The Morris Site 1 Early Navajo Land Use Study:

Gobernador Phase Community Development in Northwestern New Mexico

Volume 2

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Table of Contents

Table of Contents v

List of Figures ix

List of Tables xiii

CHAPTER 7: EARLY NAVAJO LITHIC TECHNOLOGY OF DINÉTAH 191

Introduction 191
Methods and Procedures 191
Lithic Data Collection 191
Lithic Analysis 192
Phase 1: In-field Analysis and Survey Collections—Lithic Data Summary 194
Chipped Stone Artifacts 194
Phase 2: Excavations of LA 11196 and LA 88766—Lithic Data Summary 212
LA 11196 Lithic Data Summary 212
LA 88766 Lithic Data Summary 217
Phase 3: Focused Data Recovery—Lithic Data Summary 218
Chipped Stone Artifacts 219
Battered Tools 219
Milling Implements 219
Ground Tools 219
Interpretation and Summary 220
Lithic Data Synthesis 221
Intersite Variability 221
Lithic Landscape Management 221
Early Navajo Reductive Technologies 226
Early Navajo Productive Technologies 227
Summary 231

CHAPTER 8: POTTERY OF THE MORRIS SITE 1 EARLY NAVAJO LAND USE STUDY 233

Introduction 233
Phase 1 Results: On-site Analysis and Collections Analysis 235
Phase 2 Results: Excavations at LA 11196 and LA 88766 236
LA 11196 236
LA 88766 257
Phase 3 Results: Midden Testing 258
The Data Set 259
Characteristics of the Assemblages 259
Vessel Counts and Midden Size Estimates 262
Summary 265
Consideration of the Research Questions 266
Association of Pottery by Site Type 266
Ceramic Diversity and Site Type 268
Pottery Assemblages on Habitation Sites 272
Pottery and Feature Function 275
Glaze Ware in the Morris Site 1 Project Area 280
The Origin and Characteristics of Gobernador Polychrome 285
Gobernador Polychrome in Early Navajo Households and Society 289
Summary and Concluding Remarks 291

NN029340

CHAPTER 9: VERTEBRATE FAUNAL REMAINS 297
Research Orientation 298
Effective Ecology 299
Faunal Analysis Perspectives 300
Analysis Procedure and Terminology 301
LA 11196 Results 302
Interpretive Summary 303
LA 79456 Results 303
Interpretive Summary 304
LA 83529 Results 304
Interpretive Summary 305
LA 105428 Results 305
LA 105530 Results 305
Interpretive Summary 306
LA 105630 Results 306
LA 105930 Results 307
Interpretive Summary 307
LA 106199 Results 307
Interpretive Summary 308
LA 106203 Results 308
Interpretive Summary 309
Species Descriptions and Ethnohistoric Data 310
Order Artiodactyla (Even-Toed Mammals) 310
Family Cervidae (Elk, Moose, Caribou, Deer) 310
Family Bovidae (Cattle, Sheep, Goats, Old World Antelope) 311
Order Perissodactyla (Odd/Even-Toed Mammals), Family Equidae 313
Order Lagomorpha (Rabbits, Hares, and Pikas) Family Leporidae (Rabbits and Hares) 313
Order Rodentia (Mice, Squirrels, and Allies) 314
Suborder Myomorpha, Family Cricetidae (Deer Mice, White-Footed Mice, Woodrats, and Allies), Subfamily Cricetinae (Cricetine Mice and Rats) 314
Class Reptilia 315
Order Squamata, Suborder Sauria (Lizards), Family Iguanidae 315
Interpretations and Conclusions 315

CHAPTER 10: FLORAL COMPONENTS OF EARLY NAVAJO LAND USE: THE MORRIS SITE 1 COMMUNITY 319
Introduction 319
Methods 319
Results 320
LA 11196 320
LA 88766 320
Discussion: Early Navajo Plant Use In The Four Corners Area 320
Summary 321

CHAPTER 11: POLLEN ANALYSIS OF NAVAJO PERIOD SAMPLES FROM THE MORRIS SITE 1 PROJECT 325
Introduction 325
Methods and Materials 325
Palynological Extractions 325

NN029341

Results 327
LA 88766 327
LA 11196 328
Discussion 330
Conclusions 333

CHAPTER 12: DENDROCHRONOLOGY IN THE MORRIS SITE 1 PROJECT AREA .. 335

Introduction 335
Research Domains 335
Tree-Ring Dating Theory and Interpretation 341
Formation Processes of Tree-Ring Dates 342
Heartwood/Sapwood Issues 342
The Approach Used Here 344
Methods 345
Field Sampling Procedures 345
Identifying Dateable Samples 345
Distinguishing Axe Marks 345
Laboratory Sample Analysis 346
Dendrochronological Results 346
Cumulative Date Distributions 346
Individual Site Analysis 349
Wood Use 353
Methodological Considerations 354
Discussion 355
Conclusions 356

CHAPTER 13: THERMOLUMINESCENCE DATING OF EARLY NAVAJO CERAMICS 357

Field Collection Methods 357
The TL Technique 357
Derivation of TL Dates 358
Procedures 358
Results 359
Ages 363
Discussion and Conclusions 363

CHAPTER 14: TREE RINGS AND THERMOLUMINESCENCE: CHRONOLOGY AND DATING ISSUES OF THE EARLY NAVAJO OCCUPATION 373

The Problem 373
Tree Ring Dates 375
Thermoluminescence Dates 376
Tree-Ring and TL Correlation 380
Direct Comparison 381
Aggregate Comparison 385
Thermoluminescence and Archaeological Dating 385
TL and Radiocarbon 385
TL and Ceramics 387
Conclusions 388

NN029342

CHAPTER 15: EARLY NAVAJO SETTLEMENT AND LAND USE 391
Time and Population, a Control for Settlement Analysis 391
Modeling Population 391
Settlement Pattern 398
Patterning in Site Distribution 401
Residential Patterning 406
Summary and Conclusions 414
Land Use 415
Landform and Settlement 415
Settlement Pattern and Resources 421
Summary and Conclusions 426

CHAPTER 16: THE EARLY NAVAJO COMMUNITY 427
Elements of Community in the Morris Site 1 Project 427
Economic Organization 427
Sociopolitical Organization 433
Religious Organization 441
Pueblito in the Community Context 443
Pueblito Architecture 443
Types of Pueblitos 443
Discussion 446
Frances Mesa Community: A Socioeconomic Perspective 447
Conclusions 450
Navajo Community, an Enduring Tradition 452

REFERENCES CITED: VOLUME 2 455

Appendix G: Lithic Assemblage Data

Appendix H: Obsidian Sourcing Analysis

Appendix I: Ceramic Analysis Methods

Appendix J: Ceramic Assemblage Data

Appendix K: LA 11196 Vessel Descriptions

Appendix L: Puebloan Glazeware Ceramics

Appendix M: Gobernador Polychrome Designs

Appendix N: Trade Ware Pottery Designs

Appendix O: LA 11196 Flotation Results, LA 88766 Flotation Results, Wood Species Composition, Macrobotanical Materials

Appendix P: Pollen Data, Principal Components Analysis, Simpson's Diversity Index

Appendix Q: Explanation of Symbols Used for Reporting Tree-ring Dates

Appendix R: Pueblito Data

NN029343

CHAPTER 12: DENDROCHRONOLOGY IN THE MORRIS SITE 1 PROJECT AREA

by Ronald H. Towner

Introduction

Tree-ring dating, or dendrochronology, is the most precise dating method available to archaeologists in the Southwest. Tree-ring dates are precise to the year, and sometimes season, and because they are the result of a biological activity (tree growth), they are independent of cultural or archaeological activities. There are several conditions that must be met, however, before tree-ring dating can be applied to an archaeological problem. First, the cultural group under investigation must have used wood to build structures, fashion artifacts, or as fuel for warmth and cooking. Second, the wood used must be from datable species; in the Southwest, such species include piñon pine (*Pinus edulis*), ponderosa pine (*Pinus ponderosa*), juniper (*Juniperus* spp.) and Douglas fir (*Pseudotsuga menziesii*). Third, the wood must be preserved in the archaeological record, either as wood or charcoal, and finally, archaeologists must collect and dendrochronologists analyze the samples in order for the resulting dates to be useful. Fortunately, all of these criteria have been met by the Morris Site 1 project.

A total of 119 dendrochronological samples was collected from archaeological sites and isolated manifestations in the Morris Site 1 project area (Table 81). These samples are derived from both architectural and nonarchitectural contexts. Most samples relate to the early Navajo occupation, but a few pertain to the early Hispanic and Anglo use of the project area. Architectural contexts include pueblitos, forked-stick hogans, and sweat lodges. These contexts are clearly the result of past human behavior and, based on ethnographic and other data, are demonstrably Navajo in origin. Nonarchitectural samples are derived from metal-axe-cut stumps and limbs, culturally modified trees, and burned stumps around known archaeological sites. The dates from such samples are undoubtedly precise and accurate, but identifying them as cultural features, and specifically as Navajo-produced features, requires several "hedging" arguments (Dean 1978). The model presented below suggests that sample provenience, species, harvesting technique, and axe-mark width may be useful in identifying Navajo modified wood resources in the study area and elsewhere. These samples, in combination with other data, provide absolute temporal control for the past human behaviors that produced the archaeological evidence of the human occupation of the area. The tree-ring data furnish much more than chronological information, however. If interpreted properly, these data can help delineate the human occupation of the area, illuminate various aspects of early Navajo wood use behavior, and aid in building a model for interpreting chronological information from other early Navajo sites.

Research Domains

There are three different research domains that are addressed in this chapter: chronology, wood exploitation, and methodological concerns. Each research domain consists of a set of interrelated research questions that, when combined, can aid in interpreting the archaeology and past human behavior in the project area.

The chronological information contained in the tree-ring samples may be examined in several different ways. This domain, like the others, is most relevant to aspects of the Navajo occupation. The first question in this research domain is: "When did the Navajo first enter the project area?" One way to address this question, but not necessarily the use of individual sites, is to examine the temporal distribution of tree harvesting activities. Tree-ring dates can yield a distribution that is indicative of the beginning, end, and modes of the occupation of an area; cutting, or "tree-death," dates in particular are amenable to this type of analysis. Another way to examine the initial occupation of the area is to document the tree-ring dates from individual sites. This approach yields more specific information, but is sometimes limited by poor quality dates, lack of date clusters, or small sample sizes. Finally, specific behaviors associated with single sites, or areas around sites, are examined to identify spatial patterns that may have temporal significance.

The methods, techniques, and selection processes associated with the early Navajo occupation of the area are addressed in the wood exploitation research domain. Specific topics include delineating tree species selection preferences, documenting wood harvesting and modification methods, and identifying different tools used in the procurement and modification of wood for use by the occupants of the area. The dendrochronological data provide information pertinent to all these questions, and

NN029344

Table 81. Tree-ring Dates from the Morris Site 1 Project Area

Site (LA#)	LTRR[1] (ID#)	Sample Provenience	Species[2]	Inner Date	Inner Symbol[3]	Outer Date	Outer Symbol[3]	Sapwood Rings	Sapwood/Sample Comment
11196	DNT-976	Axe-cut stump	JUN	1565		1698	vv	22	diffuse; very eroded; many missing
11196	DNT-973		JUN	NO DATE				Present	
11196	DNT-978		JUN	NO DATE				Absent	short erratic
11196	DNT-977		PNN	NO DATE				Absent	short erratic
11196	DNT-974		JUN	NO DATE				Absent	
11196	DNT-971		PNN	NO DATE				Absent	short
11196	DNT-972		JUN	NO DATE				Present	
11196	DNT-975		JUN	NO DATE				Present	short
55836	DNT-817	Log in rubble	PNN	1645		1722	vv	NA	
55836	DNT-815	Log in rubble	PNN	1646	p	1722	vv	NA	
55836	DNT-821	Log in rubble	PNN	1672		1723	vv	NA	
55836	DNT-816	Log in rubble	PNN	1603		1685	+vv	NA	
55836	DNT-822	Log in rubble	PNN	1586		1695	vv	NA	
55836	DNT-818	Log in rubble	JUN	1509		1695	++vv		too diffuse to analyze
55836	DNT-814	Log in rubble	PNN	1523		1673	vv	NA	
55836	DNT-819	Log in rubble	PNN	1628		1716	vv	NA	
55836	DNT-820	Log in rubble	PNN	1655		1718	vv	NA	
79452	DNT-953		PNN	NO DATE				Absent	
79456	DNT-970		JUN	NO DATE				Present	short
79456	DNT-967		JUN	NO DATE				Present	
79456	DNT-968		JUN	NO DATE				Absent	
79456	DNT-969		JUN	NO DATE				Absent	
83529	DNT-802	Loose log	PNN	1661		1741	vv	NA	
83529	GOV-49	Loose log	JUN	1482		1661	vv		too diffuse to analyze
83529	DNT-801	Loose log	PNN	1782		1901	++vv	NA	
83529	GOV-53	Sweat lodge loose log	JUN	1150	p	1332	+vv	0	all heartwood
83529	GOV-52	Loose log	JUN	1594	p	1748	+GB		
83529	GOV-51	Loose log	JUN	1420	p	1726	+vv		too diffuse to analyze

[1] LTRR = Laboratory of Tree-ring Research; DNT samples collected by the Morris Site 1 Project, GOV samples collected and reported by Brown (1993); IM = Isolated Manifestation

[2] PNN = Piñon, JUN = Juniper

[3] Symbols explained in Appendix Q.

NN029345

Table 81. —Continued

Site (LA#)	LTRR[1] (ID#)	Sample Provenience	Species[2]	Inner Date	Inner Symbol[3]	Outer Date	Outer Symbol[3]	Sapwood Rings	Sapwood/Sample Comment
83529	DNT-805	Axe-cut stump	PNN	1634	p	1748	+G	NA	
83529	GOV-54	Sweat lodge loose log	JUN	1442		1652	+vv	0	all heartwood
83529	DNT-803	Loose log	JUN	1461	+/-	1747	vv		too diffuse to analyze
83529	GOV-50	Loose log	JUN	1549		1687	+vv		too diffuse to analyze
83529	DNT-804	Axe-cut stump	JUN	NO DATE					
83529	GOV-55	Sweat lodge loose log	JUN	NO DATE					
88766	DNT-954		JUN	NO DATE				Absent	
88766	DNT-955		JUN	NO DATE				Absent	short
105425	DNT-951	Axe-cut stump	JUN	1491		1701	vv	75	distinct; wavy; slight erosion; few missing (<10?)
105428	DNT-948	Axe-cut stump	PNN	1607		1728	vv	NA	very eroded; many missing
105475	DNT-950		JUN	NO DATE				Absent	short
105479	DNT-834	Sweat lodge leaner	JUN	1667		1730	vv		too diffuse to analyze
105479	DNT-831	Sweat lodge fork	JUN	1514		1683	vv	67	distinct; wavy; some erosion; some missing
105479	DNT-836	Axe-cut stump	JUN	NO DATE				Present	
105479	DNT-835	Sweat lodge fork	JUN	NO DATE				Absent	
105479	DNT-832	Sweat lodge fork	JUN	1533	+/-	1679	+vv	86	distinct; uneven erosion; many missing
105479	DNT-833	Sweat lodge fork	JUN	1564		1682	vv	88	questionable sapwood; uneven erosion; many missing
105481	DNT-846	Hogan leaner	JUN	NO DATE				Absent	short
105481	DNT-843	Hogan leaner	JUN	NO DATE				Absent	short
105481	DNT-844	Sweat lodge leaner	JUN	1513	+/-p	1654	++vv	0	all heartwood; uneven erosion; many missing
105481	DNT-848	Hogan leaner	LOST						LOST (Mtn. Mahogany)
105481	DNT-845	Sweat lodge leaner	JUN	1539		1604	vv	0	all heartwood; uneven erosion; many missing
105481	DNT-847	Sweat lodge leaner	PNN	1585		1712	vv	NA	uneven erosion; many missing
105483	DNT-842	Axe-cut limb	JUN	1574		1721	++vv	0	core broken; some missing
105483	DNT-839	Axe-cut limb	JUN	1565		1740	vv	70	wavy; distinct; some erosion; <10 missing
105483	DNT-840	Axe-cut limb	JUN	1360	+/-	1629	v-inc	79	single-ring erosion; cutting
105483	DNT-841	Axe-cut stump	JUN	1528		1738	vv	96	distinct; even erosion; <5 missing
105484	DNT-906	Axe-cut stump	PNN	1767	p	1840	vv	NA	eroded; lichen; many missing

NN029346

Table 81. —Continued

Site (LA#)	LTRR[1] (ID#)	Sample Provenience	Species[2]	Inner Date	Inner Symbol[3]	Outer Date	Outer Symbol[3]	Sapwood Rings	Sapwood/Sample Comment
105529	DNT-952	Storage cist lintel	PNN	1386	p	1566	vv	NA	very eroded; many missing; tight; 30/cm; deadwood?
105530	DNT-826	Hogan leaner	JUN	1572		1689	vv	0	uneven erosion; many missing
105530	DNT-825	Loose log	JUN	1465	+/-	1719	++vv	0	indistinct sw; even erosion; few missing
105530	DNT-828	Axe-cut stump	JUN	1581		1714	vv	35	distinct; even erosion; few missing (<10?)
105530	DNT-827	Hogan leaner	JUN	NO DATE				Absent	short
105530	DNT-829	Axe-cut limb	JUN	NO DATE				Present	
105624	DNT-937		PNN	NO DATE				Absent	tight
105627	DNT-851	Stump	JUN	1526		1663	+vv		too diffuse to analyze; eroded; many missing
105627	DNT-850	Stump	JUN	NO DATE				Absent	
105627	DNT-849 (a, b)	Stump	JUN	1564		1731	vv		too diffuse to analyze; even erosion; some missing
105629	DNT-907	Axe-cut stump	JUN	1422		1679	+vv	40	distinct; wavy; very eroded; many missing
105630	DNT-823	Axe-cut limb	JUN	1688	p	1900	++v inc	55	distinct; wavy; big axe marks; slightly eroded; few missing
105630	DNT-824	Axe-cut limb	PNN	1718	p	1915	rB inc	NA	no erosion; cutting
105630	DNT-958		JUN	NO DATE				Present	short erratic
105630	DNT-957		JUN	NO DATE				Present	
105630	DNT-956	Axe-cut stump	JUN	1503		1644	vv	34	diffuse; very eroded; many missing
105925	DNT-908	Axe-cut stump	JUN	1436	+/-p	1695	v inc	45	indistinct, uniform; single ring erosion; cutting
105929	DNT-909	Axe-cut stump	JUN	1565		1695	rB inc	43	variable; distinct; wavy; no erosion; cutting
105930	DNT-949	Axe-cut stump	JUN	1509		1666	++vv	2	very diffuse; very eroded; many missing
105930	DNT-910	Axe-cut stump	JUN	1572		1695	vv	37	variable; indistinct; single ring erosion?; prob. cutting
105931	DNT-912		PNN	NO DATE					root
105931	DNT-911		JUN	NO DATE					
105945	DNT-913	Axe-cut stump	JUN	1660		1889	++B inc	52	distinct; wavy; tight; ring ct. past 1870; noncutting

NN029347

105945	DNT-913	Axe-cut stump	JUN	1660		1889	++B inc	52	distinct; wavy; tight; ring ct. past 1870; noncutting

Site (LA#)	LTRR (ID#)	Sample Provenience	Species[2]	Inner Date	Inner Symbol[3]	Outer Date	Outer Symbol[3]	Sapwood Rings	Sapwood/Sample Comment
106105	DNT-914		JUN	NO DATE				Present	erratic growth
106105	DNT-915	Axe-cut stump	JUN	1605		1807	vv	9	distinct; wavy; very eroded; many missing
106106	DNT-916	Axe-cut stump	JUN	1553		1883	++vv	23	distinct; wavy; little erosion; ring ct. past 1876; <10 missing?
106106	DNT-917	Axe-cut stump	PNN	1832		1927	rB comp	NA	bark; sharp axe marks; cutting
106168	DNT-919		JUN	NO DATE				Present	erratic
106168	DNT-918		JUN	NO DATE				Absent	tight
106199	DNT-965	Axe-cut limb	JUN	1610		1731	+vv	53	very distinct; even; some erosion; 10+ missing?
106199	DNT-963	Axe-cut limb	JUN	1656		1747	vv	62	diffuse; no erosion; rings cut off; <10 missing:
106199	DNT-964	Axe-cut limb	JUN	1555	+/-p	1750	B inc	70	distinct; uniform; cutting
106203	DNT-947	Axe-cut limb	JUN	NO DATE				Absent	short
109388	DNT-939		JUN	NO DATE				Absent	tight erratic
109388	DNT-938		JUN	NO DATE				Absent	tight erratic
109623	DNT-942		JUN	NO DATE				Present	short
109624	DNT-944		JUN	NO DATE				Present	erratic
109624	DNT-943		JUN	NO DATE				Present	short
110264	DNT-936		JUN	NO DATE				Present	short erratic
110267	DNT-959		JUN	NO DATE				Present	short erratic
110267	DNT-960		JUN	NO DATE				Present	many missing
110267	DNT-961		JUN	NO DATE				Present	short
110267	DNT-962		JUN	NO DATE				Present	short
110273	DNT-946	Axe-cut limb	JUN	1422	+/-p	1622	vv	68	very distinct; eroded; some missing
110273	DNT-945	Axe-cut limb	JUN	NO DATE				Present	tight erratic
106203	DNT-947	Axe-cut limb	JUN	NO DATE				Absent	short
110278	DNT-934	Axe-cut stump	JUN	1538	+/-	1699	+vv	65	indistinct; very eroded; many missing
110280	DNT-940	Axe-cut stump	JUN	1606		1727	+vv	64	diffuse; minimal erosion; <10 missing?
110284	DNT-941	Axe-cut stump	JUN	1473		1641	vv	41	top of core missing (cut); many missing
110970	DNT-966		JUN	NO DATE				Absent	short

NN029348

Table 81. —Continued

Site (LA#)	LTRR[1] (ID#)	Sample Provenience	Species[2]	Inner Date	Inner Symbol[3]	Outer Date	Outer Symbol[3]	Sapwood Rings	Sapwood/Sample Comment
114509	DNT-935		PNN	NO DATE					short
IM-1000	DNT-932		JUN	1517		1608	vv	0	very eroded; many missing
IM-1001	DNT-933		JUN	1564		1654	+vv	0	all heartwood; many missing
IM-12	DNT-838	Axe-cut limb	JUN	1268	+/-	1664	+vv	46	diffuse; very eroded; many missing
IM-12	DNT-837	Axe-cut limb	JUN	1432		1629	B inc	38	diffuse; protected area
IM-18	DNT-830	Axe-cut stump	JUN	1485		1605	vv	0	very eroded; many missing
IM-5	DNT-810	Leaning pole	JUN	NO DATE				Present	short
IM-5	DNT-809	Leaning pole	JUN	NO DATE				Present	short
IM-5	DNT-806	Leaning pole	JUN	NO DATE				Present	short
IM-5	DNT-811	Leaning pole	JUN	NO DATE				Present	short
IM-5	DNT-812	Leaning pole	JUN	NO DATE				Present	short
IM-5	DNT-813	Axe-cut stump	JUN	NO DATE				Present	short
IM-5	DNT-807	Axe-cut stump	JUN	NO DATE				Present	short
IM-5	DNT-808	Leaning pole	JUN	NO DATE				Present	short
IM-78	DNT-905	Axe-cut stump	JUN	1532		1859	++vv	28	eroded; distinct; uniform; tight; many missing

NN029349

provide information about possible changes in wood use through time.

The third research domain involves examining the methodologies of tree-ring sampling and analysis for early Navajo archaeological sites. Although wood from architectural contexts, such as forked-stick hogans and sweat lodges, was collected, many of the samples were taken from nonarchitectural contexts. Sampling parts of the "arboreal" archaeological record, such as burned or axe-cut stumps, limbs, etc., has become an important aspect of investigating the early Navajo occupation of the Dinétah (Towner et al. 1998). The model developed below will aid in refining the techniques for future research.

Tree-Ring Dating Theory and Interpretation

The tree-ring dates are interpreted using the principles outlined by Bannister (1962), Dean (1978), and Ahlstrom (1985). Although tree-ring dates are accurate and precise to the year, and possibly season, they still must be assessed in their archaeological contexts in order to identify anomalous dates (Graves 1982), define tree procurement and architectural construction events (Dean and Warren 1983; Lightfoot 1992), identify various behaviors associated with wood use (Dean 1996), and estimate occupation duration and abandonment times (Ahlstrom 1985; Hantman 1983). It is important to remember, however, that even samples that failed to date can provide important environmental and behavioral information.

The tree-ring dates are grouped into three classes: cutting (or tree death), near-cutting, and noncutting dates. Cutting dates (symbols B, G, L, r, v) indicate that the last ring on the sample was the last year of tree growth (Robinson et al. 1974). These symbols, alone or in combination, indicate a "true outside" and, in the absence of contrary evidence, denote the year a tree died. An associational argument, or bridging event (Dean 1978) must be made to infer that the tree died as a result of human activity. For many of the Morris Site 1 project samples, metal axe marks on nonarchitectural samples clearly indicate humans as the agency of tree (or branch) death. Near-cutting dates (symbols +B, +G, +L, +r, +v) indicate that although the sample has a "true outside," one to three rings may be locally absent from the last five years on the sample and the ring series does not extend far enough past the possibly absent ring to verify its absence. Thus, a "+" date may specify the year of tree death, or that the tree died one to three years after the date given. Like cutting dates, a bridging argument must be made to infer that near-cutting dates represent tree cutting activities. Noncutting dates (symbols vv and ++) do not signify the year of tree death. The symbol "vv" dates indicate that an unknown number of rings may have been removed from the outside of the sample; such rings may have been removed by natural factors such as erosion or human actions such as shaping or debarking of beams. Thus, tree death probably occurred some unknown length of time after the vv date. The "vv" symbol, however, only indicates that the sample contained no evidence of a true outside visible to the analyst; in some cases, an argument can be made based on field observations of the entire tree surface, that a "vv" date is close to a cutting date. Finally, "++" dates indicate that the ring series cannot be dated beyond a certain point from which the rings are simply counted rather than cross dated. These "++" dates, even if combined with indicators of true outsides, such as bark, are not cross-dated death dates, but ring counts beyond a certain year on the sample and, as such, may seriously underestimate the year of tree death.

Identifying tree procurement episodes is accomplished by distinguishing trees that were cut while living from those that were harvested as deadwood. Live-cut trees should yield cutting dates, if other factors do not remove outside rings; all dates from samples with true outsides, however, do not necessarily indicate live tree harvesting. Ahlstrom (1985:56-57, 614-617) suggests that, in general, deadwood samples produce "++" dates, although this is not always the case. Individual and multiple beam analyses can illuminate aspects of general tree harvesting trends (multiple beams), as well as information pertinent to specific events (individual beams).

Architectural construction episodes are defined as a cluster of cutting dates in the same architectural space; Towner (1992:64) defined the number of dates and type of space necessary to identify a cluster for pueblito sites differently, depending on the level of provenience information available. During this project, a strong cluster is defined as three or more cutting dates in the same year from the same architectural space; a weak cluster may contain fewer dates, include noncutting dates, or be only weakly associated with architectural space.

Documenting various wood use behaviors depends on identifying terminal ring characteristics (procurement seasonality), species (tree selection), tool marks (tree or beam modification), and anomalous dates (beam stockpiling and reuse, and structure repair and remodeling). Such behaviors may also be identified, in part, by the archaeological context of the wooden elements. Terminal ring characteristics are indicated by the symbols "inc," and "comp." Incomplete terminal rings (inc) may indicate tree death during the growing season if accompanied by cutting or near-cutting date symbols; if accompanied by noncutting

NN029350

date symbols, the condition of the outer ring is most likely a result of the removal of outer rings by human or natural agencies. Complete terminal rings (comp) indicate tree death after the end of the growing season and, in most cases, are accompanied by cutting or near-cutting date symbols.

Site occupation duration and abandonment are difficult to establish, even given the precise nature of tree-ring dates. Regarding site occupation span, Hantman (1983:143) espouses the formula of subtracting the date that provides the best evidence of initial construction from the latest date and adding a constant of 10 years. He does not recognize, however, the value of construction clusters and often uses anomalous dates to calculate occupation span. Hantman (1983:123) also suggests that "when beams are no longer recorded within a site over the course of several years, we can assume that the site was abandoned at or about the date of the latest tree-ring date recorded at the site." Ahlstrom (1985:653-659) points out the limitations of such a "cookbook" approach to interpreting tree-ring dates. He provides several examples indicating that "a gap in the middle of site's date distribution may indicate a period of abandonment" and should not be included in the computation of occupation spans. Regarding abandonment dates, Ahlstrom (1985:658-659) justifies the use of the latest date as an abandonment date only if (a) the date distribution is relatively continuous and ends abruptly, (b) the latest occupied areas of a site are included in the sample of dates, and (c) the "latest dates from several sites are mutually reinforcing." Only the last of these criteria was generally met by the tree-ring data from the Morris Site 1 project area.

Formation Processes of Tree-Ring Dates

As discussed earlier, there are several criteria that must be met before dendrochronology can be successfully used. Although the single most important factor is the behavior of a group towards wood as a resource (Dean 1996) (use of wood, species selection preferences, etc.), archaeological formation processes and dendrochronological sampling biases play important roles as well. Archaeological formation processes (Schiffer 1987) tend to remove outer rings from samples, and thus distort the sample dating toward an earlier time frame (Smiley and Ahlstrom 1998). Navajo architectural units in particular often collapse, and when the wooden elements contact the ground surface they are subject to physical, chemical, and biological decay. Standing structures, although not immune to such forces, are much less affected by these processes. In a similar fashion, nonarchitectural "arboreal" cultural features (axe-cut limbs, stumps, etc.) are typically located above the ground surface and suffer much less exterior ring loss. An exception to the chemical and biological agents mentioned above occurs when wood is converted to charcoal. As an inert substance, charcoal is not subject to chemical decay or biological destruction by insects or fungi. Recently, Seseman and Hovezak (1999) have identified different abandonment modes of Navajo hogans, one of which is intentional burning. The dendrochronological preservation inherent in burned structures indicates the necessity of excavating, or at least judicially sampling, burned hogans in order to recover precise and accurate chronological data.

Dendrochronological sampling bias may also play an important role in successfully dating a site or feature. For example, in the 1950s the Navajo Land Claims (NLC) project collected only piñon, ponderosa, and Douglas fir specimens under the assumption that juniper would not produce dates. Thus, any analysis based only on NLC data may be seriously compromised. The sampling criteria that guided the Morris Site 1 project are described in more detail below, but an important criterion was avoiding short-lived ring-porous species, such as cottonwood (*Populus* spp.) and willow (*Salix* spp.) that do not produce dates because they contain too few rings and exhibit little ring-width variability. It should be noted, however, that a sample (since lost) from a forked-stick hogan at LA 105481 was identified in the field as mountain mahogany (*Cercocarpus montanus*). It is currently the only tentatively identified Cercocarpus sample from a Dinétah Navajo hogan, and contributes to the list of species exploited by the early Navajo.

Heartwood/Sapwood Issues

Noncutting dates from samples that lack the last ring grown by a tree can, in some cases, be augmented by additional analysis. Several species, including Douglas fir, piñon pine, ponderosa pine, juniper, and oak (*Quercus* spp.) exhibit distinctive visual differences between heartwood and sapwood rings. Although the only living nonleaf or needle section of a tree is the cambial tissue (the outermost ring), in some species several, or many, rings are still used to transfer fluids from the roots to the crown of the tree. Such rings still exhibit thin-walled, open-lumined cells that are relatively light in color. At a certain age, however, cell walls and openings become lignified, and these rings acquire a distinctive dark color. These cells can no longer translocate fluids, and serve only as structural support to keep the tree upright where it can conduct photosynthesis. The heartwood/sapwood boundary, however, can provide some chronological as well as biological information.

Several attempts have been made to quantify the number of sapwood rings on various species, and such a technique has been successfully used for many years in Europe where oak is the dominant tree species used in

dendrochronology (Bailey 1995). Douglass (1939) initially suggested that ponderosa pine and Douglass fir contained 50 sapwood rings, but later realized that was an oversimplification. Plog (1980) and Graves (1991) both attempted to estimate cutting dates, but their results were only minimally successful. Nash (1997) has developed a regression technique for estimating the number of sapwood rings that should have been present on a sample that yielded a noncutting date based on a known number of heartwood rings for Douglas fir and ponderosa pine samples. Using randomly selected tree-ring samples and Walpi pueblo as a case study, Nash is able to provide statistical estimates of cutting dates by examining Douglas fir and ponderosa pine samples with identified pith dates and heartwood/sapwood boundaries. For Douglas fir samples, Nash (1997:264) uses the formula:

$$y = 3.2(x^{.5}) + 8.4$$

where x is the known number of heartwood rings and y is the predicted number of sapwood rings. In his experiments, this approach explained 85 percent of the variability in the number of sapwood rings. For ponderosa pine samples, Nash's (1997:265) equation is:

$$y = 7.0(x^{.5}) + 36.9$$

By adding the estimated number of sapwood rings to the known number (and dated) heartwood rings, Nash was able to estimate cutting dates for 141 samples at Walpi. Such estimates are the only valid tree-ring dates that are associated with confidence intervals—an important consideration in the analysis of tree-ring dates collected earlier in this century from Navajo sites (cf., Hall 1951).

Unfortunately, such a straightforward statistical approach is not possible with the Morris Site 1 project samples because of the tree species used. Piñon pine (*Pinus edulis*) most often does not form a visually distinguishable heartwood. The cells of the interior rings rarely become lignified, and therefore the entire cross section of a piñon typically appears similar in color from the pith to the outside ring (Figure 148). Juniper (*Juniperus* spp.), on the other hand, presents somewhat of the opposite problem. Although the cells on the interior of junipers become heavily lignified, the heartwood/sapwood boundary is typically very wavy and/or indistinct (see Figure 148). Thus, one area of a sample may contain, for example, 25 sapwood rings and 250 heartwood rings, but another area on the sample may contain 150 sapwood rings and 125 heartwood rings. Any statistical calculations based on the heartwood/sapwood ratio, therefore, may have unacceptably large margins of error. Any estimate of the number of sapwood rings originally

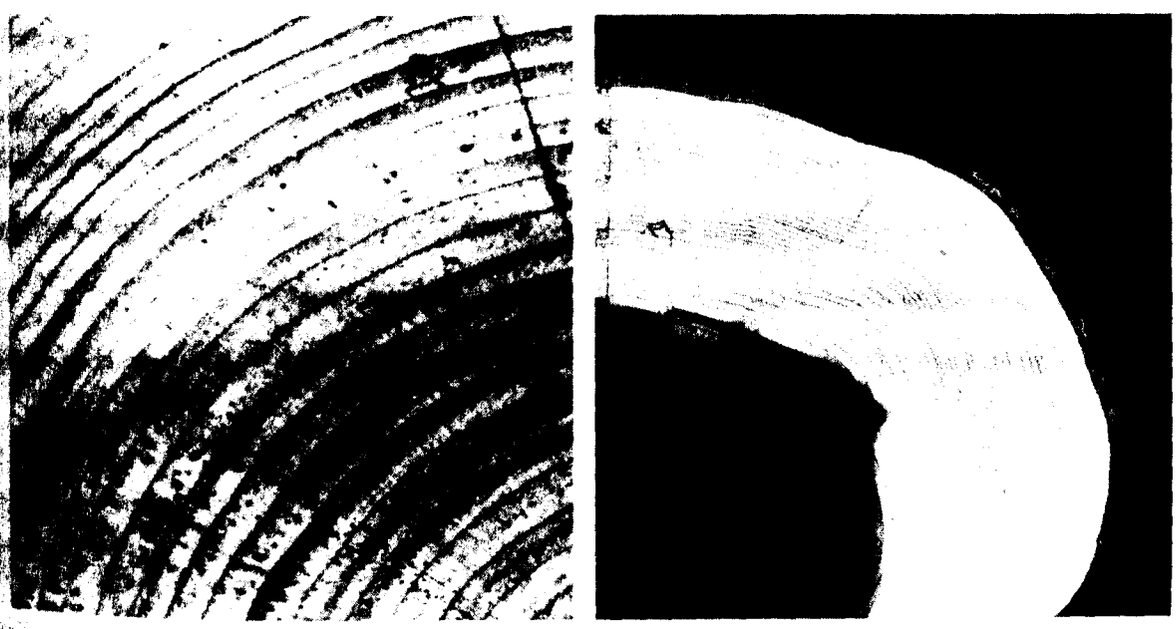

Figure 148. Cross sections of piñon and juniper trees.

NN029352

present on a sample is subject to an error factor (Nash 1997), and such an error factor would be particularly acute for core samples that yield information on only one small part of a tree (Figure 149). The most important point to remember, however, is that any sapwood estimate can only add rings (years) to noncutting dates. For example, a noncutting date of 1600vv can only be younger (post-A.D. 1600) by estimating an additional number of sapwood rings.

The Approach Used Here

As a test of Nash's calculations applied to the Morris Site 1 project collection, I examined the five juniper samples that yielded cutting dates and which had definable heartwood/sapwood boundaries: DNT-840 (1360+/- - 1629v inc), DNT-837 (1432-1629B inc), DNT-908 (1436+/-p - 1695v inc), DNT-909 (1565-1695rB inc), and DNT-964 (1555+/-p - 1750B inc). As can be seen in Table 82, Nash's formulas applied to juniper samples yield results that vary tremendously. In some cases the Douglas fir equation underestimates the true cutting date, but in all cases the ponderosa equation overestimates the actual date, sometimes by as many as 94 years. Using both equations sometimes brackets the true date, but the degree of resolution is extremely coarse and probably not very useful. Additional research may be successful in developing a formula for use with juniper, but many more high quality samples are needed for such an effort. Indeed, Nash (personal communication, 1999) attempted to develop such an equation, but was hampered by problems similar to those encountered here.

Because of the potential problems associated with estimating the number of sapwood rings on juniper samples, and the impossibility of doing so with piñon samples, the approach used for the Morris Site 1 project samples is relatively simple. Using the five juniper samples that yielded cutting dates and have definable heartwood/sapwood boundaries, a minimum (N = 38), maximum (N = 96), and mean number of sapwood rings was calculated. These data were then applied to most juniper samples that yielded noncutting dates. For example, using the maximum formula, 96 years were added to a sample that lacked sapwood, but only 46 years were added to a sample that exhibited 50 sapwood rings. Although this cookbook approach is certainly subject to widely varying estimates and significant error, it is based on the collection of samples from a specific area and time period, factors that may mitigate some of the intrinsic problems of the method.

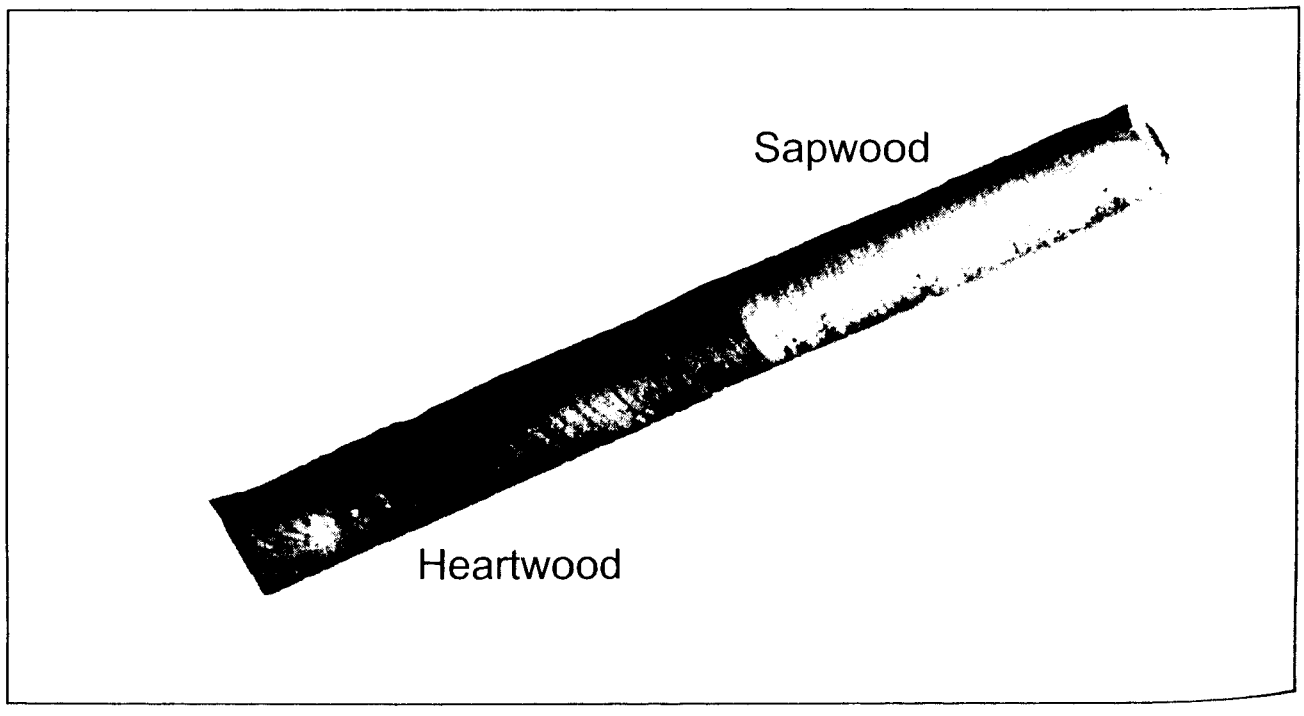

Figure 149. Core sample from a juniper beam.

NN029353

Table 82. Evaluation of Heartwood/Sapwood Estimates Using Juniper Specimens

Sample Number	Outside Date	Douglas Fir Estimate	Ponderosa Estimate	Evaluation
DNT-837	1629B inc	1640	1716	Overestimates
DNT-840	1629v inc	1602	1683	Brackets
DNT-908	1695v inc	1705	1789	Overestimates
DNT-909	1695rB inc	1638	1702	Brackets
DNT-964	1750B inc	1724	1795	Brackets

Methods

Field Sampling Procedures

Two methods were used to collect the tree-ring samples in the field. Architectural samples were collected using a specialized drill and bit similar to an elongated hole saw (Figure 150). The resulting cores (see Figure 149) contain a faithful record of the ring sequence, but as noted above, they provide only a limited view of the heartwood/sapwood boundary and other interior beam attributes. Some nonarchitectural samples were collected as cores, but most were procured as cross sections using a handsaw. Cross sections have the advantage of retaining all the ring attributes of a beam, but cannot be used to collect architectural samples without seriously damaging a structure.

Figure 150. Drilling a tree-ring core in the "hallway" of Romine Canyon ruin.

Identifying Dateable Samples

The most important criterion in the selection of samples to collect was whether or not the dendrochronologist believed a potential sample would yield a high quality (cutting or near-cutting) date. The archaeological crews had already identified the sites with possible samples. The dendrochronological crews then examined the architectural wood and culturally modified trees for their dating potential. Although no one can accurately determine in the field if a sample will yield a date, there are attributes that can improve the percentage of samples that provide cutting and near-cutting dates. First and foremost, a sample must be of a dateable species. In the Morris Site 1 project area, piñon (*Pinus edulis*) and juniper (*Juniperus* spp.) are the most common datable species and can be readily identified in nonarchitectural and architectural contexts. Second, we wanted samples with "true outsides;" in other words, samples that had not suffered significant exterior ring loss due to erosion or other natural or cultural factors. Unfortunately, the nature of early Navajo architecture, particularly forked-stick hogans, is such that most wooden elements collapse and lose their exterior rings to erosion and weathering. Thus, nonarchitectural wood (Figure 151) has assumed added significance in early Navajo archaeology. Still, it is often difficult to distinguish true outsides in the field, as is apparent from the number of cutting and noncutting dates obtained during the project.

Distinguishing Axe Marks

As nonarchitectural samples assume greater importance in the study of early historic and protohistoric period sites, it is becoming increasingly important to identify differences between modern and earlier wood procurement methods. Simply put, archaeologists cannot collect nor dendrochronologists analyze every axe-cut timber in the forest. Distinguishing between various types of mechanical and hand-operated saws is relatively simple and largely irrelevant to most

NN029354

research questions. Likewise, characteristics used to distinguish between stone- and metal-axe-cut beams have been known for decades (Robinson 1967). Identifying the attributes of beams cut by different types of metal axes, such as early Spanish, early American, and modern American styles is more difficult however. The width of the axe blade, and the resulting marks on samples, should provide clues to the period of tree harvesting. Spanish axes in particular were relatively narrow and are often distinguishable from later axe types. No quantitative data are yet available, but the study of a correlation between axe width and tree-ring dates may be a fruitful avenue for future research. The Laboratory of Tree-Ring Research has used several qualitative approaches, including axe-scar width, cutting angle, and degree of weathering to separate historic from recent procurement episodes, but as is apparent in the date distributions below, such criteria are not always reliable.

Laboratory Sample Analysis

All samples were prepared and analyzed at the Laboratory of Tree-Ring Research at the University of Arizona in Tucson. Sample preparation included sanding the sample surface with increasingly finer grit sandpaper until all ring characteristics and cells are visible under the microscope at 10-30x power. The analyst next provides four important pieces of data: tree species, inner and outer date (if possible), heartwood/sapwood boundary (if identifiable), and terminal ring condition. Every tree species, and some sub-species, exhibit specific ring characteristics that allow the analyst to unambiguously determine tree species (or at least genus). By skeleton plotting a sample (Stokes and Smiley 1968) against a local master chronology, the analyst is able to account for locally absent or missing and false rings, and assign a date to every ring on the sample. If the plotted ring sequence does not agree with the master chronology, which is based on scores or hundreds of other samples, no date can be assigned to any ring; "probable" or "tentative" matches that do not meet the cross-dating criteria are not assigned dates.

Dendrochronological Results

The 119 samples collected as part of the project yielded 65 dates, a 54.6 percent dating ratio. Of the 65 dates, however, only 9 (13.8 percent) are cutting or near-cutting dates. This low proportion of cutting dates is a direct result of the poor preservation of wood in open-air sites, and reinforces the need for excavation of well-preserved charcoal samples.

Cumulative Date Distributions

The distribution of tree-ring dates is presented in Figure 152 as a stem-and-leaf diagram (Ahlstrom 1985). The three-digit column on the left shows the decades, and the column on the right displays the year in that decade for each dated sample. For example, the decade of the A.D. 1650s is represented by the 165, and samples dated in A.D. 1652 and A.D. 1654 are represented by the "2" and "4," respectively. Asterisks in the left-hand column indicate a break in the decadal sequence. Distinct advantages of the stem-and-leaf method of displaying tree-ring dates are the ability to illustrate individual dates, and to distinguish between cutting and noncutting dates; the former are denoted by an underline below the individual year.

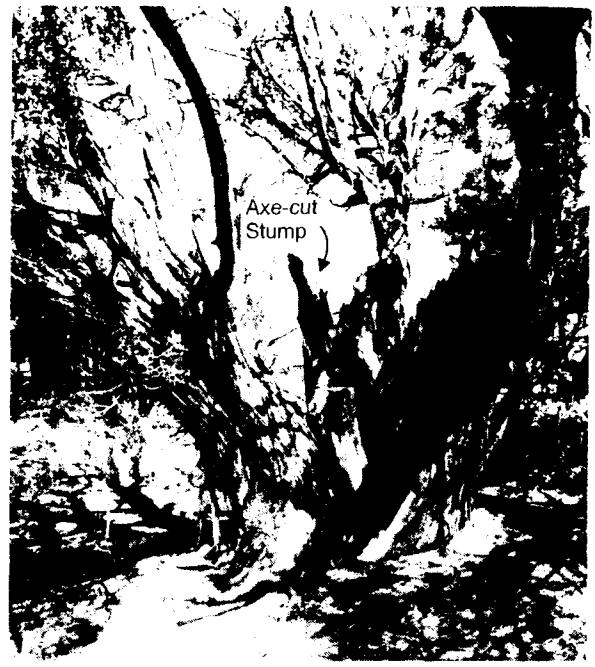

Figure 151. An axe-cut stump suitable for tree-ring sampling.

The temporal distribution of dates (see Figure 152) provides important information about the Navajo occupation, as well as subsequent use of the area. The two A.D. 1629 cutting dates indicate some tree harvesting in the early seventeenth century, and support other dates that clearly indicate a Navajo occupation of the general area in the early A.D. 1600s (Sesler and Hovezak 1996). The six noncutting dates prior to A.D. 1629 do not indicate that the area was unoccupied, but cannot be used to argue for an earlier occupation; it is possible that the dates in the first decade of the A.D. 1600s indicate a separate occupation, but such an inference is somewhat speculative. Because of preservation problems and sampling criteria, these earlier noncutting dates probably indicate the use of deadwood (the A.D. 1332 date) and exterior ring loss due to erosion. The two A.D. 1629 cutting dates, on the other hand, may signify the initial importing of metal axes into the Navajo country from the Rio Grande.

NN029355

```
133  2
***  *
156  6
***  *
160 458
***  *
162  299
***  *
164  14
165  244
166  1346
167  399
168  23579
169  5555589
170  1
171  24689
172  1223678
173  0118
174  017788
175  0
***  *
180  7
***  *
184  0
185  9
***  *
188  39
***  *
190  01
191  5
192  7
```

Figure 152. Stem-and-leaf diagram of all original tree-ring dates collected from Morris Site 1 project sites.

Although there is a break in the distribution after A.D. 1629, the number of dates increases throughout the A.D. 1600s until there is a precipitous drop after A.D. 1695. Although none of the pre-A.D. 1695 dates are cutting dates and undoubtedly postdate the dated year of the sample, the distribution suggests increasing activities in the area throughout the latter half of the seventeenth century. Distinct occupation episodes cannot be identified, but the loose clustering of dates suggests a low but consistent level of tree harvesting. The two A.D. 1695 cutting dates, supported by three A.D. 1695 noncutting dates, signify tree-harvesting activities near the end of the century shortly after the Spanish reconquest of New Mexico, and signify an occupational episode (or more than one). The paucity of dates between A.D. 1695 and A.D. 1710 (N = 3, all noncutting) mirrors the gap noted by Towner (1996, 1997) and calls into question the purported massive influx of refugees following the reconquest. Interestingly, some of the only cutting dates between A.D. 1695 and A.D. 1710 from Navajo sites were collected from Three Corn ruin (LA 1871) in San Rafael Canyon just south of the Morris Site 1 project area (Towner and Johnson 1998). Although far from conclusive, those data may suggest occasional movement between the two areas, possibly for economic or social reasons.

The distribution indicates a resumption of tree cutting in the A.D. 1710s that lasted until at least A.D. 1731. Fifteen samples date to this period, and although none are cutting dates, the shape of the plot suggests relatively continuous use of the Morris Site 1 area for at least two decades. The spatial distribution of these samples is discussed below, but it is clear that the area saw an intensive use during these decades. Such a date distribution is more or less consistent with dates from a number of the surrounding areas (Towner 1997).

The next group of dates that indicates occupation of the area begins in A.D. 1738 and ends with a cutting date of A.D. 1750; this group includes eight dates, three of which are cutting or near-cutting dates. It is unknown if the Morris Site 1 area was abandoned between A.D. 1731 and A.D. 1738, but again it is interesting to note that Three Corn ruin witnessed substantial construction in the early to mid-A.D. 1730s and was abandoned shortly after A.D. 1737 (Towner 1997; Towner and Johnson 1998). The end of the Navajo occupation probably occurred shortly after A.D. 1750, and almost certainly prior to A.D. 1760. This inference is based on the fact that dated samples occur in every decade from the A.D. 1640s to the A.D. 1750s, but none occur after A.D. 1750 until an A.D. 1807 noncutting date at LA 106105. It is also consistent with data from other projects concerning the Navajo occupation of Dinétah (Sesler and Hovezak 1999; Towner 1997; Towner and Johnson 1998).

The early to mid-A.D. 1800s dates (N = 3) are all noncutting dates that do not cluster; thus, they contribute little information except that they postdate the Navajo occupation. The 1859++vv date may suggest a minimal use of the area during the Carson campaign (A.D. 1863-1864) or Bosque Redondo incarceration (A.D. 1864-1868), but is far from conclusive. Towner and Johnson (1998), however, have identified tree-cutting activities during these time periods in San Rafael Canyon. The two A.D. 1880s and single 1901 noncutting date suggest activities of Hispanic immigrants to the area in the late A.D. 1800s. The 1915 cutting date may indicate similar activities, or may actually document Earl Morris' archaeological efforts at the Morris Site 1 pueblito. The 1927 cutting date probably represents Hispanic herding or wood collecting activities.

NN029356

The date distribution shown in Figure 153 includes the maximum sapwood estimates (N = 96 rings) presented in Table 81. Tree cutting dates are still noted by an underline, but some juniper dates were changed by the estimation of additional sapwood rings on noncutting dates. As can be seen, the shape of the distribution is somewhat trimodal. The two A.D. 1629 cutting dates indicate an early occupation, but appear much more aberrant. The bulk of the dates fall between A.D. 1685 and A.D. 1775, which is almost precisely the time span of the Gobernador phase as suggested by Brown (1996). Any suggestion of a Bosque Redondo period use of the area has been eliminated, and the late A.D. 1800s and early 1900s Hispanic occupation appears consistent, but infrequent. A 1956 date would suggest modern tree cutting.

The date distribution shown in Figure 154 includes the minimum sapwood estimates (N = 38 rings). The earliest occupation is clearly the A.D. 1629 cluster, but this approach suggests a significant use of the area in the A.D. 1640s as

```
142 8
*** *
156 6
*** *
162 99
*** *
164 0
*** *
166 13
167 3
168 579
169 0555556
170 0146
171 124689
172 222368
173 00118
174 137888
175 0009
176 2
177 145
178 1
*** *
181 57
*** *
184 0
*** *
188 9
189 4
190 01
191 5
192 77
*** *
195 6
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Figure 153. Stem-and-leaf diagram including maximum estimated dates (96 sapwood rings on all juniper samples) collected from Morris Site 1 project sites.

```
137 0
*** *
156 6
*** *
162 299
*** *
164 12368
*** *
166 134
167 399
168 2357
169 02555559
170 01
171 24678
172 2236778
173 0118
174 017788
175 079
*** *
183 6
184 0
*** *
186 9
*** *
188 9
189 8
190 01
191 5
192 7
```

Figure 154. Stem-and-leaf diagram including minimum estimated dates (38 sapwood rings on all juniper samples) collected from Morris Site 1 project sites.

NN029357

well. The bulk of the dates fall between the A.D. 1660s and A.D. 1750s, however, and conform to the traditional interpretations of the occupation of Dinétah. Like the original date distribution, this method shows occupation in the last half of the seventeenth century peaking in the A.D. 1690s, and a significant drop in activity during the first decade of the A.D. 1700s. After A.D. 1712, the intensity of tree modifying activities again increases and shows a relatively consistent distribution until the A.D. 1750s. Again there is a seven-year gap in the A.D. 1730s that could signal abandonment of the area, but may also be a function of small sample size. Any evidence of a Bosque Redondo period occupation is no longer apparent, and the late A.D. 1800s Hispanic use of the area appears infrequent.

Figure 155 is a stem-and-leaf diagram that includes the mean sapwood estimates (N = 74 rings). The A.D. 1629 occupation is clearly shown, but appears as something of an outlier, possibly indicating a discontinuous Navajo presence in the Morris Site 1 project area. The bulk of the distribution covers from the A.D. 1660s to the A.D. 1760s, and suggests that the Navajo occupation was limited to a 100-year time span. The two A.D. 1790s noncutting dates may indicate use by Navajos, Utes, or Comanches, but that inference is relatively speculative. Again, no evidence of a Bosque Redondo period occupation is shown, but the Hispanic occupation of the late A.D. 1800s and early 1900s appears somewhat more significant, especially in the first decade of the twentieth century.

These data demonstrate that there is some variability in the date distributions and sapwood estimates that may significantly alter our perceptions concerning the past occupations of the Morris Site 1 project area. Until more reliable and consistent juniper heartwood/sapwood estimates are developed, however, it is probably best to rely on the original, nonestimated dates. The original dates, although somewhat conservative in their temporal assignments, clearly indicate a Navajo use of the area in the late A.D. 1620s, again toward the end of the A.D. 1600s, a possible abandonment in the first decade of the A.D. 1700s, renewed use from the A.D. 1710s until about A.D. 1750 with a tentatively identified abandonment during the mid-A.D. 1730s, and Navajo abandonment of the area shortly after A.D. 1750. Hispanic exploitation of the area appears to have been minimal and limited to the late A.D. 1800s and early 1900s.

Individual Site Analysis

Some of the sites in the Morris Site 1 project area are amenable to a site-based tree-ring analysis, but many are not. In order to examine individual sites, each site must have yielded a large enough sample of dates to assess date clustering, cutting date distributions, etc. Unfortunately, 14 sites and a series of isolated timbers failed to yield any dates, and cannot be analyzed chronologically. Sites with few dates, particularly if they are noncutting dates, are much harder to assess in terms of their temporal occupation span. The analysis of these sites is based on the number of cutting dates, clusters of cutting and noncutting dates, and a qualitative microscopic assessment of the number of sapwood rings and condition of exterior rings on samples. Although interpretations are based on these criteria, inferences regarding sites and samples that produced only

```
140  7
***  *
156  6
***  *
162 999
***  *
166 13
167  3995
168  023557
169  1255555
170  19
171  2468
172  2236789
173  01889
174  157788
175  0134
176  4
***  *
179  46
***  *
184  0
***  *
187  3
188  9
190  016
191  5
192  7
```

Figure 155. Stem-and-leaf diagram including mean estimated dates (75 sapwood rings on all juniper samples) collected from Morris Site 1 project sites.

NN029358

noncutting dates should be considered tentative and somewhat speculative.

Morris Site 1 Pueblito (LA 83529)

Morris Site 1 is a four- or five-room masonry structure atop a boulder on a bench overlooking Romine Canyon. Carlson (1965:4-5) identified four rooms on top of the boulder, and Brown (1993:88), suggests that five rooms may have been present. Morris' map (Carlson 1965:4) indicates that the structure was built in a single construction episode. Although deterioration has obscured some of the details, Brown's (1993:89) map indicates that the structure may have been built in two distinct episodes. The wall alignments of Room 1 and 2 in particular suggest that Room 1 was added after Room 2 was complete.

Twelve tree-ring samples, 10 of which produced dates, have been collected from the site (see Table 81). Seven of the samples, five juniper beams and two piñon beams, were collected from loose logs probably associated with pueblito construction. Three juniper beams were collected by Brown (1993) from the sweat lodge. Three other samples, including two juniper and one piñon, were collected from metal-axe-cut stumps around the pueblito (Dykeman and Wharton 1996).

Although none of the samples produced a cutting date, three samples probably date the construction relatively well. A loose juniper log and an axe-cut juniper stump both date to at least A.D. 1748 and another stump was cut sometime after A.D. 1747; this weak cluster of dates suggests pueblito construction and wood harvesting sometime after A.D. 1748. There is a possibility, however, that these near-cutting dates actually represent tree harvesting in A.D. 1749. If the possible missing ring indicated by the "+" symbol is A.D. 1748, the last ring on the samples grew in A.D. 1749. The other noncutting dates provide no evidence contrary to this inference. Thus, the entire pueblito, whether built in one unit or multiple construction episodes shows no evidence of having existed prior to A.D. 1748, nor does it exhibit evidence of use after that year. The masonry structure may simply have been built rather quickly, used for temporary shelter or storage, and abandoned. Interestingly, the late A.D. 1740s were a time of intensive Ute raiding and warfare (Schroeder 1963), and a significant number of pueblitos were built during that time. Sample DNT-801, a loose piñon log, is interesting because the noncutting date of 1901++vv probably represents the use of deadwood and may actually date Earl Morris' activities around the site.

Romine Canyon Ruin (LA 55836)

Romine Canyon ruin is a six-room pueblito and a defensive wall across a narrow neck of land above Romine Canyon. The site is certainly part of an extensive community in Romine and San Rafael canyons (Towner and Johnson 1998; Dykeman and Wharton 1996). The pueblito was built around a small courtyard, probably in two or three construction events. Rooms 5 and 6 were certainly built at the same time, as were Rooms 3 and 4; however, it is impossible to determine whether all these rooms were built at the same time. Rooms 1 and 2 were built after the other rooms were complete.

Nine tree-ring samples, all of which dated, were collected from the site (see Table 81). One loose log on the floor of Room 5 was sampled; the remaining samples were collected from loose logs on the slope below the pueblito. Although none of the dates are cutting dates, a weak cluster of noncutting dates in the early A.D. 1720s suggests some construction at that time. Most of the samples (N = 8) are piñon, but the distribution is certainly a reflection of dendrochronological sampling bias. Five of the samples exhibit metal axe marks.

The weak cluster of dates indicates some construction activity in the early A.D. 1720s. Detailed analysis of each sample suggests that fewer than five rings have eroded from the exterior of the samples, and it is possible that only one or two rings have been removed. Thus, the site was probably built in a single year, but as two separate construction events; construction of the site probably in A.D. 1723 or shortly thereafter. It shows no evidence of ever having been repaired. Interestingly, the early A.D. 1720s were a time of declining activity at Three Corn ruin, but not necessarily throughout San Rafael Canyon (Towner and Johnson 1998).

LA 105479

Six samples were collected from this site, five from the sweat lodge structure, and one from a nearby metal-axe-cut stump. All samples are juniper, and four produced noncutting dates. Three of the samples (DNT-831, 832, and 833) yielded dates in the late A.D. 1670s or early A.D. 1680s, but all have suffered serious exterior ring loss due to erosion. The latest date from the site, 1730vv (DNT-834) exhibits much more consistent erosion, and probably has lost fewer than 10 rings from its exterior. It is possible that two occupations are represented, one in the A.D. 1690s and another in the mid-A.D. 1730s, but because sweat lodges were rarely repaired and deadwood was often used in their construction (Dean and Russell 1978), I suspect that all the samples represent a single occupation episode in the mid- to late A.D. 1730s.

LA 105483

Four samples were collected from this site, three from axe-cut limbs and one from an axe-cut stump. All the samples are juniper, and all yielded dates. The most significant sample, DNT-840, yielded a cutting date of 1629v inc, indicating that

this limb was cut sometime during the juniper growing season (May-October) of A.D. 1629. The other three samples (DNT-839, 841, 842) probably all postdate DNT-840 by more than a century. Sample DNT-842 is missing a portion of the top of the core, is a ring count past A.D. 1710, and probably dates 10-20 years later than the last ring on the sample; sample DNT-841 (1738vv) contains abundant sapwood rings, shows even erosion, and probably has lost only a few rings; sample DNT-839 (1740vv) exhibits many sapwood rings, relatively even erosion, and has probably lost few exterior rings. These three samples suggest a second occupation of the site in the early or mid-A.D. 1740s.

LA 106199

Three samples were collected from this site (DNT-963, 964, 965). All were procured from metal axe-cut limbs, all are juniper, and all yielded dates. Sample DNT-965 (1731+vv) retains some sapwood, shows some erosion, and has probably lost more than 10 exterior rings; sample DNT-963 (1747vv) retains sapwood, but the top of the core was damaged during sampling, and some rings are missing; sample DNT-964 yielded a cutting date of 1750B inc, indicating procurement during the juniper growing season (May-October) of A.D. 1750. The condition of all these cores suggests that all the limbs were cut at about the same time, probably in the summer or fall of A.D. 1750.

LA 105530

Five samples were collected from this site. Two (DNT-826, 827) are hogan leaners (Jett and Spencer 1981), one (DNT-825) is a loose log, one (DNT- 828) is an axe-cut stump, and one (DNT-829) is an axe-cut limb. All the samples are juniper, and three yielded noncutting dates. The only date from the hogan (1689vv) is from a sample that retains no sapwood, shows uneven erosion, and is probably missing many exterior rings. The dated stump sample (1714vv) retains some sapwood, displays relatively even erosion, and has probably lost fewer than 10 exterior rings. The heartwood/sapwood boundary on the dated sample from the loose log (1719++vv) is relatively indistinct; the sample exhibits relatively even erosion, is a ring count past A.D. 1650, and was probably procured as deadwood. These samples suggest a single site occupation sometime in the early or mid-A.D. 1720s, or possibly later.

LA 105481

Six samples were collected from this site, three yielded dates, and one was lost prior to analysis in Tucson. Field notes indicate, however, that the lost sample was probably mountain mahogany (*Cercocarpus mountanus*). Unfortunately, none of the samples from the hogan produced dates; all the dates relate to the construction or use of the sweat lodge. The two earliest samples, dated 1604vv and 1654++vv, both consist entirely of heartwood, and thus have lost many exterior rings. The sample dated 1712vv is piñon and does not exhibit a heartwood/sapwood boundary; it shows uneven erosion on its exterior surface, and has probably lost many exterior rings. This group of samples suggests that the sweat lodge, if not necessarily the hogan, was used at least after A.D. 1720, and possibly as late as the A.D. 1750s when the area was abandoned.

LA 105930

Only two samples were collected from this site, DNT-910 and DNT-949. Both samples are juniper, and both were collected from metal-axe-cut stumps. Sample DNT-949 (1666++vv) retains only two sapwood rings, appears very eroded, and has probably lost many exterior rings; sample DNT-910 retains 37 sapwood rings, shows minimal even erosion, and probably is a cutting or near-cutting date. These two samples were almost certainly procured at the same time, probably in A.D. 1695 or A.D. 1696.

LA 105627

Three samples were collected from this site (DNT-849, 850, 851). All are juniper, all were collected from stumps, and two yielded noncutting dates. The heartwood/sapwood boundary on sample DNT-851 (1663+vv) is too diffuse to analyze, but the sample appears unevenly eroded and is probably missing many exterior rings; likewise, the heartwood/sapwood boundary on sample DNT-849 (1731vv) is too diffuse to analyze, but the sample shows relatively even erosion and is probably not missing an inordinate number of exterior rings. These samples suggest a single occupation sometime in the late A.D. 1730s or A.D. 1740s.

LA 110273

Two samples were collected from LA 110273. Both are juniper, and were collected from axe-cut limbs. Sample DNT-946 is the only sample that dated, and it yielded a 1622vv noncutting date. The sample retains 68 sapwood rings and shows somewhat uneven erosion indicative of exterior ring loss. The relatively good condition of the sample leads me to believe that it may date as early as the A.D. 1660s, and almost certainly predates A.D. 1700. It is uncertain, however, how this single date actually relates to the occupation of the site.

LA 11196

Eight samples were collected from this site, but unfortunately, only one dated. Sample DNT-976 yielded a noncutting date of 1698vv. The sample retains 22 sapwood rings and is extremely eroded on the exterior. These factors suggest it postdates A.D. 1700 by at least a decade or two, and possibly by 40 to 50 years.

LA 105425

A single sample was collected from an axe-cut stump at this site. Sample DNT-951 is juniper, retains 75 sapwood rings.

NN029360

exhibits slight exterior erosion, and yielded a noncutting date of 1701vv. It is probable that this sample dates in the first or second decade of the eighteenth century.

LA 105428

A single sample was collected from an axe-cut stump at this site. Sample DNT-948 is piñon that does not show a heartwood/sapwood boundary, and which yielded a noncutting date of 1728vv. The sample appears very eroded and probably dates at least 20 years later than the last ring on the sample.

LA 110278

A single juniper sample from an axe-cut stump was collected from this site. Sample DNT-934 retains 65 sapwood rings, exhibits very uneven erosion, and yielded a noncutting date of 1699+vv. The condition of the sample indicates many exterior rings are missing, and it probably dates later than A.D. 1720.

LA 110280

A single juniper sample from an axe-cut stump was collected from this site. The sample (DNT-940) retains 64 sapwood rings, exhibits relatively even and probably minimal erosion, and yielded a noncutting date of 1727+vv. The condition of the sample suggests only a few exterior rings are missing, and it probably dates in the early A.D. 1730s.

LA 110284

A single juniper sample from an axe-cut stump was collected from this site. The sample (DNT-941) retains 41 sapwood rings, but the top of the core was destroyed during sampling; it yielded a noncutting date of 1641vv. The damage to the core undoubtedly removed many rings, but the sample may still indicate a pre-A.D. 1700 activity.

LA 105925

A single juniper sample from an axe-cut stump was collected from this site. The sample (DNT-908) yielded a 1695v inc cutting date, and indicates tree harvesting during the juniper growing season (May-October) of A.D. 1695.

LA 105929

A single juniper sample from an axe-cut stump was collected from this site. The sample (DNT-909) yielded a 1695rB inc cutting date, and indicates tree harvesting during the juniper growing season (May-October) of A.D. 1695.

LA 105945

A single juniper sample from an axe-cut stump was collected from this site. The sample (DNT-913) yielded an 1889++B inc noncutting date. The sample retains the final ring grown by the tree, but the year of tree harvesting cannot be specified. The sample is a ring count after A.D. 1870, and may be missing many rings; it was probably harvested sometime after 1900 as deadwood.

LA 106105

Two juniper samples from axe-cut stumps were collected from this site. One sample did not date, and the other (DNT-915) yielded an 1807vv noncutting date. The sample retains only nine sapwood rings, exhibits very uneven erosion, and probably dates to the latter half of the nineteenth century.

LA 105484

A single piñon sample from an axe-cut stump was collected from this site. The sample (DNT-906) retains lichen on its exterior surface, appears very unevenly eroded, and yielded an 1840vv noncutting date. It probably dates to the latter half of the nineteenth century.

LA 105529

A single piñon sample from the lintel of a storage cist was collected from this site. The sample (DNT-952) appears very unevenly eroded and yielded a 1566vv noncutting date. Many of the exterior rings are missing and the ring sequence is very tight (ca. 30 rings/cm). The specimen probably indicates the use of deadwood sometime during the Navajo occupation of the area.

LA 105629

A single juniper sample from an axe-cut stump was collected from this site. The sample (DNT-907) retains 40 sapwood rings, appears very unevenly eroded, and yielded a 1679+vv noncutting date. It probably dates to the early A.D. 1700s at the earliest.

LA 105630

Five specimens, four juniper and one piñon, were collected from this site. Only two specimens collected from axe-cut limbs or stumps yielded dates. DNT-956 retains 34 sapwood rings, appears very unevenly eroded, and yielded a noncutting date of 1644vv. The condition of the sample suggests a late A.D. 1600s activity at the earliest. The juniper specimen (DNT-823), which dates 1900++v inc, retains 55 sapwood rings, shows some uneven erosion, and may be close to the true outside of the specimen; it is, however, a ring count after A.D. 1870 and may actually postdate 1910 or even later. The piñon sample (DNT-824) yielded a 1915rB inc cutting date indicative of tree cutting during the piñon growing season (April-August) of 1915. Both samples may indicate the same event, but there is no direct evidence to support such a conclusion. It may also be interesting to know exactly when Earl Morris was conducting archaeological activities in the area because these axe-cut limbs may relate to them.

NN029361

LA 106106

A juniper and a piñon sample were collected from axe-cut stumps at this site. The juniper sample (DNT-916) retains 23 sapwood rings, exhibits little uneven erosion, and yielded a noncutting date of 1883++vv. It is a ring count after A.D. 1876, and may date sometime prior to the end of the nineteenth century. The piñon sample yielded a cutting date of 1927rB comp indicative of tree harvesting after the end of the 1927 piñon growing season (April-August), but prior to the start of the 1928 growing season. These two samples may represent contemporaneous activities, but it is considered very unlikely.

Isolated Manifestations

IM-1000, a single juniper sample (DNT-932), retains no sapwood rings, is very unevenly eroded, and yielded a noncutting date of 1608vv. Given the very poor condition of the sample, it is possible that it represents tree harvesting in the late A.D. 1600s or even A.D. 1700s.

IM-1001 is a single juniper sample (DNT-933) that retains no sapwood rings, is very unevenly eroded, and yielded a noncutting date of 1654+vv. Given the very poor condition of the sample, it is probable that it represents tree harvesting in the late A.D. 1600s or early A.D. 1700s.

Two samples are included in IM-12, DNT-838 and DNT-837; both samples are derived from axe-cut juniper limbs in relatively close proximity to each other. Sample DNT-838 retains 46 sapwood rings, is very eroded, and yielded a noncutting date of 1664+vv. It probably dates sometime to the late A.D. 1600s or early A.D. 1700s. Sample DNT-837 yielded a 1629B inc cutting date indicative of tree cutting activities during the juniper growing season (May-October) of A.D. 1629. Thus, two different activities, potentially separated by 50 years or more, are represented by the two parts of the isolated manifestation.

IM-18 is a single juniper sample (DNT-830) from an axe-cut stump that retains no sapwood rings, is very unevenly eroded, and yielded a noncutting date of 1605vv. Given the very poor condition of the sample, it is probable that it represents tree harvesting in the late A.D. 1600s or early A.D. 1700s.

The single juniper sample (DNT-905) designated IM-28 retains 28 sapwood rings, is very unevenly eroded, and yielded a noncutting date of 1859++vv; it is a ring count after A.D. 1830 and the ring series is very tight. It probably represents deadwood harvesting sometime in the late A.D. 1800s or early 1900s.

Wood Use

Understanding the wood use behavior in the Morris Site 1 project area is important for understanding how the site occupants viewed wood as a resource and exploited it to meet their construction, artifactual, and fuel needs. Most wood use models are derived from the dendrochronology of large Puebloan structures (Dean and Warren 1983; but see Towner 1997), and thus may not be applicable to Navajo archaeological remains. The Morris Site 1 project data present some difficulties, however. The sampling strategy was dictated by the desire to retrieve high quality dates and poor preservation of some samples was a frequent occurrence.

The species used by occupants of the area are shown in Table 83. Although these data are clearly influenced by the sampling strategy and preservation of materials, they suggest several interesting aspects of wood use behavior. First, it is clear that piñon was preferred for use in pueblitos, probably because such masonry rooms require longer, straighter beams than do forked-stick hogans. Piñon apparently met these requirements, but other species did not; these data are similar to those described for the Dinétah as a whole (Towner 1997). Juniper appears to be used more in forked-stick hogans, but the small sample size (N = 6) makes any conclusions somewhat suspect. Mountain mahogany was identified as a hogan leaner in one structure. Interestingly, juniper is clearly the favored material for use in sweat lodge construction, as it was in other Dinétah samples (Towner 1997). One possible reason for this selection is that juniper exudes much less sap and pitch than piñon, and probably is less affected by the heat and steam in a sweat lodge. The species distribution of culturally modified trees (axe-cut limbs and stumps) is undoubtedly heavily influenced by preservation in the archaeological record. Indeed, three of the five axe-cut piñon trees date to the late A.D. 1800s or 1900s and thus influence the distribution; Navajo culturally modified trees are almost entirely juniper specimens.

Unfortunately, tool use and marks were not universally recorded for the samples. The nature of most of the samples is such that many were identified by metal axe marks on their ends, but little information regarding debarking or delimbing of beams is available. Deadwood appears to have been used for a variety of functions and is not uncommon, especially in sweat lodges. On the other hand, deadwood was apparently not preferred for use in pueblitos and was uncommon in forked-stick hogans.

NN029362

Table 83. Listing of Wood Species Utilized by Early Navajo Inhabitants in the Morris Site 1 Project Area

	Pueblitos	Hogans	Sweat Lodges	Axe-cut Trees	Total
Juniper (*Juniperus spp.*)	6	4	9	32	51
Piñon (*Pinus edulis*)	10	1	1	5	17
Mountain Mahogany (*Cercocarpus mountanus*)	-	1	-	-	1
Total	16	6	10	37	69

Methodological Considerations

The large number of samples collected during the Morris Site 1 project provides an important data set for examining issues related to early Navajo archaeology within and beyond the project area. Important Navajo behavioral factors in the creation of this data set have been discussed above. The purpose of this section is to suggest ways in which archaeologists can maximize the amount of information available in the arboreal archaeological record of the early Navajo.

The proportion of piñon samples that yielded dates (74 percent) is substantially higher than that of the juniper samples (51 percent), and indicates that archaeologists should collect piñon samples whenever possible. This is not to say that juniper samples should not be collected; quite the contrary, both species were exploited and contain important information about the occupation. Indeed, juniper samples produced the earliest cutting dates in the project area, and there is some evidence that the earliest Navajos in the area preferred juniper for construction purposes, or possibly they sought to preserve piñon nut resources. Piñon samples dominate the timbers in and associated with pueblitos, and may have been selected specifically for that type of masonry construction due to length and straightness requirements. Thus, as architectural wood, piñon may have been used later in time and in structures that increase the chances of good sample preservation. Juniper, on the other hand, may be more frequently associated with earlier hogans and sweat lodges because they did not have such stringent construction requirements.

Few piñon samples were collected from axe-cut limbs, or stumps, and some of those yielded late eighteenth- or early nineteenth-century dates. There are several possible explanations for the piñon sampling strategy and date distributions. First, piñon trees can rarely, if ever, survive the harvesting of the main bole (meristem) of the tree. The remaining stump is then subject to attack by insects and other destructive forces, especially if it is in contact with the ground. Thus, the few piñons that survive in the archaeological record typically yield noncutting dates; such a poor survival rate may also partially explain the later dates derived from piñon samples. Junipers, on the other hand, particularly one-seed juniper (*Juniperus monosperma*), can easily survive harvesting of the main trunk; a different branch simply assumes apical dominance and the tree continues to photosynthesize and produce fruit. Thus, the active parts of the tree keep the trunk upright and away from destructive biological, chemical, and physical processes. In addition, the living portion may provide some protection from wind and water erosion as well. Finally, both architectural and nonarchitectural juniper samples may preserve better in the archaeological record because of the presence of distinctive heartwood. The lignins and other substances in heartwood strengthen the wood cells and inhibit infestation by microbes and other destructive agents. Until better methods of estimating sapwood erosion are devised, however, these samples may not substantively contribute to site dating, except to provide baseline dates prior to which tree cutting could not have occurred.

The scarcity of metal axes early in the historic period also may play a role in the paucity of early seventeenth-century cutting dates from Navajo sites. The earliest possible evidence of metal axe use is A.D. 1540, the year of Coronado's entrada and, coincidentally, the date of the earliest tree-ring dated Navajo site (Hancock 1997; Reed et al. 1997). It is much more likely, however, that metal axes began to filter into the Dinétah shortly after Oñate's colonization of the Rio Grande in A.D. 1598. Thus, both for behavioral and preservation reasons, is likely that the earliest cutting dates from metal-axe-cut stumps or limbs will be in the first decade of the seventeenth century.

There is little or no evidence that the Navajo ever fully adopted the stone axe. No stone-axe-cut timbers have ever been recorded on Navajo sites, and only one stone axe has

NN029363

been recovered from a single-component Navajo site (Brown 1993). Brown's (1993) depiction of an axe from the Morris Site 1 pueblito is far from conclusive proof it was used at that site, even if it is actually a stone axe. If the Navajo disdained the use of the stone axe, their options for wood procurement included breaking, burning, and deadwood utilization—methods that are not mutually exclusive. Breaking tree limbs for use in hogans, sweat lodges, and other structures may have been facilitated by the informal nature of such architecture. It is, of course, easier to break dead limbs than green ones, and such practices may produce only deadwood dates. In addition, it is unreasonable to expect archaeologists to sample all the broken limbs in the forest. If sampling of broken limbs is attempted, such specimens should be evaluated carefully and documented thoroughly in terms of the size and age of the tree, degree of weathering on the break, and overall archaeological context of a number of samples.

Deadwood harvesting of tree boles is evident in a number of instances by the presence of root flares, twisted grain, and other indicators of natural tree death. Although sampling such specimens will not indicate the precise year of wood procurement, it will provide a baseline date before which construction could not have occurred.

In order to investigate pre-metal-axe Navajo wood procurement without site excavation, I believe that intensive collection and analysis of burned stumps in association with Navajo sites is the most promising avenue of future research. Burning as a method of tree harvesting has been ethnographically documented for the Ute (Smith 1974) and tentatively identified on Navajo archaeological sites in the Dinétah (Towner and Johnson 1998; Towner et al. 1998). Without metal or stone tools, burning at the base is probably the only method of procuring the meristems of live trees. Placing a pile of hot coals, supported by sherds or rocks, against the base of the tree weakens the stem enough for it to be felled by hand. Although the Ute (and Navajo) may have used this technique to harvest deadwood (Smith 1974), the possibility of fully igniting a dead tree suggests the technique was probably used for green wood procurement as well. The identifying characteristics of such tree harvesting methods are still not well defined. Attributes that may prove useful in the future include: evidence of true exterior surfaces, evidence of burning above the root flare, and complete burning on only one exterior side of the stump. Completely burned stumps, stumps burned below the root flare, and those burned around the circumference are least likely to yield dates relevant to the occupation of the area. Excavation of burned Navajo structures, of course, is most likely to yield dates that illuminate the years and seasons of Precontact Navajo occupations.

Discussion

The tree-ring samples and dates collected as part of the Morris Site 1 project provide important behavioral and chronological information pertinent to the early Navajo occupation of northwest New Mexico. Although traditional sampling methods were used to investigate architectural features, it was the development and use of new methods to collect samples from the arboreal archaeological record that have provided the most significant data.

Behaviorally, it is clear that the early Navajo occupants of the area exploited various tree species for use as construction materials. Juniper, piñon, and possibly mountain mahogany, were certainly used in structures; other species may have been used as well, but may not have been collected because the sampling was oriented toward dendrochronologically useful species and specimens with true exterior surfaces. Elsewhere Douglas fir, ponderosa pine, and cottonwood have been documented archaeologically (Towner 1997), and a plethora of both conifers and angiosperms have been documented ethnographically (Elmore 1944).

The characteristics of the wood samples and dates suggest that the early Navajos in the Morris Site 1 area eschewed the use of the stone axe. There are no stone-axe-cut timbers, and no cutting dates predate the introduction of the metal axe. Alternatively, the project area may not have been occupied prior to the introduction of metal tools, but that is considered unlikely. There is some evidence of the use of deadwood, particularly in the construction of sweat lodges.

As the most precise and accurate dating technique available, dendrochronology has contributed significant information to the interpretation of the early Navajo occupation of the Dinétah. The tree-ring dates indicate that the Navajo use of the Morris Site 1 area began in the early seventeenth century, fluctuated until the second half of the A.D. 1600s, stabilized in the first half of the eighteenth century, and ceased shortly after the middle of the A.D. 1700s.

The earliest definitive tree-cutting activities in the Morris Site 1 area occurred during the summer or fall of A.D. 1629 at two different sites. A few noncutting dates suggest activity in the first decade of the seventeenth century, but are not conclusive evidence of tree harvesting. Although the next cutting dates in the project area date in the summer or fall of A.D. 1695, loose clustering of noncutting dates suggests that the use of the area increased in intensity beginning in the A.D. 1660s and continued until the end of the century. The small number of dates, both cutting and noncutting, in the first

NN029364

decade of the A.D. 1700s in the Morris Site 1 area, and throughout the Dinétah, indicates an important change in the behavior of the early Navajo toward wood as a resource. This paucity of dates indicates that the purported large influx of Puebloan refugees did not occur, but may also indicate an early Navajo response to Spanish entradas into the Dinétah (c.f., Hendricks and Wilson 1996). Only one pueblito was constructed in Dinétah in the first decade of the A.D. 1700s (Towner et al. 2001), and Navajos may have been avoiding inhabiting the valley bottoms where the Spaniards concentrated their forces. It is likely that sites built during this time period, predominately forked-stick hogans, were located in relatively inaccessible areas away from the main drainages.

In the second decade of the seventeenth century, tree cutting returned to previous levels throughout the project area. This increase culminated in the early A.D. 1720s with the founding of the site at Romine Canyon ruin. The pueblito was clearly an important locus of activity in the project area during this time period. Interestingly, it is during this same time period that tree-cutting activity almost ceases in the Three Corn area of San Rafael Canyon. The tree-ring data cannot demonstrate the movement of people between the two areas, but it is an idea worth pursuing with other artifact classes. There is a small gap in the Morris Site 1 project data between A.D. 1731 and A.D. 1738. In the early A.D. 1730s, the activity level at Three Corn is relatively high, but ceases after A.D. 1737. Again, the negative correlation between dates in the Morris Site 1 area and dates in San Rafael Canyon is interesting and warrants additional research.

Tree harvesting in the Morris Site 1 project area again increases throughout the A.D. 1740s and culminates with the construction of Morris Site 1 pueblito in A.D. 1748 or A.D. 1749. During this decade, however, activity in San Rafael Canyon, and indeed throughout the Dinétah, increases as well. Whether this project- and region-wide increase is a result of a tremendous population increase due to immigration, or a dramatic increase in residential mobility has yet to be determined.

The latest date from Morris Site 1 project area is a 1750B inc cutting date from LA 106199, and I believe the area was abandoned shortly thereafter. Hantman's (1983) suggestion that adding 10 years to the latest date would indicate abandonment about A.D. 1760. The latest date from the Dinétah is 1762v inc from a storage cist (Fetterman 1996), and the latest date from San Rafael Canyon is 1756++vv from a culturally modified tree (Towner and Johnson 1998). Thus, A.D. 1760 may be the latest possible date of occupation in the Morris Site 1 project area, but given the continuous nature of tree harvesting throughout the A.D. 1740s, I believe the project area was abandoned by the middle of the A.D. 1750s, if not earlier.

Conclusions

The Morris Site 1 Early Navajo Land Use study has demonstrated the utility of intensive dendrochronological sampling of both architectural and nonarchitectural features. Although the majority of samples relate to the Navajo occupation, other samples contribute to understanding the Hispanic and Anglo activities in the area as well. This distribution of samples and dates among archaeological sites created by different ethnic groups is important because it shows that dendrochronological sampling of both the architectural and arboreal components of the archaeological record of the recent past can contribute important information for interpreting past human behavior of any cultural group that used wood as a resource.

NN029365