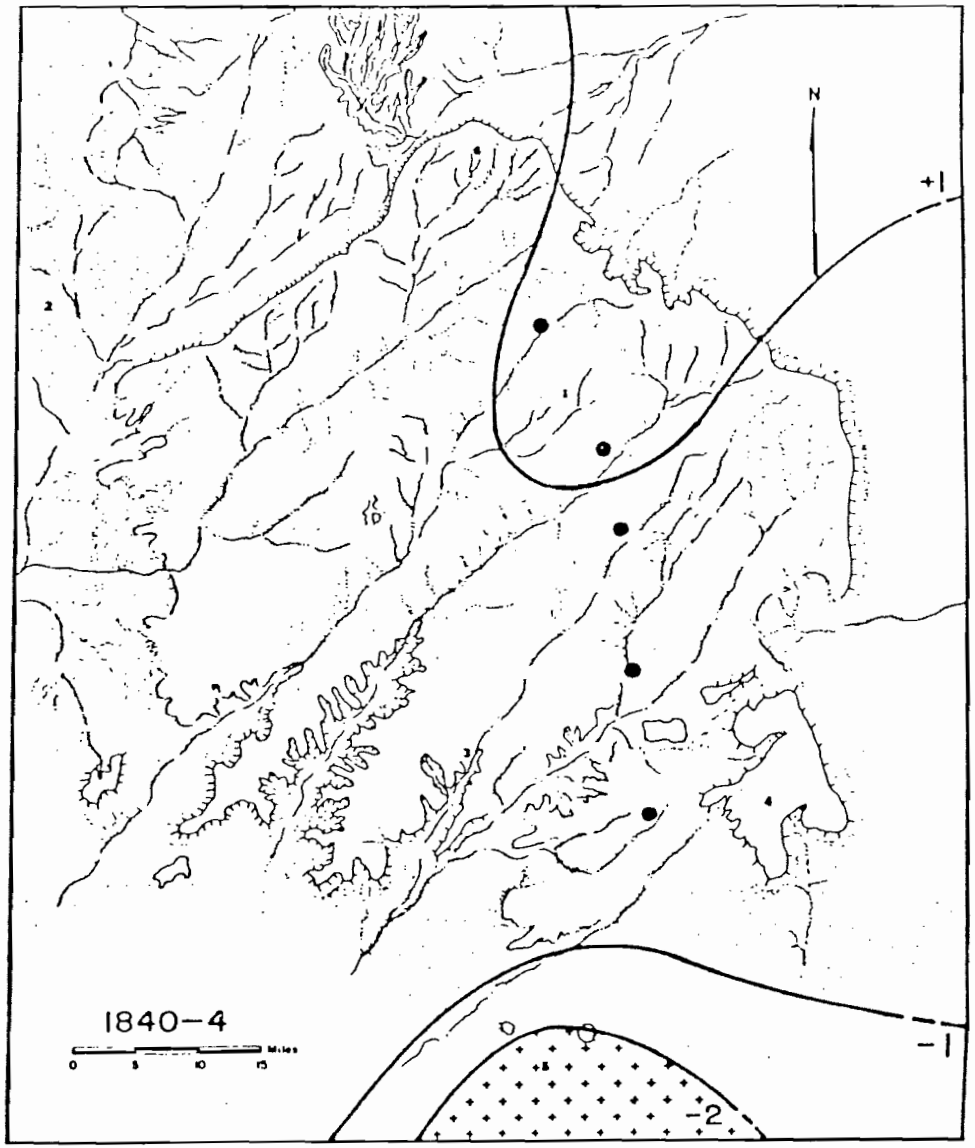

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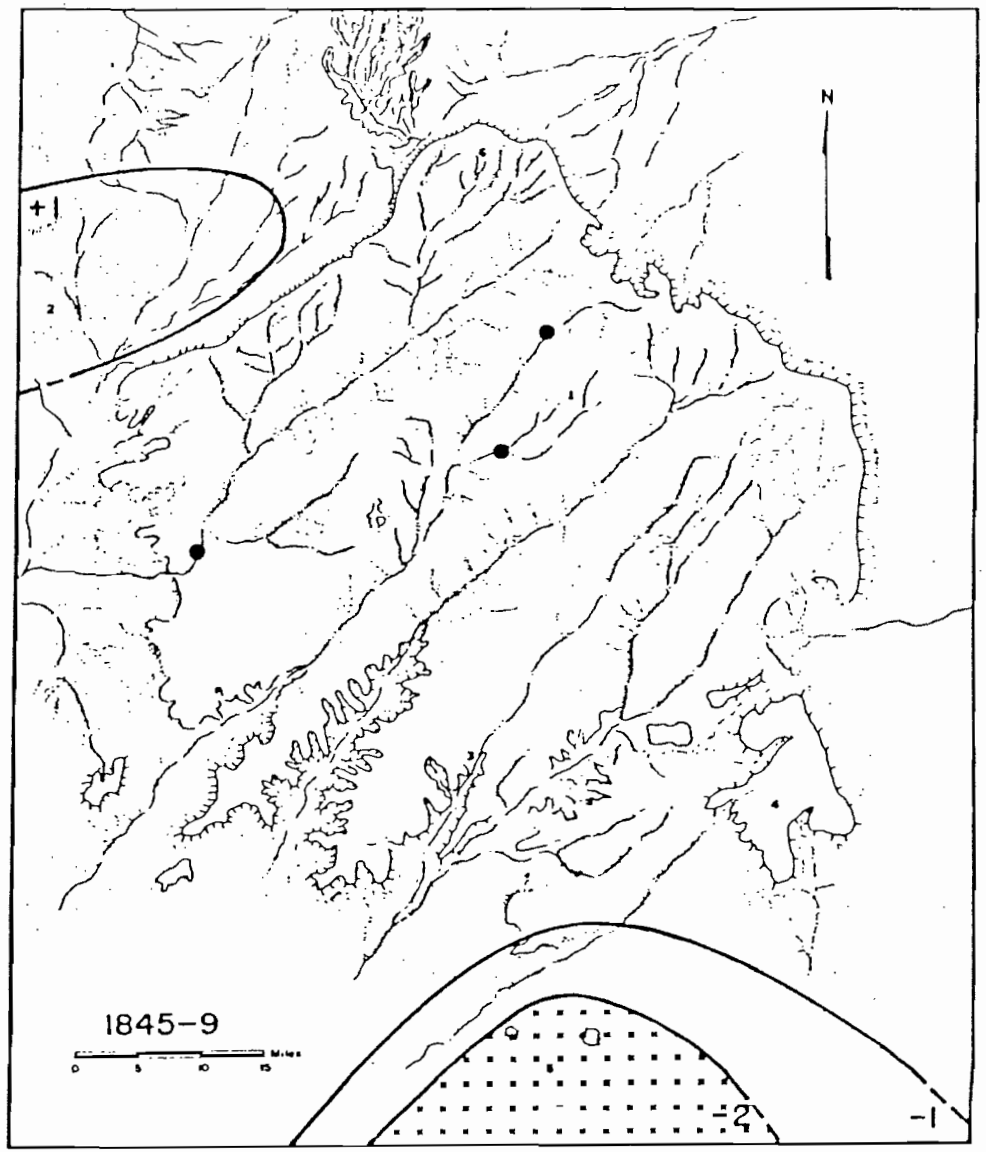

Dendroclimatic Interval 1845-1849

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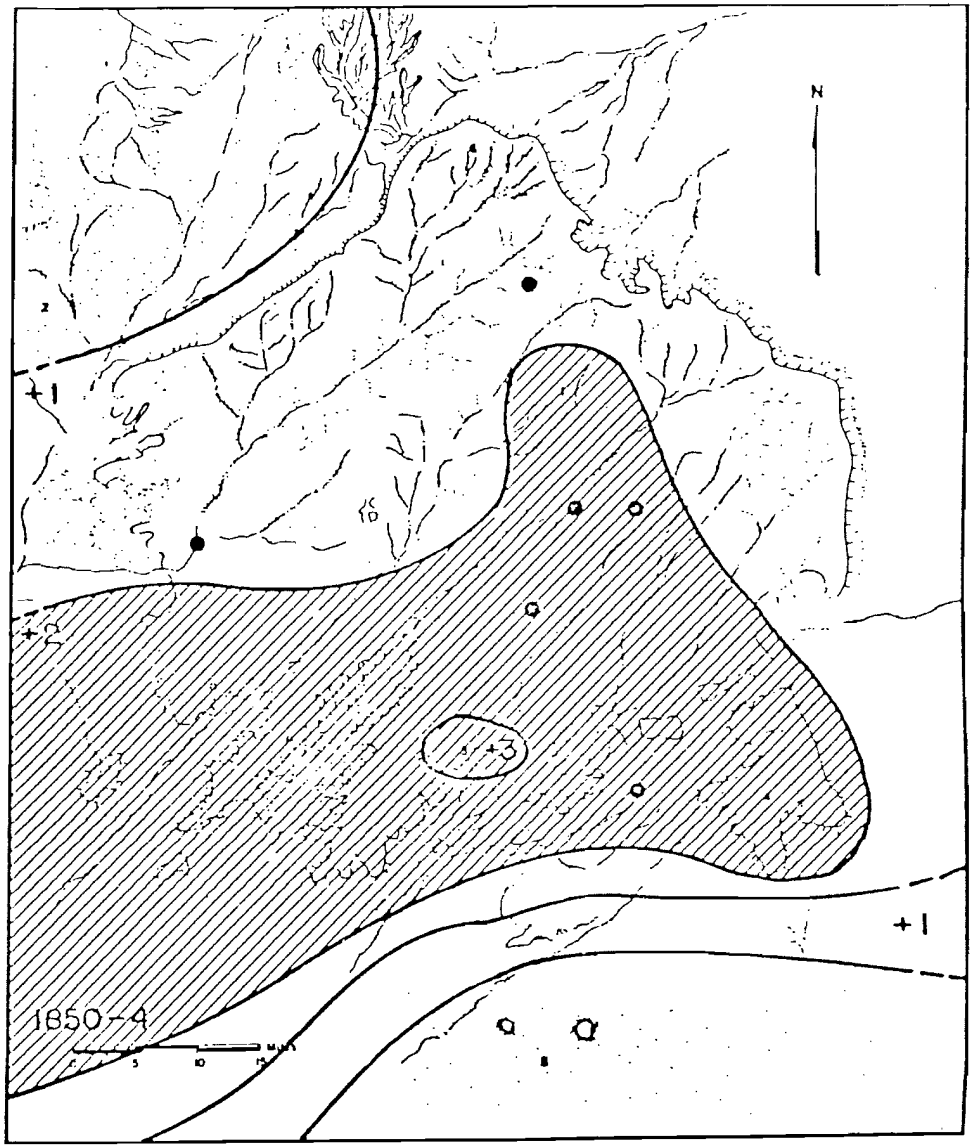

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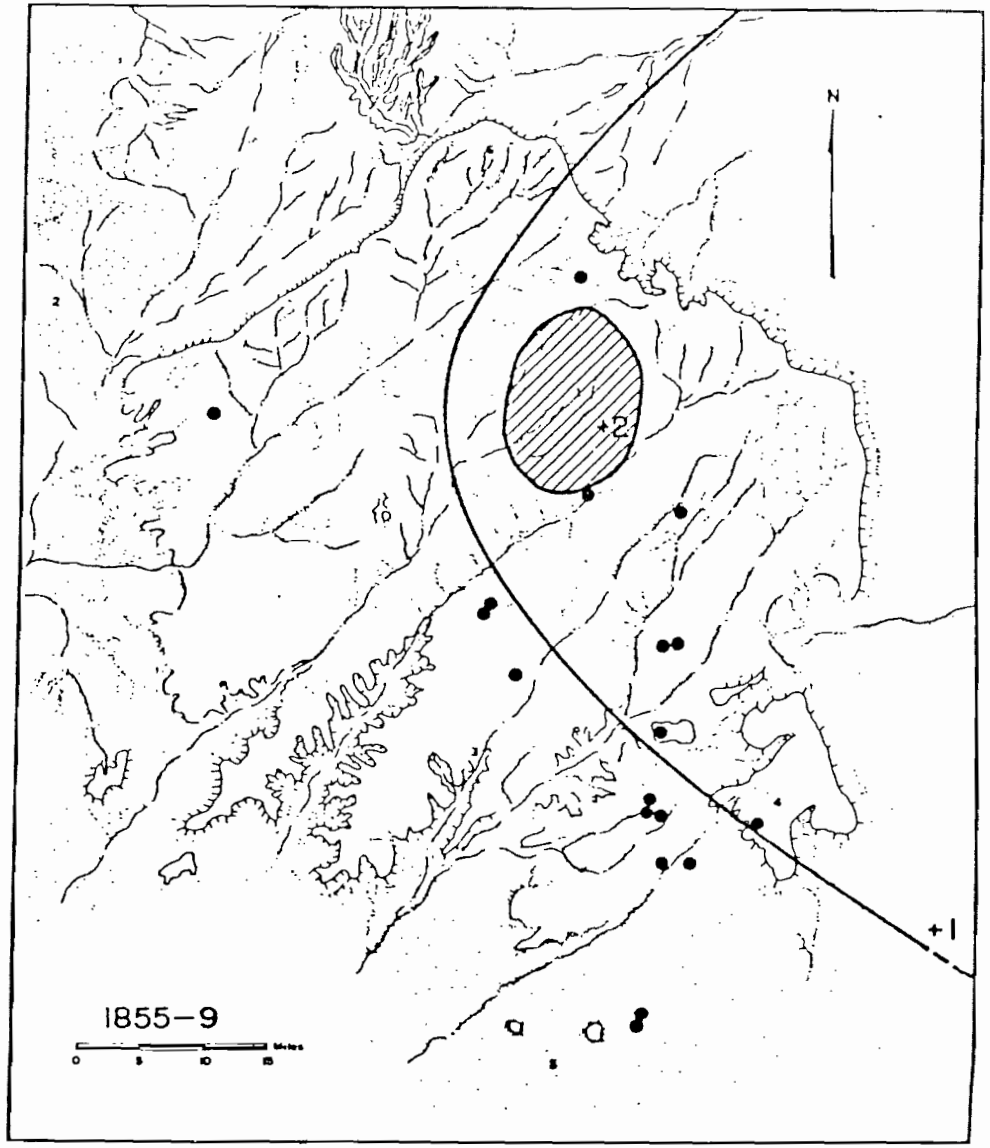

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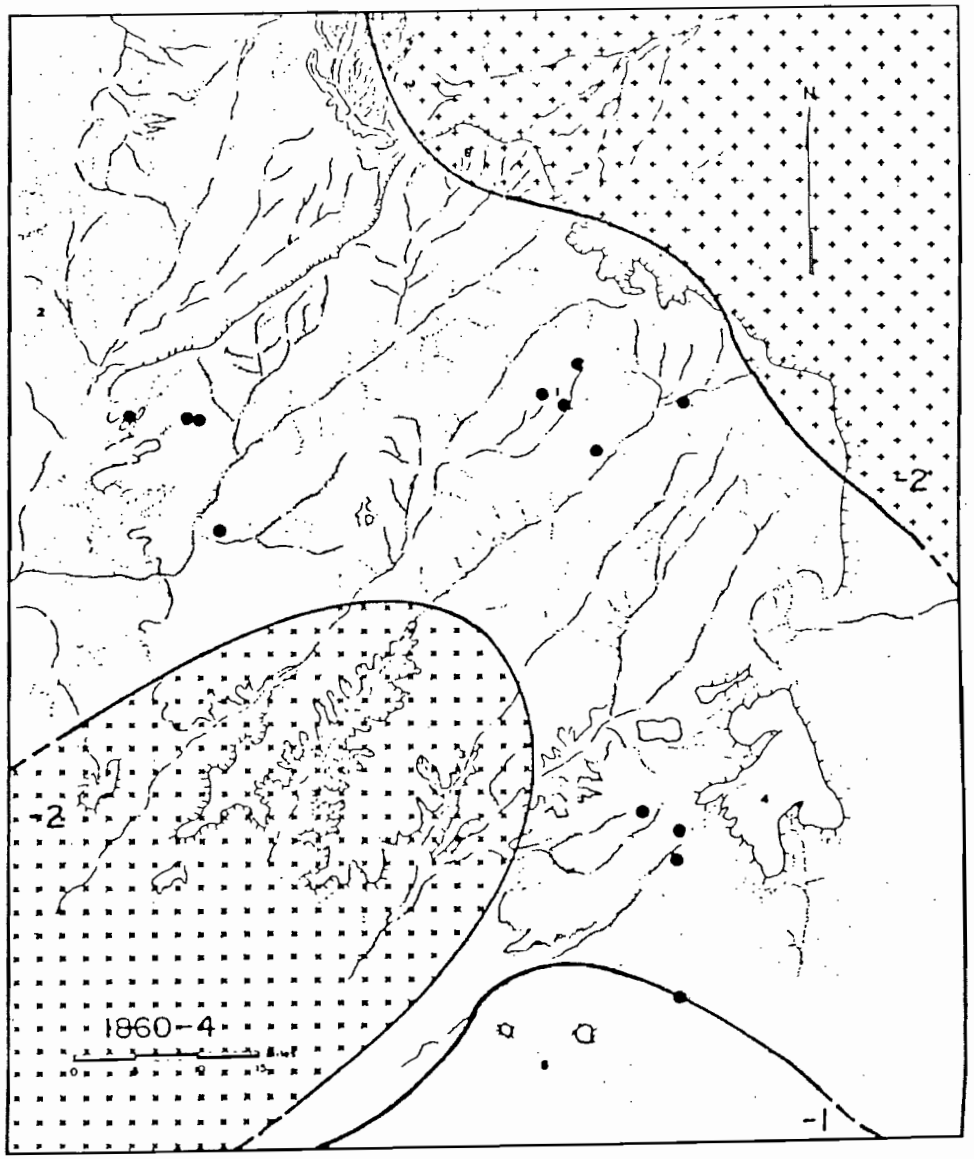

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Dendroclimatic Interval, 1865-1869.

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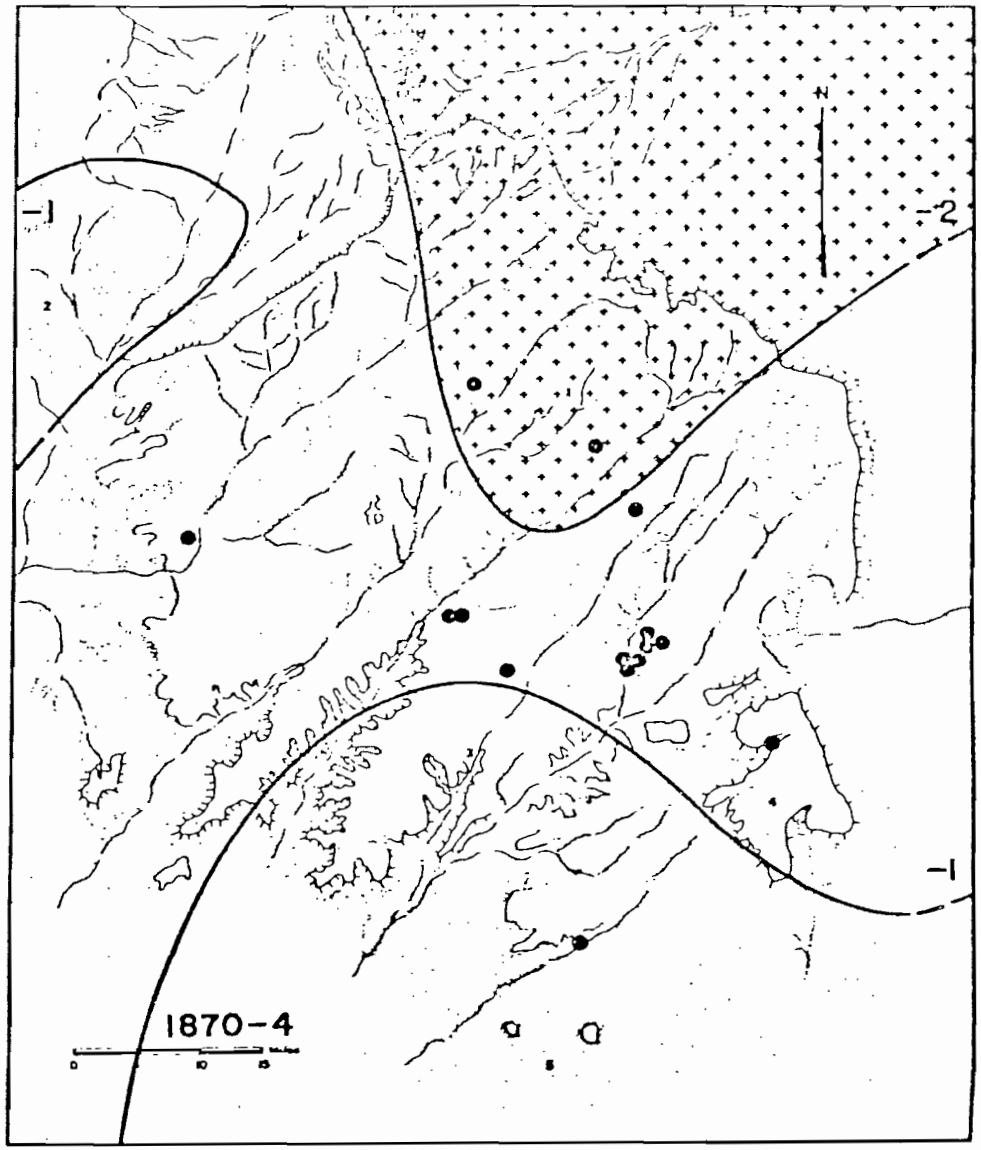

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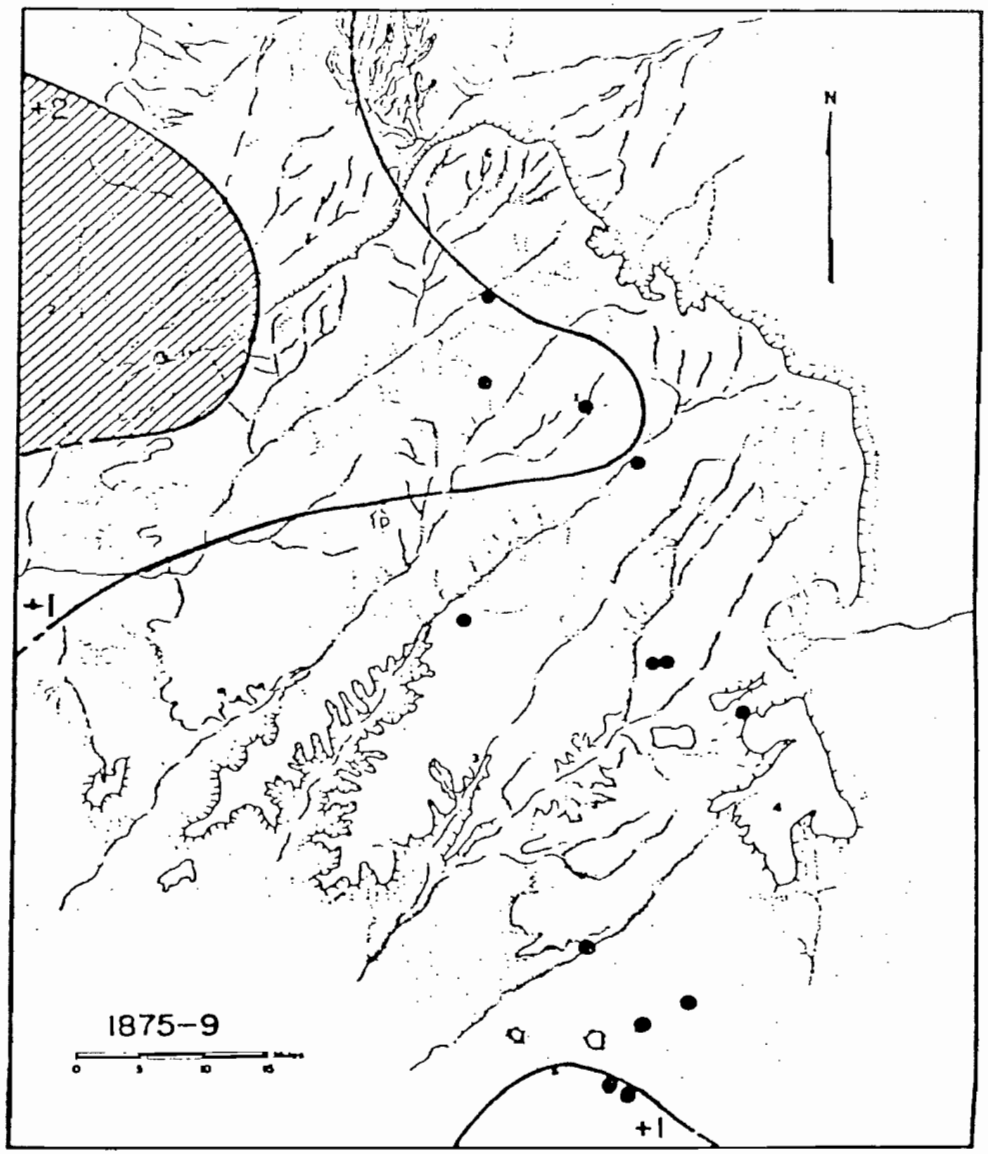

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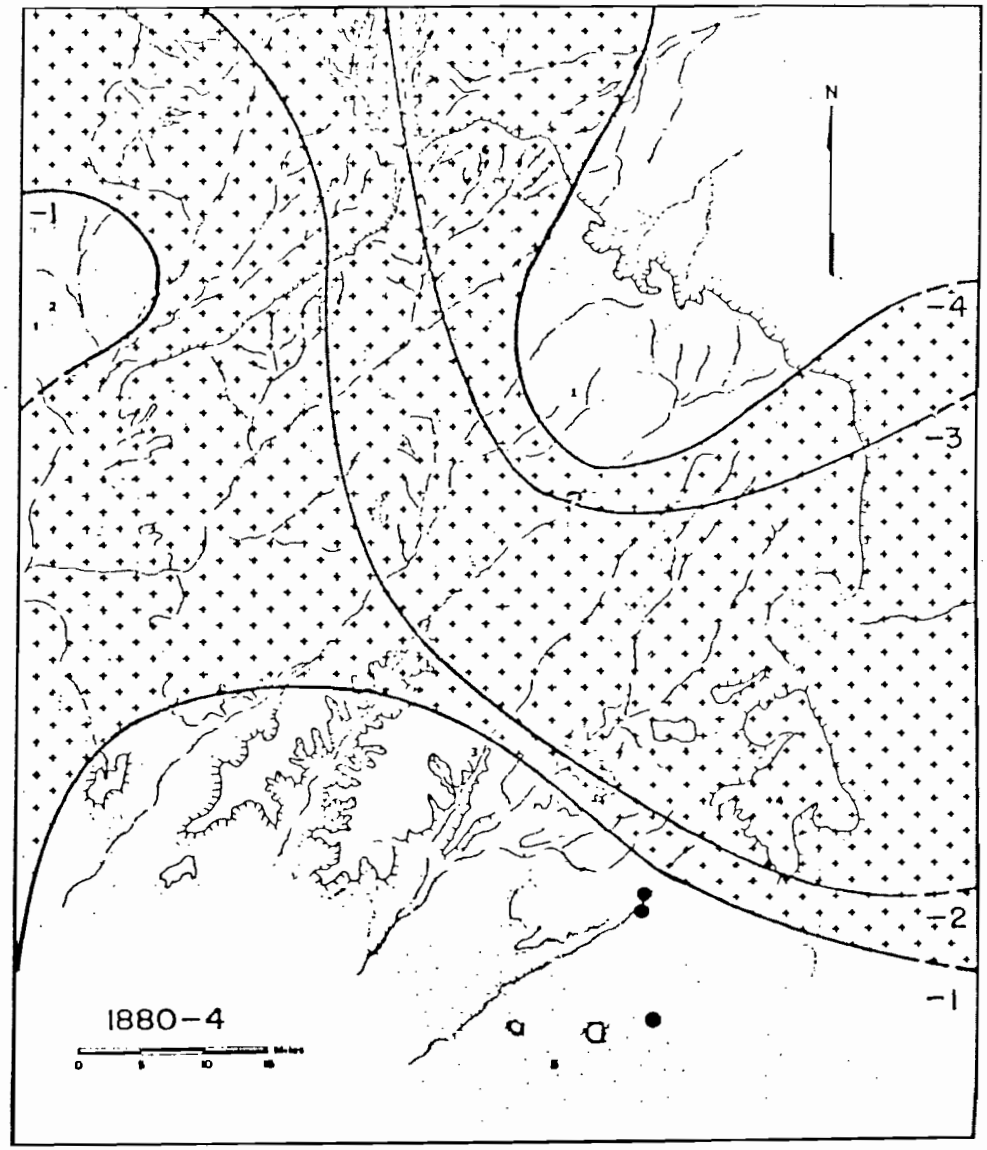

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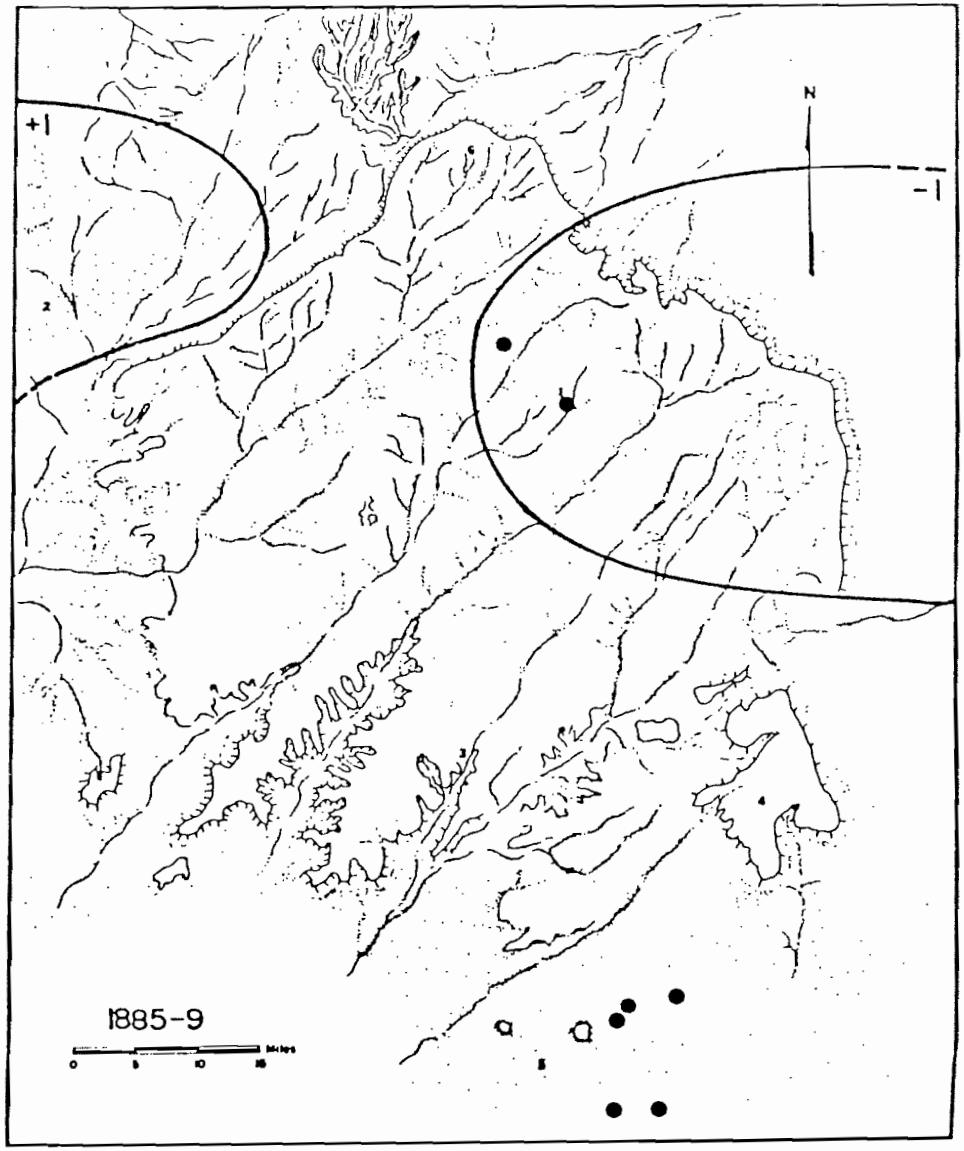

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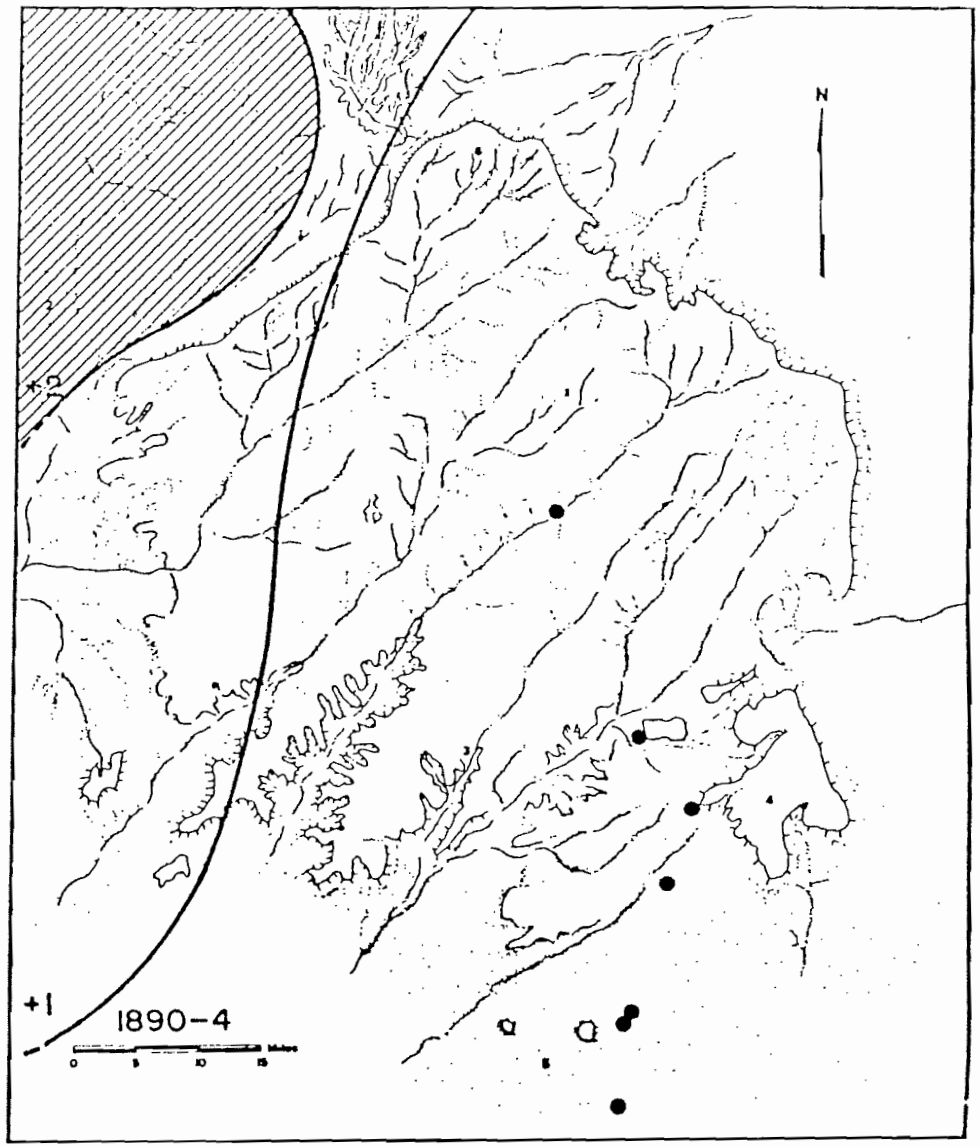

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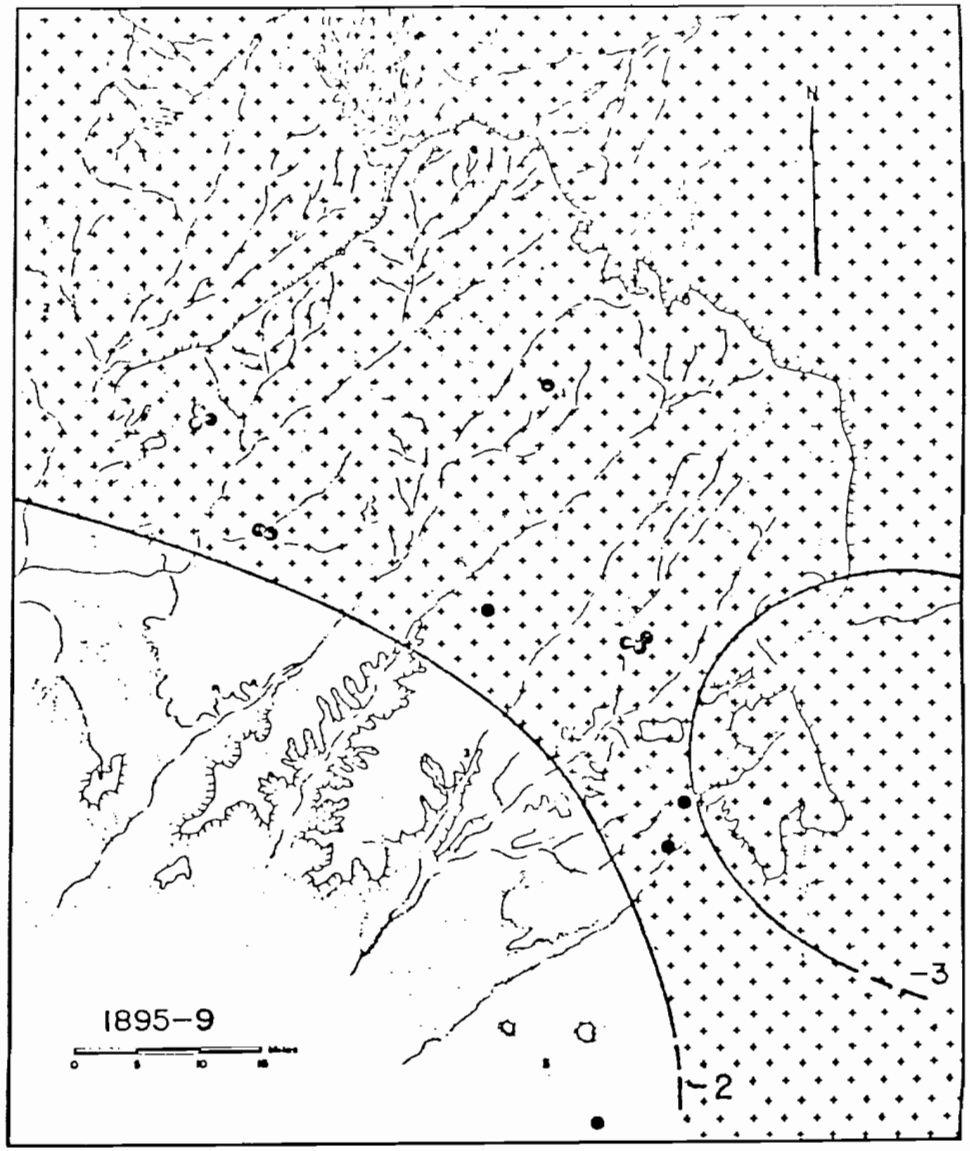

Dendroclimatic Interval, 1895-1899.

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