Cultural implications of architectural mortar and plaster selection at Mesa Verde National Park, Colorado

Shane David Rumsey
University of Nevada, Las Vegas

Follow this and additional works at: https://digitalscholarship.unlv.edu/rtds

Repository Citation
https://digitalscholarship.unlv.edu/rtds/2261

This Thesis is brought to you for free and open access by Digital Scholarship@UNLV. It has been accepted for inclusion in UNLV Retrospective Theses & Dissertations by an authorized administrator of Digital Scholarship@UNLV. For more information, please contact digitalscholarship@unlv.edu.
CULTURAL IMPLICATIONS OF ARCHITECTURAL MORTAR AND PLASTER SELECTION AT MESA VERDE NATIONAL PARK, COLORADO

By

Shane David Rumsey
Bachelor of Science
Weber State University
2002

A thesis submitted in partial fulfillment of the requirements for the

Master of Arts Degree in Anthropology
Department of Anthropology
College of Liberal Arts

Graduate College
University of Nevada, Las Vegas
December 2007
The Thesis prepared by

Shane David Rumsey

Entitled

Cultural Implications of Architectural Mortar and Plaster
Selection at Mesa Verde National Park, Colorado

is approved in partial fulfillment of the requirements for the degree of

Master of Arts in Anthropology

Karen A. Hamy
Examination Committee Chair

[Signature]
Dean of the Graduate College

[Signature]
Examination Committee Member

[Signature]
Examination Committee Member

[Signature]
Graduate College Faculty Representative
ABSTRACT

Cultural Implications of Architectural Mortar and Plaster Selection at Mesa Verde National Park, Colorado

By

Shane David Rumsey

Dr. Karen G. Harry, Examination Committee Chair
Associate Professor of Anthropology
University of Nevada, Las Vegas

The research presented here utilizes both mineralogical and elemental analyses to examine prehistoric architectural mortar and plaster samples from kivas at two Pueblo III period cliff house sites in Mesa Verde National Park. In order to provide a thorough geochemical characterization of mortar and plaster samples analytic techniques including x-ray diffractometry (XRD), inductively coupled plasma – mass spectrometry (ICP-MS), and analytical electron microscopy (SEM-EDS) have been utilized. Similarities and differences in mortar selection among those sites and kivas sampled are then discussed in terms of cultural implications. The most significant result is a temporal trend in mortar selection from early to late periods of occupation at Spruce Tree House. Also discussed are several preservation issues dealing with the accumulation of gypsum soft masses in kiva walls at those sites sampled. This research evaluates the effectiveness of using geochemically based techniques to answer culturally significant questions about building material selection and use.
# TABLE OF CONTENTS

ABSTRACT....................................................................................................................... iii

LIST OF FIGURES ........................................................................................................... vi

LIST OF TABLES............................................................................................................ vii

ACKNOWLEDGMENTS ............................................................................................... viii

CHAPTER 1  INTRODUCTION .................................................................................... 1
  Research Objectives....................................................................................................... 5

CHAPTER 2 ENVIRONMENTAL SETTING ............................................................ 12
  Geology........................................................................................................................ 13
  Soils.............................................................................................................................. 17
  Climate......................................................................................................................... 19
  Flora............................................................................................................................. 20
  Fauna............................................................................................................................ 21

CHAPTER 3 CULTURAL SETTING ......................................................................... 23
  History of Research...................................................................................................... 24
  Prehistory ..................................................................................................................... 30
  Mesa Verde Phase Social Organization....................................................................... 40
  The Kiva....................................................................................................................... 42

CHAPTER 4 METHODOLOGY ................................................................................. 48
  Field Procedures........................................................................................................... 48
  Mortar Analysis ........................................................................................................... 56
  Plaster Analysis............................................................................................................ 60

CHAPTER 5 RESULTS ............................................................................................... 63
  Mortar Analysis Results............................................................................................... 63
  Plaster Analysis Results............................................................................................... 87

CHAPTER 6 DISCUSSION AND CONCLUSIONS .................................................. 95
  Further Research........................................................................................................ 109

REFERENCES CITED.................................................................................................... 112
LIST OF FIGURES

Figure 1  Mesa Verde site map ................................................................. 4
Figure 2  Mesa Verde regional map .......................................................... 13
Figure 3  Mesa Verde style kiva ............................................................. 44
Figure 4  Map of Spruce Tree House ....................................................... 51
Figure 5  Map of Nordenskiold’s Ruin 12 ............................................... 52
Figure 6  Gypsum soft masses under magnification ............................... 67
Figure 7  Elemental analysis of gypsum soft mass ................................. 67
Figure 8  Factor score scatterplot of components 1 and 2 ....................... 85
Figure 9  Line scan of specimen C ......................................................... 89
Figure 10  Elemental mapping of specimen D ......................................... 90
Figure 11  Line scan of specimen E ....................................................... 91
Figure 12  Elemental mapping of specimen G ......................................... 92
Figure 13  Elemental mapping of specimen L ......................................... 92
LIST OF TABLES

Table 1  Research Objectives .................................................................................................. 5
Table 2  Mesa Verde chronology ....................................................................................... 24
Table 3  Location of mortar sample removal at Spruce Tree House ................................. 49
Table 4  Location of mortar sample removal at Nordenskiold’s 12 ................................. 50
Table 5  Location of plaster sample removal at Nordenskiold’s 12 ................................. 55
Table 6  Spruce Tree House mortar sample descriptions ................................................. 64
Table 7  Nordenskiold’s Ruin 12 mortar sample descriptions .......................................... 65
Table 8  Mineralogical phases in Spruce Tree House samples ........................................ 69
Table 9  Mineralogical phases in Nordenskiold’s Ruin 12 samples ................................ 70
Table 10 ICP-MS elemental results of Spruce Tree House samples ............................... 80
Table 11 ICP-MS elemental results of Nordenskiold’s Ruin 12 samples ........................ 81
Table 12 Results of furthest neighbor cluster analysis ..................................................... 82
Table 13 EDS random point analyses of Ruin 12 plaster samples ................................. 88
Table 14 Cross tabulation of chemical cluster assignment by kiva ............................... 96
Table 15 Spruce Tree House kiva construction dates ....................................................... 97
ACKNOWLEDGMENTS

The completion of this Masters thesis would have never been possible without the support and direction of a number of individuals and organizations. First thanks to my committee chair and members Karen Harry, Barbara Roth, Alan Simmons, and special thanks to Patrick Drohan for his assistance during the field and lab phases of the project.

This project would have never been possible without the support of the Park Service staff at Mesa Verde National Park. Most notably the efforts of Rebecca Carr and Kay Barnett are much appreciated. Grants from both the UNLV graduate college, as well as the UNLV geoscience department made the geochemical analyses possible. Most importantly thanks to my wife Camille for her extreme patience and encouragement through the whole process.
CHAPTER 1

INTRODUCTION

Mesa Verde National Park has long been recognized as an important and unique archaeological resource. This is evidenced by not only a substantial public interest in the region, but also a long history of governmental protection. Located in the Four Corners region of southwestern Colorado, the Park is well known for the large prehistoric cliff dwelling structures built by the Puebloan culture that inhabited the region. These ancient dwellings are often precariously perched in alcoves formed in vertical sandstone cliff faces that characterize the canyon/mesa topography. Official recognition and protection of the area began when Mesa Verde was established as the ninth national park in 1906. Additionally, the unique nature of the archaeological remains in the Park were once again recognized in 1978 when Mesa Verde became the first World Heritage Cultural Park in the United States. The exceptional quality of the ruins preserved in the Park were well described by Gustaf Nordenskiold, one of the earliest researchers to study the region, when he declared that within Mesa Verde were “…ruins so magnificent that they surpass anything of the kind known in the United States (Nordenskiold 1893:12).” Although the largest cliff dwellings within the Park such as Cliff Palace and Spruce Tree House have come to characterize the region, in total there are more than 600 cliff dwellings and numerous mesa top ruins of widely varied shape and size within the boundaries of the
Park (Matero 2003). Due to a combination of the relatively dry climate, the location of cliff ruins in protective sandstone alcoves, and long-term governmental protection, many of the ruins are in a state of superb preservation. Masonry pueblos as constructed by the prehistoric Puebloan population who occupied much of the region have proved to be quite resilient to the passage of time.

The research presented here will take advantage of these ideal conditions focusing specifically on the building materials utilized by the ancestral Puebloans with particular emphasis on the cultural implications of material selection and use. Under the direction of the Park Service a series of architectural mortar and plaster samples were retrieved from two cliff dwellings, both of which date to the 13th century A.D. (Spruce Tree House, Nordenskiold's Ruin 12).

The two sites are located approximately 2.5 miles from each other, and are separated by three steep walled canyons (Long Canyon, Wickiup Canyon, and Navajo Canyon) and two mesas (Wetherill Mesa and Long Mesa) (see Figure 1). Both sites are located in the southwest portion of the Park. Ruin 12 is a moderately sized cliff dwelling composed of approximately 17 rooms and 5 kivas (see Figure 5). The site is located on the northwest face of Rock Canyon, just below Wetherill Mesa. Ruin 12 was discovered by Richard Wetherill and Charlie Mason, and subsequently underwent minimal excavations under the direction of Gustaf Nordenskiold (1893). Nordenskiold describes very little of the findings of this investigation, besides making mention of woven belts being discovered in one of the kivas. Since the work of Nordenskiold little investigative research has been carried out at the site; however, the Park Service has conducted a minimal amount of stabilization work there. Currently the site is inaccessible to the general public, partly
due to its precarious location high in the sandstone cliff face above Rock Canyon. In contrast, the impressively large Spruce Tree House has undergone a long history of stabilization and restorative work aimed at allowing public visitation at the site.

Spruce Tree House was discovered by Richard Wetherill and Charlie Mason in 1888. The large cliff dwelling is located near Park headquarters on the east side of Spruce Tree Canyon, just below the rim of Chapin Mesa. Containing some 120 rooms and 8 kivas, the site is the third largest of its kind at Mesa Verde (see Figure 4) (Fewkes 1909, Morgan 1994). Unfortunately, the site was thoroughly pilfered for artifacts by the Wetherill family and others during the first several years of its known existence. Gustaf Nordenskiold introduced the Wetherills' to a more scientific approach to excavation at the site. Nordenskiold's work at Spruce Tree House consisted of only a few days excavation, the results of which are summarized in his 1893 work, The Cliff Dwellers of The Mesa Verde (Nordenskiold 1893). After Mesa Verde was made a national park, Walter Fewkes was placed in charge of preparing the Park for public visitation. These preparations included intensive stabilization and restorative work at Spruce Tree House. This work also included a fair amount of excavation at the site (Fewkes 1909).

Following Fewkes work at Spruce Tree House, work at the site was limited to maintenance and repair associated with public visitation (see Horn 1989 for detailed descriptions of the numerous maintenance projects). Since the time of Fewkes, archaeological investigations into Spruce Tree House have remained relatively non-invasive, and have therefore been primarily constrained to architectural research. The majority of these studies are summarized in chapter three.
Figure 1. Mesa Verde Map with locations of Nordenskiold's Ruin 12 and Spruce Tree House (adapted from Rohn 1971).
Retrieval of architectural mortar and plaster samples from several kivas at these sites was carried out in order to address several research objectives related directly at discovering the degree of homogeneity among the samples. The elemental and mineralogical analyses that followed were catered at achieving these specific research goals.

Research Objectives

The research presented here aims at addressing several research goals that not only have direct applicability to the sites under investigation, but the methods tested as part of this research may also be applied to sites throughout the Southwest to aid in answering a myriad of research questions. The results of this research are therefore directed at several levels of analysis and discussion. The first and largest scale of analysis, geographically speaking, involves those research questions that are site specific (see Table 1).

Table 1. Research Objectives

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Determine temporal consistency or lack thereof in mortar source selection within each site</td>
</tr>
<tr>
<td>2</td>
<td>Examine patterns and range of mortar selection at distinct locations within each site in an effort to determine the extent and makeup of the mortar source primary resource access group</td>
</tr>
<tr>
<td>3</td>
<td>Gain a regional perspective on the similarities and differences in mortar procurement</td>
</tr>
<tr>
<td>4</td>
<td>Determine the effectiveness of using XRD as a primary research tool in examining prehistoric Southwestern mortars</td>
</tr>
<tr>
<td>5</td>
<td>Determine if plaster layers were taken from unique sources and whether patterns indicate annual regularities in plaster application</td>
</tr>
<tr>
<td>6</td>
<td>Aid the Park Service in efforts to document and develop conservation programs and action plans to conserve masonry structures within Mesa Verde National Park</td>
</tr>
</tbody>
</table>
This research will address the question as to the temporal consistency or lack thereof in mortar source material selection within each site. Were the ancestral Puebloan groups occupying these sites consistently using the same sources of mortar over time, and if not, what are the possible explanations of why mortar technology changed? In order to deal with such temporally specific questions intra-site chronological data from each of the sampled areas will be considered. Fortunately, due to the extensive dating by both radiocarbon and dendrochronological techniques, these data are readily available for a large majority of the structures at many cliff dwellings within the Park. However, nearly all of the cliff dwellings within the Park, including those tested for this study, were constructed during a very constricted time period spanning the first half of the 13th century A.D. Any attempt at developing a sequence of construction events within any one site can be a daunting task given errors inherent in dating techniques. Fortunately the dendrochronological record in the Four Corners region is so well documented that many structures within Mesa Verde can be dated with fairly precise accuracy. Additionally, when alterations have been made to a pre-existing structure these separate building episodes are evident in the architecture and can be readily determined by observing wall abutments and relative position of construction. Structures that exhibit such characteristics can then be assumed to be temporally distinct, and where possible absolute dating techniques may aid these assumptions. Structures that exhibit temporally distinct building episodes will be sampled in order to address this first research question.

The patterns resulting from these analyses can then be discussed in terms of behavioral implications. Using primarily finished mortar color as a guide, Rohn (1971) indicates a definite temporal pattern of mortar use at Mug House, a classic period cliff
dwelling located in Mesa Verde. The pattern Rohn discovered can be described as follows: initially a combination of mesa top red loess with some percent of sandy soil was used, then tan and buff residual soils from the canyon rim were used, and most recently crudely crushed blue-gray shales were used. The results of these analyses will be used to determine if a similar pattern holds true for Ruin 12 and Spruce Tree House.

Several other explanations of temporal variability in mortar selection may be, at least partially, involved as well. Differences may simply indicate new kiva ownership, as can occur in the case of abandonment and reoccupation. Depending on the availability of source materials it could also indicate source material depletion. This circumstance could also be an argument against Griffitt’s (ca. 1996, 2003) conclusion that mortar selection at Mesa Verde was based primarily upon the proximity of the source to the construction site. If in fact proximity to the source was the prime factor motivating selection one would expect it to remain the same at any given site through time assuming that source depletion is not an issue. Another possibility is that temporal change may have resulted from technological change or a change in the knowledge of available local resources as may be indicated by the patterning visible at Mug House (Rohn 1971). Do the latter mortars have unique mineralogical and chemical properties that somehow improve the effectiveness over their predecessors? Whatever the case, mortar selection is certainly the result of a conscious decision making process undertaken by one or more individuals involved with the construction process.

The second research question to be addressed is in regard to the consistency of the mortar used at spatially distinct locations within each site being sampled. Do the mineralogical characteristics of the mortar from separate kivas within a single site
indicate the mortar may have come from different sources, or does the mineralogy indicate a fairly homogenous distribution? This question is aimed at discovering the makeup of the mortar source “primary resource access group,” as described by Adler (1994). A primary resource access group can be made up of an individual or some collection of individuals who control direct access to a specific resource such as arable land. Prehistoric land tenure systems are extremely difficult to determine using the archaeological record, so the majority of ideas concerning prehistoric Puebloan land tenure have been derived from ethnographic data. Historically, access to clan lands was dependant upon participation in the ceremonial system, and therefore intimately tied to privileged access of ritual knowledge. However, clan lands only pertained to corn fields and all lands used for other purposes were individually owned (Upham 1989, Whiteley 1998). Whitely (1998) elucidates the considerable amount of flexibility inherent in the Hopi land tenure system.

Architectural mortar is a soil that has been removed from the natural environment and incorporated into a cultural context. At Zuni Pueblo, Mindeleff (1989 [1891]) observed adobe bricks being taken directly from agriculturally productive fields. Hypothetically, even if it had not been observed first hand, using geochemical techniques those adobe bricks could be mineralogically and elementally tied to the field from which they were removed. One could therefore posit that the same group doing the constructing must have control over those agricultural lands. This research will examine architectural mortars in a similar fashion hoping to discover the extent and possibly the makeup of the mortar source primary resource access group. Alder (1994) indicates that prehistoric Puebloan co-residential units shared a basic level of common access to land and productive
resources. These analyses may aid in determining if this is the case in regard to architectural mortar. If the analyses show distinct differences in mortar selection between kivas this may indicate that the makeup of the primary resource access group was composed of a household residential unit. As defined by Rohn (1971) a household residential unit consists of “... any group of individuals who share the economic workload and occupy jointly one house or a cluster of contiguous spaces that are well demarcated and into which outsiders do not freely intrude.” Architecturally, the kiva/roomblock residential unit that was characteristic of Mesa Verde cliff dwellings can be thought of as representing a household level social group. On the other hand, a more homogenous distribution of mortar source use among the kivas may indicate a community or larger scale access group.

Rather than being site specific, the third research question is more regional. By sampling structures from two spatially distinct cliff dwellings within the Park a more regional view of the similarities and differences in prehistoric mortar procurement and use will begin to emerge. Does the mortar mineralogy support the conclusion reached by Griffitts (ca. 1996, 2003) that mortar selection was entirely based upon proximity to the site and ease of procurement, or are sources with a distinct mineralogy preferred over others? By looking at the total amount of mortar mineralogical variability, both within and between sites, more broadly applicable questions such as these can begin to be addressed.

The fourth research goal will address the effectiveness of using x-ray diffraction (XRD) analysis as a primary research tool when examining prehistoric southwestern mortars. Since this application is a relatively new technique for examining prehistoric
masonry mortars, its success as a tool for mortar analysis will be accessed. Brown (1990) describes the results of previous XRD applications to mortar analysis as being difficult to interpret, and therefore difficult to apply when asking archaeological questions. The majority of recent research using XRD technology to analyze architectural mortar comes from Old World studies most often involving large historic churches and cathedrals (Alessandrini et al. 1991, Alvarez et al. 2000, Bellanca et al. 1999, Genestar and Pons 2003, Moropoulou et al. 2003). These studies use XRD to characterize the mineralogy of the mortars, and varied other methods to provide a more complete chemical and elemental characterization of the mortars in question. The research presented here will advance such studies, and seek to explore the extent of useful application within the context of prehistoric southwestern architecture.

Although beyond the original scope of this study, during the initial phases of this research, the Park Service requested the removal and analysis of several plaster samples from the kivas sampled as part of the mortar analysis. Cross-sections of these samples were analyzed using analytical electron microscopy (SEM-EDS) to determine the elemental makeup of the layers visible therein. Ethnographic data indicate that kivas were replastered frequently, and in addition, replastering may have been done so according to a seasonal ceremonial cycle. Rohn (1971) points out a similar pattern visible in the archaeological record as possible evidence for a ceremonial tie to replastering and color of surface washes within kivas. The layer based elemental results will be used to determine if the layering appears to be elementally distinct enough to have been taken from unique sources. In addition, the samples will be visually inspected under the SEM for patterns which could indicate annual regularities in plaster application.
The final objective of this research is that by providing elemental and mineralogical characterizations of the mortars prehistorically used at those sites sampled, the Park Service will be more informed and better prepared to effectively deal with architectural preservation issues at these sites. This research will aid the Park Service in their continuing efforts to document and develop conservation programs for the cliff ruins within the Park (Matero 2003). Much effort has been spent documenting and explaining the deterioration of the cliff dwellings (see Matero 2003, Petuskey et al. 1995). A knowledge of the mortar mineralogy at the sites under investigation will supplement these studies in their goal of developing effective action plans to conserve the structures. This research will also aid the Park Service in their efforts to authentically maintain and stabilize structures that may be susceptible to collapse.
CHAPTER 2

ENVIRONMENTAL SETTING

The Mesa Verde Region is located in the Four Corners area of the southwestern United States (see Figure 2). Physiographically the region encompasses much of the east-central edge of the Colorado Plateau (Herold 1961). The Colorado Plateau is a physiographic province characterized by relatively horizontal geologic strata. The province extends through portions of Utah, Colorado, Arizona, and New Mexico, and is dominated by sedimentary formations (Lipe 1967). The Colorado Plateau is bounded to the east by the Rocky Mountains, to the west by the Basin and Range Province, and to the South by the Sonoran Desert (Woodbury 1979).

Mesa Verde National Park is located in southwestern Colorado in an area dominated by south- to southwest-trending sandstone capped mesas. These mesas are typically bisected by deep, straight-walled canyons, forming the characteristic canyon/mesa topography (Herold 1961). The Park is situated at an elevation ranging between 6,200 and 8,500 ft., decreasing in elevation from north to south. Park headquarters is located on Chapin Mesa at an elevation of 7,070 ft (Erdman et al. 1969). The local topography is composed of a complex series of approximately 15 south trending steep-sided canyons that drain into the southwest flowing Mancos River at their southern termini. These deep, fingerlike canyons have divided the mesa into several roughly parallel parts. The main
mesas in the Park include, from west to east: Wetherill Mesa, Long Mesa, Chapin Mesa, Park Mesa, and Moccasin Mesa. Major canyons include, from west to east: Rock Canyon, Long Canyon, Navajo Canyon, Spruce Canyon, and Soda Canyon (see Figure 1).

Figure 2. Mesa Verde National Park regional map (Adapted from Rohn 1971).

Geology

The prehistoric Puebloan groups that occupied Mesa Verde maintained an intimate relationship with the surrounding geologic environment. Not only did they occupy the unique sandstone alcoves that dot the park, they also derived structural materials to build
these dwellings (sandstone bricks, masonry mortar, plaster, etc.) from the surrounding geologic environment. Knowledge of the geologic history of the area is therefore crucial in order to understand the relationship of that environment with the prehistoric inhabitants that occupied it. In addition, the research presented here focuses specifically on the nature of just such an interplay by examining cultural behavior from an analysis of cultural modifications to the geologic environment.

The geologic formations currently visible at the surface within Mesa Verde National Park were deposited as a result of a great Cretaceous sea, which inundated the area between 78 and 91 million years ago (Griffitts 1990). Although the geologic history of the area goes back some two and a half billion years, for the purposes of the research presented here it will be sufficient to describe only those formations currently visible at the surface. For a more complete description of the geologic history of the Park one is referred to Griffitts (1991).

During the Cretaceous, Mesa Verde was located at the western margins of a great sea that divided North America. The initial advance of the sea into the Mesa Verde area deposited the Dakota Formation. This formation was deposited in a near shore transgressive (rising sea level) marine environment and is composed primarily of sandstone with some shale and coals (Griffitts 1990). Although this formation is not visible in the Park itself, there are several exposures in the surrounding area.

As the sea continued to advance the Mesa Verde Region was positioned further and deeper in the sea. In this low energy, offshore environment more finer-grained sediments were deposited creating the thick Mancos Formation. The Mancos Formation is composed primarily of gray shale, although thin limestone beds and bentonites also occur.
Bentonites are layers of volcanic ash that have been altered by weathering. They often appear as thin orange layers within the mass of gray shale. Bentonite exposures in the Park were particularly important as prehistoric sources of ceramic clay.

Overlying the Mancos formation is the Mesaverde Group of formations. As the sea began to retreat the Point Lookout Formation was deposited as the first in the Mesaverde Group. Although the boundary between the Mancos and Point Lookout Formations is very gradual, Point Lookout is characterized by massive beds of cliff-forming sandstone (Griffitts 1990, Nickens 1977). These beds are generally separated by thinner shale beds, with a layer of bentonite occurring below one of the lower major sandstone beds.

As the sea continued to regress the Mesa Verde region was exposed above sea level. This new depositional environment was characterized by broad swamps and meandering streams. Deposition during this period resulted in the Menefee Formation. The high amount of organics was an ideal environment for the creation of large coal beds characteristic of this formation. These coal layers are interbedded with layers of shale and sandstone. Stream deposited sandstones are prevalent in the mid-section of the Menefee Formation. Between these sandstone beds are several layers of bentonite with one unusually thick deposit occurring as well. The upper section of the formation resembles the lower section with shales, sandstones, and coals interbedded with frequency.

The Cliff House Formation was the last in the Mesaverde Group to form. The sea once again advanced and the Mesa Verde area was inundated in a shallow marine environment. The sand deposited during this period formed the capstone currently
visible on much of the surface at Mesa Verde. Within the Park the Formation generally consists of two extremely thick (both over 100 feet) sandstone layers separated by several thin shale and sandstone layers. The Formation is named after the prehistoric Puebloan dwellings that are found in alcoves within these cliff forming sandstone layers. The Cliff House Formation does not represent the end of the depositional history at Mesa Verde, and in fact the Formation was covered with up to 1500 ft. of late Cretaceous sediment (Griffitts 1990). However, due to general uplift of the surrounding region during a period known as the Laramide Revolution those sediments were completely eroded down to the present surface of the mesa by early Tertiary time. Evidence of this erosive period can be found on the present surface of the mesa where pebbles that originated some distance away in the San Juan and La Plata mountains can be located. Of note is the fact that much of the gravel deposited on the mesa from these distant sources are of the type utilized by prehistoric inhabitants as lithic raw material (Nickens 1977). Renewed uplift in parts of the region within the last 20 million years initiated an active period of downcutting on the mesa. This phase of downcutting continues to the modern era and has resulted in the deep canyon/mesa topography so characteristic of the Park today. The steep narrow canyons in the Park that have resulted from the current phase of downcutting have an average depth of around 650 feet (Hayes and Lancaster 1975).

The presence of large alcoves in the upper portions of many of the sandstone cliffs within the Park is of particular note. These alcoves are most prevalent in the cliffs of the Cliff House Formation. Alcove formation commences as groundwater percolating through the pervious sandstone meets the less permeable shale layers. The water is then forced to flow along the slope of these shale layers till it meets one of the many canyons
in the Park. As the water exits it dissolves and loosens the calcium carbonate cement holding together sand grains, and slowly undermines the upper sandstone layer. When given enough time, ground water seepage combined with freeze/thaw cycles and wind and rain storms can significantly enlarge niches in the sandstone into large habitable alcoves (Erdman et al. 1969, Griffitts 1990). In some of the larger alcoves this process has been sped up due to the presence of a layer of bentonite between the shale and sandstone. Bentonite absorbs water and can significantly increase in volume. This would effectively quicken the disintegration of the overlying sandstone layer. In addition to groundwater seepage, smaller-scale alcoves have formed by processes of sandstone exfoliation combined with freeze/thaw and wind and rain storms (Erdman et al. 1969, Griffitts 1990). The genesis of these alcoves is significant due to the fact that during certain periods of time the prehistoric Puebloan chose to construct dwellings in these formations. Both of the sites sampled as part of this investigation are located in alcoves that were formed by these processes.

Soils

Soils can be defined as “...a natural body consisting of layers (horizons) of mineral and/or organic constituents of variable thickness, which differ from the parent materials in their morphological, physical, chemical, and mineralogical properties and their biological characteristics” (Birkeland 1999). The characteristics of any given soil are typically dependant upon five major factors: climate, organisms, topography, physical and chemical properties of the parent material, and time.
Soils found at Mesa Verde can be divided into three types. Eolian soils are the most abundant soil type in the Park. The parent material of these soils is derived from transported, wind-deposited loess that has blown in from the desert region to the southwest (Nickens 1977). Although quite variable, eolian soils which blanket the mesa tops within the Park can reach depths of up to 15 feet (Erdman et al. 1969). In areas where significant erosion has occurred, these soils may also be found on talus slopes mixed with rock fragments and residual soils (Rohn 1971).

Residual soils are soils that have not moved from their original location, and are a result of in-situ weathering and breakdown of the parent material. In the Park these soils are often associated with weathered sandstone formations such as the Cliff House Formation. This type of soil often occurs on talus slopes, terraces, and along the canyon rims (Nickens 1977).

Another type of transported soil that occurs within the Park are the alluvial soils that can be found in the canyon bottoms. These are soils that have been transported into and down the canyons by water.

Although the carbonate content of the soils varies considerably, the majority of the soils in the Park are quite basic. The eolian soils on the mesa tops in the southern portion of the Park are particularly carbonate rich, and are often visibly white and flaky. This is significantly different from the slightly acidic residual soils that occur in the higher elevations at the north end of the Park (Erdman et al. 1969, Herold 1961).
Climate

According to Koppen's classification of world climates, a system based on annual and monthly means of temperature and precipitation, Mesa Verde has a cold, middle latitude, semiarid or steppe climate (Erdman et al. 1969, Nickens 1977). The environmental research carried out by Erdman et al. (1969) over a two year period as part of the Wetherill Mesa studies highlights the sometimes extreme climatic variability that characterizes the region. The temperature and precipitation of the region vary considerably by elevation and topography as well as by annual fluctuation in weather patterns (Herold 1961, Nickens 1977). According to the 41 year climate record presented in Erdman et al. (1969) July is the hottest month of the year with mean highs reaching 88°F and mean lows at 57°F. In contrast, highs in January, the coldest month of the year, average 40°F with a mean low temperature of 18°F. Both seasonal and diurnal temperature variability are great at Mesa Verde, with an even more impressive disparity when considering extreme temperatures which are often the rule in the region. Despite the high altitude, the growing season at Mesa Verde is quite long, averaging around 167 frost-free days in the middle elevations (Herold 1961).

Although quite variable from year to year, the average annual precipitation at Mesa Verde is approximately 18 in. (Erdman et al. 1969). One of the main factors determining precipitation totals is elevation. The lower elevations receive only 8 in. while the higher elevations in the northern section of the Park receive around 20 in. (Nickens 1977). Precipitation totals peak seasonally during late summer and again during winter and early spring. Summer rain storms peak during August with an average of 2 in. This moisture is typically received in the form of a few intense but short-lived thunderstorms. The
majority of winter precipitation occurs as snow. Winter precipitation peaks in February
with an average of 1.8 in. of moisture (Erdman et al. 1969, Nickens 1977). Winter snow
is not only the major determining factor for spring vegetation, but also becomes the
source moisture for seeps and springs which in large part make the dry springtime
hospitable. May and June are typically the driest months and yet the most critical for the
success of agricultural endeavors.

Flora

The distribution of vegetation is closely associated with variable climatic regimes and
therefore tied closely to elevation. The most abundant trees on both the mesa tops and
within the canyons are pinyon pine (Pinus edulis) and Utah juniper (Juniperus
osteosperma) although the understory of these dominant species varies by location.
Species occurring on mesa top areas in the north section of the Park include: bitterbrush
(Purshia Tridentata), mountain-mahogany (Cercocarpus montanus), and to a lesser
extent serviceberry (Amelanchier utahensis) and fendlerbush (Fendlera rupicola)
(Nickens 1977, Rohn 1971). Due to the lower elevations on the southern mesa tops
shrubs are sparse and grasses such as mutton grass (Poa fendleriana) and cheatgrass
(Bromus tectorum) dominate the understory.

A number of brushy species occur in the talus zone that extends from the base of the
cliff face to the canyon bottom. Most dominant of these species are oak (Quercus
gambelii), mockorange (Philandelphus microphyllus), brickellbush (Brickellia
grandiflora), and Mormon tea (Ephedra viridis). Douglas-fir (Pseudotsuga menziesii)
and yucca (*Yucca harrimaniae, Yucca baccata*) occur to a lesser extent in this zone (Erdman et al. 1969, Rohn 1971).

Flora occurring in the alluvial terraces and washes in the canyon bottoms include sagebrush (*Artemisia tridentate*), coyote willow (*Salix exigua*), saltcedar (*Tamarix pentandra*), and Indian ricegrass (*Oryzopsis hymendoides*) (Rohn 1971). Other species occurring to a lesser extent within the Park include: aspen (*Populus tremuloides*), ponderosa pine (*Pinus ponderosa*), Rocky Mountain juniper (*Juniperus scopulorum*), and cottonwood (*Populus fremontii*). Although the above describes present-day floral conditions, prehistoric inhabitants of the area probably encountered much of the same environmental setting as today despite the presence of a few invasive species (Erdman et al. 1969, Herold 1961).

**Fauna**

Like the distribution of floral species the faunal distribution is similarly complex. Mule deer (*Odocoileus hemionus*) and bighorn sheep (*Ovis canadensis*) are the two largest game species on the mesa. During the harsh winter months when the mesas are covered in snow these species often migrate to the more hospitable lower elevations surrounding the elevated mesas (Nickens 1977).

The majority of smaller mammals seem to be fairly evenly distributed throughout the area. These include but are not limited to the following: porcupine (*Erethizon dorsatum*), jackrabbit (*Lepus californicus*), cottontail (*Sylvilagus Nuttallii*), spotted skunk (*Spilogale gracilis*), prairie dog (*Cynomys gunnisoni*), wood rat (*Neotoma mexicana*), and ringtail
(Bassariscus astutus). In addition, a variety of rats, mice, squirrels, chipmunks, snakes, and lizards inhabit the region (Nickens 1977, Rohn 1971).

The pinyon-juniper woodland is also home to several species of carnivores including: mountain lion (Felis concolor), bobcat (Lynx rufus), coyote (Canis latrans), badger (Taxidea taxus), and weasel (Mustela frenata). The remaining fauna are composed of numerous species of both birds and insects (Herold 1961, Nickens 1977).

Due to seasonal ecosystemic variation of both floral and faunal species found within Mesa Verde, prehistoric exploitative activities were of necessity seasonally based. For example, the majority of wild plant resources are available between April and October, and many of these species such as pinyon exhibit significant annual variation in production. As a result of this, both wild species and cultivated crops were stored for use during other times of the year (Plog 1979). In addition, several of the smaller faunal species would have been available year round, but larger game such as deer and mountain sheep would be most easily procured during spring and fall migrations between higher and lower elevations.
CHAPTER 3

CULTURAL SETTING

Due in part to the sheer volume of archaeological research that has been carried out in the Mesa Verde region a great deal can be said of the prehistoric Puebloan population that occupied the area. This mass of research in conjunction with the superb dating of many sites via dendrochronological dating techniques has provided a general framework within which one can begin to contextualize the prehistoric population. Historically the most widely used chronological framework within the prehistoric Puebloan region has been the Pecos Classification which is divided into Basketmaker II-III and Pueblo I-III periods (Kidder 1927). Ensuing research has determined that these periods are by no means universal in the prehistoric Puebloan world, and therefore many researchers have substituted localized chronologies. This is certainly true at Mesa Verde where several cultural chronologies have been proposed (Hayes 1964, O’Bryan 1950, Rohn 1977). The explanatory value of these chronologies is geographically varied from the regional level down to mesa specific chronologies. In order to gain a regional perspective but incorporate localized Mesa Verde specific phenomena, a modified form of the Pecos Classification will suffice for the purposes of the research presented here (see Table 2).
Table 2. Mesa Verde chronology.

<table>
<thead>
<tr>
<th>Period</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basketmaker II</td>
<td>A.D. 1 - 450</td>
</tr>
<tr>
<td>Basketmaker III</td>
<td>A.D. 450 - 700</td>
</tr>
<tr>
<td>Pueblo I</td>
<td>A.D. 700 - 900</td>
</tr>
<tr>
<td>Pueblo II</td>
<td>A.D. 900 - 1100</td>
</tr>
<tr>
<td>Pueblo III</td>
<td>A.D. 1100 - 1300</td>
</tr>
</tbody>
</table>

History of Research

As an archaeological province, the Mesa Verde region has experienced one of the longest and most intensive histories of archaeological research as any other in North America. Similarly to other regions, research in the area has undergone a profound progression from an era of initial discovery to modern day scientific endeavors.

No discussion of the history of discovery within the southwest would be complete without mention of the missionary explorers Dominguez and Escalante who journeyed through the region in their search for a route to the California coast in 1776. Although they did not encounter any of the impressive ruins on the Mesa Verde itself, mention is made in Escalante’s journal of several ruins they encountered while traveling through the Four Corners region (Escalante 1995). For nearly a century after the Escalante-Dominguez expedition the region was visited by various explorers, trappers, and missionaries; however, written accounts of these ventures are few.

During the later half of the 17th century government sponsored expeditions to the region brought a new recognition of the abundance of archaeological treasures in the area. Newberry (1876), Jackson (1876), and Holmes (1878) all led expeditions to the region as part of government geologic and geographic surveys reporting on the ancient ruins they encountered; however, none of these parties ventured far enough into the
deeply carved canyons of the Mesa Verde itself to observe the full extent and magnitude of the ruins therein. Ranchers Richard Wetherill, Al Wetherill, and Charlie Mason are generally credited with the discovery of the majority of the large cliff dwellings now located within Mesa Verde National Park (Herold 1961, Lister 2004, Plog 1979). The Wetherill's had established a ranch in Mancos Valley located near Mesa Verde in 1881, and in the years following discovered a large number of the cliff dwellings within Mesa Verde. These discoveries by the Wetherill brothers brought on a time period referred to by some as “…the tragic period in the history of the Mesa Verde (Watson 1954).”

Almost immediately the Wetherills’ realized they had discovered a potentially lucrative new source of income, and for approximately the next twenty years the Wetherill brothers and others unsystematically dug many of the larger sites within the mesa recovering the ancient artifacts to be sold. Unfortunately, much of the scientific value of those sites the Wetherills dug has been forever lost. In 1891 Baron Gustaf Nordenskiold, an archaeologist visiting from Sweden, showed up on the doorstep of the Wetherill Ranch. For the next six months Nordenskiold was personally involved in the partial excavation of 22 cliff dwellings, during that time he was able to introduce the Wetherills’ to basic geologic concepts and excavation techniques (Nordenskiold 1893, Lister 2004, Watson 1954, and Herold 1961). In addition, the report Nordenskiold compiled as a result of these excavations has been highly regarded by many given the time period during which it was produced.

In 1906 Mesa Verde was set apart as a National Park and soon thereafter an intensive program of excavation and repair of the major ruins commenced under the direction of Jesse Walter Fewkes (Fewkes 1908, 1909, 1911, 1926). Of particular interest to the
study presented here is Fewkes early work at Spruce Tree House, reported on in 1909. The majority of Fewkes' work was focused on preparing the larger cliff dwellings for public visitation, unfortunately as a result, many of the reports he produced leave much to be desired (Lister 2004, Herold 1961). During the 1920's the first tree ring specimens were collected from the Park under the direction of A. E. Douglas (Watson 1954). This is significant because dendrochronological studies at sites within the Park have proven particularly useful for determining site specific occupational chronologies. Other work of note during this time period included Kidders' recognition of a Basketmaker component in the caves of Mesa Verde (Herold 1961), Nusbaum's excavations of three 7th century pithouses (Herold 1961, Watson 1954), and Gladwin's surveys of mesa-top and canyon head sites (Watson 1954). During the 1930's research outside the Park predominated and aided in developing a more regional understanding of the prehistoric Four Corners region. One of the more significant studies was Brew's (1946) report which detailed excavations at thirteen sites on Alkali Ridge. The sites Brew excavated on Alkali Ridge characterize the transitional Pueblo II period. These sites reflect a period of transitional architecture and lifestyle in the Pueblan world, as indicated by the coexistence of subterranean structures and above ground masonry pueblos. This and other research in areas surrounding the Park helped to integrate the archaeology of Mesa Verde into a more regional perspective of chronology and change within the prehistoric southwest. Research within the Park picked up once again in the 1940's. This work was generally carried out by Park staff, and included the excavation of several pithouse structures (Smiley 1941, Lancaster and Watson 1943).
Under the direction of Don Watson extensive site surveys were conducted on Chapin Mesa during the early 1950's (Watson 1954). The Wetherill Mesa Studies, a long term intensive archaeological project, commenced in 1958. This project consisted of survey as well as excavation and stabilization efforts at some sites, and resulted in several publications (Hayes 1964, Erdman et al. 1969, Swannack 1969, Rohn 1971, Hayes and Lancaster 1975). In addition, several publications resulted from salvage archaeological investigations conducted in association with the University of Colorado (Lister 1964, 1965, 1966, 1967, 1968). These studies represent a general transition in the archaeology of the region. They tended to be more interpretive and theoretical in nature as opposed to the chronology based previous research. Studies conducted at Mesa Verde after the onset of the Wetherill Mesa project are extensive and numerous, and to mention all is beyond the scope of this summary. However, more recent projects of note in the region include the Dolores Archaeological Program (Breternitz et al. 1986, Kohler et al. 1986, Lipe et al. 1988) and the Sand Canyon Archaeological Project (Varien et al. 1996, Varien 1999). The Dolores Archeological Program included extensive data recovery and excavation at a number of sites affected by dam construction in the Dolores Valley. The mass of data that resulted from the Dolores Program emphasizes the dramatic variability among prehistoric Puebloan sites in the region. Initiated in 1983, the Sand Canyon Archeological Project has included intensive research of a number of Late Pueblo II and Pueblo III sites (Huber 1993). Much of the research associated with this project has centered on discovering the extent and nature of interaction between population centers. For Example, the ceramic sourcing work of Pierce, Glowacki, and Thurs (2002) indicates extensive ceramic exchange between the Sand Canyon Locality and Mesa Verde.
Research at Mesa Verde that has direct application to the study presented here are few in number, but several are worth mentioning. Bohnert’s (1990) summary of plaster related studies highlighted the need for more extensive composition related building material analyses. In 1994 CASPAR or Conservation of Architectural Surfaces Program of Archaeological Resources was founded as a multi-phase project to develop a model program for the study and treatment of the masonry and architectural surface finishes in the cliff dwellings of Mesa Verde National Park (Matero 2003). This project resulted in a number of publications dealing with many aspects of Mesa Verdean building materials (Fiero 1997, 2001, Matero 1997). In order to gain a better understanding of ancient construction technologies and to develop more effective preservation techniques, the first detailed mortar analyses accompanied the introduction of this program (Dix 1996, Griffitts ca.1996, 2003, and Hartzler 1996, 1997). Dix (1996, 1997) analyzed a suite of construction materials including mortar from Mug House. Griffitts (ca.1996, 2003) analyzed mortar samples taken from Double House, Kodak House, Spruce Tree House, and Cliff Palace. In addition to macroscopic and thin section analyses of the mortars, Griffitts attempted in the cases of Cliff Palace and Spruce Tree House to identify the probable source locations of the mortars. Griffitts concludes that it is highly probable that the prehistoric Puebloan population who occupied these sites were using sources based on availability and proximity to construction sites rather than relying on any individual specific sources. Although less applicable, Harzler (1996, 1997) examines the effectiveness of acrylic-modified earthen mortars that have been used for stabilization purposes at Chaco Canyon, Aztec Ruins, and Mesa Verde. In 2002 Nordby and others introduced a collective standard for documenting archaeological sites within the Park
(Nordby et al. 2002). This document standardized terminology and procedures for field data collection and documentation. Several other studies undertaken at Mesa Verde have relied on a geophysical approach for understanding the prehistoric Puebloan culture, a few of which will be mentioned here. Oppelt's (1994, 1996) petrographic analyses of Mesa Verde pottery was quite informative as to probable locations of raw material procurement. Petuskey et al. (1995) investigates aspects of sandstone masonry deterioration at sites within the Park, specifically focusing on rates and possible causes of deterioration.

Due in part to the impressive state of structural preservation that characterizes much of the prehistoric Puebloan architecture present in the region, architecturally based studies have enjoyed a long and productive history in the area. Some of the earliest yet most informative work was the ethnographic work carried out by the detail oriented Mindeleff brothers at the Hopi and Zuni pueblos (Mindeleff 1989 [1891]). The Mindeleff brothers described in detail the construction process for several different forms of Historic Puebloan architecture as well as any associated rituals. In addition, they provided meticulous maps and drawings of much of the architecture they described. More recent architecturally based prehistoric Puebloan research is quite extensive. It will be sufficient to mention only those of interest to the research presented here. Using a unique approach Scarborough and Shimada (1974) conducted a systematic compositional analysis of building stones at Grasshopper Ruin finding interesting patterns of building stone selection among those structures sampled. Saile (1977, 1981) has made several important contributions to the understanding of both historic and prehistoric architecture in the Puebloan world. Lekson's detailed descriptions of the architectural forms utilized
in the Great Pueblos at Chaco Canyon were a much needed addition to Chacoan studies (Lekson 1986, 1990). Catherine Cameron (1991) successfully compiled and added to the abundance of information regarding architectural change that occurred within the historic pueblos.

Much of the modern research dealing with mineralogical and chemical characterization of plasters and mortars comes from Europe. Alessandrini et al. (1991) analyze plasters from the church of San Niccolo in Northern Italy. Alvarez et al. (2000a, 2000b) study both the mineralogy and chemistry of mortars from Spanish cathedrals, using several of the techniques adapted for the research presented here. Using similar methods Genestar and Pons (2003) study mortars from several Islamic and Gothic palaces in Spain. In a statistically based study Moropoulou et al. (2003) attempted to classify historic mortars into distinct groups based on physicochemical properties. Although the research mediums used in these studies are far removed from the prehistoric southwest the methods employed are quite similar, and offer valuable insight into mortar characterization. In addition, no comparable research has taken place among the architectural remains of the prehistoric Puebloan therefore the European research becomes an even more valuable resource.

Prehistory

Although the southwest was being occupied some 9,000 years prior to the onset of Basketmaker and Puebloan times, there is no evidence of a Paleo-Indian or Archaic occupation of the Mesa Verde proper (Cordell 1997, Woodbury 1979). Therefore, the discussion of Mesa Verde prehistory provided here will begin with the Basketmaker
culture. The Basketmaker II period dates from approximately A.D. 1 to 450, although some have proposed a much earlier beginning date of around 1,000 B.C. (Lister 2004). Basketmaker II is a transitionary stage in respects to subsistence and sedentism. Although domesticates such as corn and squash occur at archaeological sites in the Southwest dating to this period, the majority of food was still derived from wild plants and game. However, groups were experimenting with small scale cultivation on a seasonal basis in some areas. This new skill may have been an important factor contributing to some groups’ ability to occupy formerly unoccupied areas in the Mesa Verde Region. Prehistoric groups were certainly increasingly less mobile during this period, occupying individual sites seasonally for longer durations. The majority of identified Basketmaker II sites occur in prominent caves and rockshelters (Plog 1979). These cave sites served as habitation sites as well as for storage or burial (Nickens 1982). Open air habitation sites dating primarily to the latter part of this period have also been discovered in the Four Corners’ region (Matson 1994). These sites are characterized by shallow pithouse depressions and slab lined storage cists (Nickens 1982, Lancaster et al. 1954). As the name may suggest, the Basketmaker II period is known for the finely made baskets and bags that are often found in dry cave deposits from the period. No cultural deposits dating to this period have been discovered within Mesa Verde, although some have speculated of their possible existence below later Puebloan deposits (Lancaster et al. 1954).

Basketmaker III dates from A.D. 450 to around 700, and represents the first definitive occupation of the Mesa Verde proper. Localized Mesa Verde chronologies often refer to this period as the La Plata Phase (Hayes and Lancaster 1975, Plog 1997). Population
during this period increases significantly in the region with many Basketmaker groups spreading into formerly unoccupied areas. Additionally, several important advents have come to characterize the Basketmaker III period. Pottery becomes widespread during this period. Early pottery assemblages on the mesa are dominated by plain gray-ware ceramics known as Chapin Gray. Chapin Black-on-white pottery also occurs, but to a lesser extent (Cordell 1997, Lancaster et al. 1954). The bow and arrow comes into general use at this time gradually replacing the atlatl as the primary hunting implement (Plog 1979). Plog (1997) has suggested that this shift may have occurred in response to a focus on hunting small animals that would have accompanied greater reliance on plant resources. A greater reliance on plant foods including cultivated crops may be inferred by the introduction and widespread use of trough metates during this period. In addition to corn and squash, beans were added to the diet.

The majority of Basketmaker III sites within Mesa Verde are located on mesa tops, and often occur in site clusters. These groups of multiple habitation sites represent the beginnings of village life at Mesa Verde. Basketmaker III sites have also been found in rockshelters, but to a much lesser extent (Cordell 1997, Hayes and Lancaster 1975). Habitation sites seem to have maintained a much more standardized form than in previous periods. Pithouses were generally shallow until the latter part of the 7th century when deeper forms (4-5 feet) became common (Hayes and Lancaster 1975). Common pithouse characteristics included antechambers oriented to the south, clay lined central hearths, a distinctive four-post superstructure support system, banquettes, and slab lined storage pits (Cordell 1997, Nickens 1982). Toward the latter part of Basketmaker III when deeper pithouse forms became the rule; several aspects that would subsequently
come to characterize kivas became well established. These features included a bench, sipapu, deflector, and ventilator.

Pueblo I dates from A.D. 700 to 900, and is known as the Piedra Phase on Mesa Verde. Although the population remains similar or slightly higher than in Basketmaker III times, sites from this period seem to be less evenly distributed. Habitation sites often occur in groups with several settlement clusters. Populations at some of these settlement clusters have been estimated at 600 individuals (Cordell 1997). Sites were most often clustered in areas that had rainfall that was adequate for agriculture, such as mesa tops near well watered drainages. This phenomenon left some areas in the region such as Cedar Mesa in southeastern Utah very sparsely occupied (Matson et al. 1988). Although not yet widespread, this is the period when water control devices were used for the first time. These included field terracing, irrigation, and field gridding (Plog 1979). By this period and continuing through Pueblo III times it has been estimated that cultivated maize contributed approximately 70-80% of the calories in the Puebloan diet (Decker and Tieszen 1989).

Fully above ground structures were constructed for the first time during Pueblo I times. Originally these were crudely made jacal storage structures built of interwoven sticks and twigs coated in mud resting on an upright slab foundation (Cameron 1999). These original forms were eventually replaced by more permanent crude masonry pueblos used for habitation. Individual settlements were fairly uniform in construction. They usually consisted of either a single arc of above ground rooms or several parallel rows of rooms. Both forms continued to be associated with deep pithouse structures generally situated in front of an arc of rectangular habitation rooms. Although their
function varies through time, subterranean structures persist throughout the prehistoric period and even into the historic times.

Ceramic styles and wares became much more varied and abundant during this period. In addition to Chapin Gray and Chapin Black-on-white, Moccasin Gray, Piedra Black-on-white, Abajo Red-on-orange, and Bluff Black-on-red commonly occur at sites in the region dating to Pueblo I (Cordell 1997).

Pueblo II dates from A.D. 900 to 1100. Within Mesa Verde this period has been divided into the Ackman Phase dating from A.D. 900 till around 975 and the Mancos Phase dating from A.D. 975 to approximately 1060. The Period also includes a portion of the McElmo Phase which dates from A.D. 1060 to 1140, and extends into the latter Pueblo III period (Hayes and Lancaster 1975, Plog 1997). This period saw a general population decrease in the region. A lower population is indicated by a settlement pattern consisting of smaller, more widely scattered settlements. Pueblo II settlements occur in geographically diverse locations including talus slopes, low ridges, and mesa tops. The general population decrease within Mesa Verde may be due at least in part to the fluorescence of the Chacoan culture to the south during this period which may have drawn inhabitants from the Mesa Verde region (Cordell 1997, Varien et al. 1996).

Masonry architecture was continually refined during the period, eventually double-coursed, horizontal masonry with shaped stones became the rule. It was also during Pueblo II that the deep pithouse structures from the previous period made a complete transition to stone lined ceremonial rooms known as kivas. Kivas were circular, subsurface structures that had a consistent set of internal features including: a bench encircling the interior, several masonry pilasters rising from the benches to support the
superstructure, banquettes between the pilasters, ventilators, hearths, sipapus, and four-post roof supports. Latter in the period wall niches, a deep southern recess, and a characteristic six pilaster form became common. Artifacts recovered from kivas dating to this time indicate that kivas served multiple functions in both the domestic and ritual realms. Settlement layout was similar to that of the previous period with a row of habitation rooms opening to a kiva in the front. These settlements are generally considered to represent nuclear family or extended family units conforming to the Prudden unit model of settlement (Prudden 1903). Unordinarily large kivas known as great kivas were sometimes built during this period in association with multiple settlements, and are thought to represent larger scale integrative architecture where communal gatherings occurred.

By Pueblo II the majority of the prehistoric Puebloan diet was derived from food production. Although dry farming was still the rule, intensified agricultural practices are indicated by an increased use of water control features such as reservoirs, canals, terraces, and grid systems (Cordell 1997, Plog 1979). Ceramic technology is once again diversified with the addition of corrugated pottery styles. These included two main types, Mancos Corrugated and Dolores Corrugated. Common local painted wares included Cortez and Mancos Black-on-white. In addition, several types of imported trade-ware ceramics have been found at Pueblo II sites. Puerco and Tusayan Black-on-red, as well as Sosi, Dogozhi, Gallup, and Escavada Black-on-white types were all imported to the Mesa Verde region during later Pueblo II times (Cordell 1997, Lancaster et al. 1954).

Pueblo III dates from A.D. 1100 to 1300. This period has been divided into the latter part of the McElmo Phase and the Mesa Verde Phase which dates from A.D. 1140 to
1300 (Hayes and Lancaster 1975, Plog 1997). Population increases during this period, and in the beginning settlements are fairly evenly distributed among a variety of eco-zones including canyon rims, rock shelters, talus slopes, and in canyon bottoms (Cordell 1997, Lancaster et al. 1954). Some sites in the region during the McElmo Phase have been characterized as Chacoan-style great houses. These sites have a distinctive set of characteristics associated with the Chacoan culture. By A.D. 1130 it appears as if the political power and dominance at Chaco had shifted north to the San Juan Region centering around Aztec Ruin (Leckson and Cameron 1995, Plog 1997). Located approximately midway between Chaco Canyon and Mesa Verde, the ascendancy of Aztec Ruin occurred during the decline of Chaco Canyon. This shift also seems to correspond with the introduction of Chacoan-style structures to the Mesa Verde Region.

The latter part of the period or Mesa Verde Phase can be characterized as the “Classic” period of Puebloan culture at Mesa Verde (Lancaster et al. 1954). It was during this phase that settlements contracted and aggregated into rock shelters. By the mid 13th century many habitation sites were located in the numerous sandstone alcoves that dot the cliffs of Mesa Verde. The Mesa Verde Phase is particularly relevant this study because both of the sites being examined, Spruce Tree House and Nordenskiold’s 12, were constructed and occupied during the period. An often discussed topic of Mesa Verde archaeology is why the prehistoric Puebloans moved into such precariously situated habitation sites. One of the few advantages of living in a cliff house is that they are located in very defensible positions. The development of tower kivas and the construction of walls around some mesa top settlements have also often been interpreted as defensive features. Recent research indicates abundant evidence of warfare and
violence during the period; however, it does not appear to have been much more rampant or widespread than in previous periods (Lipe 2002). One frequently discussed question is: who were the Puebloans defending against? Perhaps there was infighting and feuding among Puebloan communities, or maybe as some have suggested the mere threat of violence and raid from some outside party was enough motivation for the Puebloans to seek refuge in the cliffs (Cordell 1997). Large aggregated mesa top villages also occur in the region during this period, but not within the Mesa Verde proper. These villages often contained 50 or more structures. Aggregated settlements were frequently surrounded by small number of dispersed one and two family habitation sites.

As constrained by the individual characteristics of the alcove being occupied, cliff dwellings were of necessity a variety of shapes and sizes. However, general architectural techniques, forms, and features were widespread. In general, architecture was more elaborate during this period. Cliff houses often consisted of multistoried room blocks accompanied by multiple kivas that were incorporated into the room blocks instead of being separate from them as in previous periods. As previously mentioned the shape and size of cliff houses vary considerably from one room sites to the largest of the cliff houses, Cliff Palace that had about 220 rooms and 23 kivas. Shaped sandstone blocks with small chinking stones placed in the mortar between stones was a common construction technique. Tree-ring dates indicate that a large majority of cliff houses were built during a 30 year flurry of construction lasting from A.D. 1230 to 1260, after which building activity ended fairly abruptly (Lancaster et al. 1954). By the mid 1280’s Mesa Verde had been abandoned, and much of the surrounding region experienced a dramatic reduction of population.
Prehistoric Puebloans continued to construct a variety of water control devices as their dependence on agricultural production only became more pronounced during this period. Perhaps the most impressive was a man-made reservoir known as Mummy Lake located on Chapin Mesa. The roughly circular reservoir was about 30 m in diameter and was bounded by earthen banks supported by a masonry-wall. Water collected in the reservoir could be diverted to several farming terraces. In addition a large canal took the water nearly 4 miles down the main ridge of Chapin Mesa providing several villages with water (Plog 1979, 1997, Rohn 1963, Wilshusen et al. 1997). Such a large scale water-works project that served a number of communities with different needs indicates a complex level of cooperation and interaction between villages.

Perishable artifacts from cliff house contexts are typically characterized by a superb state of preservation. This has allowed archaeologists to get a unique look into the lives of these cliff dwelling Puebloans. A number of perishable artifacts have been recovered from these dry cave sites including baskets, mats, fire drills, bags, sandals, and a variety of other clothing items. In stark contrast with the previous period, ceramics recovered from the cliff houses were almost exclusively produced locally and primarily include Mesa Verde Corrugated and Mesa Verde Black-on white types.

The ultimate abandonment of the Mesa Verde Region by prehistoric Puebloan groups can perhaps best be attributed to a combination of factors rather than any single impetus. Tree ring studies indicate that the region experienced a severe drought that lasted from A.D. 1276 to 1299, probably not coincidentally coinciding with the Mesa’s abandonment (Lancaster et al. 1954). Environmental degradation caused by widespread deforestation which in turn led to a significant loss of topsoil on the mesa tops may have been a factor
If the causes were exclusively environmental one would not expect the abandonment of the Mesa to be so absolute. For this reason many have proposed social causes. Although seemingly less apparent within the Park, it is well established that violence was a part of everyday life for the prehistoric Puebloans in the region (Kuckelman 2002). However, it certainly does not appear that warfare or the threat of violence alone provided enough motivation to cause such a widespread exodus. Community level internal strife has also been proposed as possible factor (Cordell 1997). It may be that social turmoil was accentuated by a less than average climatic regime. This may have in turn led to social fracturing probably occurring along kin lines. Some have indicated that such fracturing may have occurred due to a lack of integrating social mechanisms. The adoption of kachina ceremonialism, just such an integrating mechanism, by large aggregated Puebloan groups to the south during later years may have been a response to the failed attempt at large scale aggregation in the Mesa Verde Region (Lekson and Cameron 1995). More than likely it was a combination of multiple “push” and “pull” factors that ultimately led to a Puebloan migration out of the region (Cameron 1995, Lipe 1995, Varien et al. 1996).

Puebloan groups abandoning the region moved in a southern and southeastern direction aggregating with other Puebloan groups into larger villages in Arizona and New Mexico. This aggregation eventually led to the formation of the large historic and modern Pueblo groups, namely the Hopi, the Zuni, and the Rio Grande Pueblos. Some archaeologists use the presence of Galisteo Black-on-white ceramics in the Northern Rio Grande as evidence that a majority of those who left the Mesa Verde region ended up in the Rio Grande. Minus the use of local materials, Galisteo Black-on-white is nearly
identical to Mesa Verde Black-on-white (Roney 1995). Although some argue that this may simply be a result of regional interaction, there does appear to be a sharp increase in the number of Rio Grande sites after A.D. 1300 (Cameron 1995). However, there doesn’t seem to be any massive influx of immigrants and minus the introduction of a Mesa Verdean ceramic style there seems to be scant evidence of immigrant intrusion in the Rio Grande sites. The abandonment of Mesa Verde appears to have been a very divisive matter occurring over the span of about 25 years. It appears that communities were abandoned as small kin groups left one at a time, rather than any single massive exodus. Dissatisfaction with their previous social or ideological situation would have caused these groups to quickly assimilate to the local social environment in the receiving regions. Due to this, one would not expect to find much evidence of a Mesa Verdean presence in these new regions.

Mesa Verde Phase Social Organization

Despite the large scale aggregation that continued throughout the A.D. 1200’s, it appears that power was not centralized within Puebloan society. Community leadership was probably situational and skill-based. Lipe (1994) has suggested that the high degree of uniformity in housing and material culture indicate that the Puebloans may have practiced an “ideology of egalitarianism.” This idea is certainly bolstered by the distinct lack of evidence for a hierarchy. Although the architecture-based research carried out by Metcalf (1997) indicates a similar pattern of undifferentiated egalitarian leadership, her research also points out the possibility of experimentation with several different leadership and political organizational modes in the region.
Adler (1990, 1994) sees aggregation occurring as a response to a combination of population growth, agricultural intensification, and uncertainty in the natural and social environments. In his view large aggregated villages enabled groups to better maintain land and water rights during a period of moderate resource scarcity. The location of many of the largest sites from the period near critical water sources certainly indicates a concern for maintaining access to those sources. In general, communities tended to be more and more independent during the 1200's, although this trend is less pronounced within the Mesa Verde proper. Rohn (1977) provides an example where several communities on Chapin Mesa interacted on a daily basis sharing access to resources such as water and land. In addition, communities shared integrative ritual structures such as towers, great kivas, and D-shaped structures. In some situations these ritual structures are directly associated with storage rooms. The presence of storage facilities at these sites indicates authority over their collection and distribution was probably held by a few who also possessed certain ritual knowledge. As Lipe (2002) indicates, the construction and use of public architecture such as great kivas implies the exercise of social power. However, the extent of this power does not appear to have been either great or widespread.

By A.D. 1200, 40% of the population was living at sites with three or more resident households (Adler 1994). Many of these sites may have been made up of more than one primary resource access group, which is defined by Adler (1994) as the group controlling direct access to a resource such as arable land. Despite this, each household had its own storage indicating that the household remained the primary unit of production and consumption. Adler reasons that since land tenure systems do not leave physical residues
more abstract methods must be used to interpret past land-rights systems. Methods evoked by Adler include a combination of theories drawn from other disciplines with ethnographic research. Certainly, much insight can be gained from such studies, but the research presented here indicates that land tenure systems may leave physical residues within structures the prehistoric Puebloans left behind. Soil used as mortar for the construction of masonry architecture may indicate exclusivity in source selection, and therefore may aid in the interpretation of prehistoric land tenure systems.

The Kiva

Due to the fact that kivas were the structures exclusively tested during this project a more detailed description of the nature of prehistoric Puebloan kivas will be provided here. Information pertaining to the history, construction, and function of the kiva can be derived from two primary sources. The first is archaeological interpretation which is generally not mutually exclusive from the second, which is the mass of ethnographic literature drawn from studies of the historic pueblos. Unfortunately as Upham (1989) so soundly recognizes, ethnographic analogy, particularly in the case of the historic pueblos can be fraught with inaccuracy and misinterpretation. That the historic pueblos are not a pristine example of aboriginal life in the Four Corners region can be generally assumed given at least two periods of rapid change that occurred within the pueblo world. The first event occurred during the prehistoric period and has been described above. This is the period when much of the Mesa Verde Region was abandoned during the late 13th century. It appears that the disbursed migrating groups were rapidly assimilated into the receiving regions. Evidence indicates that one consequence of this rapid integration may have been the adoption of new ideologies toward the form and function of the kiva (Lipe
1995, Varien et al. 1996). The second period occurred during that time period that directly followed initial Spanish contact with the Pueblos; otherwise know as the Protohistoric Period. The Protohistoric Period was characterized not only by rapid change of Puebloan ideology, but also in day to day life. Due to the difficulties inherent in interpreting the nature of the Mesa Verde kiva, the descriptions and interpretations provided in this section will come from a variety of sources and viewpoints.

As Mindeleff (1989 [1891]) observed, the prehistoric form of the kiva deviates considerably from historic or modern analogs. However, the general form of the kiva during the Mesa Verde Phase remains quite consistent and widespread. Perhaps the most obvious of the similarities is the characteristic circular subterranean masonry form. In addition, interior features of Mesa Verde kivas from this time period share a suite of similar characteristics. These features include a ventilator shaft, deflector, firepit, sipapu, bench, pilasters, roof hatchway, and a southern recess (see Figure 3). Historic kivas often share one or more of these features, but none in their entirety. One ideologically significant feature which persists in many modern kivas is the sipapu. The sipapu is a circular hole in the floor of the kiva that imitates the original house of human creation through which human kind climbed to the surface of the earth. Historically the sipapu was ritually used to evoke special powers and spirits (Mindeleff 1989 [1891], Titiev 1992).

Historically, kivas were owned by the clan whose member or members took the initiative in building them or restoring them from a state of disrepair (Howard n.d., Stephen 1969, Titiev 1992). Most ethnographic accounts indicate that men did much of the heavy construction work such as placing floor and ceiling beams, and retrieving and
dressing the stones. However, beyond those tasks it appears that the women were largely responsible for laying the masonry and finishing the structures (Mindeleff 1989 [1891], Stephen 1969, Zulauf 1982). Historically this pattern seems to be the case no matter the construction project, be it a kiva or a new habitation room. In one example of structure repair described by Stephen (1969) he observes six old women retrieving clay, sand, and water to be mixed as mortar for the masons. He later describes women bringing earth and water to the construction site, mixing the mud, and chinking the structure wall. In addition, Mindeleff (1989 [1891]) observed women retrieving earth and water to be mixed into a mud plaster. It appears that in most cases new construction and repair was a group effort characterized by a distinct division of labor (Dozier 1960, Stephen 1969).

Figure 3. (illustration by Eric Carlson)
One aspect of kiva upkeep is well described in the ethnographic literature. In preparation for seasonal ceremonies, most notably including the Buffalo Dance and the Pawamu ceremony, young men and women were expected to replaster and decorate the kivas. A variety of references describe young women plastering smoke blackened kiva walls (Mindeleff 1989 [1891], Stephen 1969, Zulauf 1982). It is not clear who was charged with the retrieval of the plastering mixture, but it is clear that the mixture varied. Sometimes the walls were whitewashed as Mindeleff (1989 [1891]) describes with gypsiferous clay found “...in the neighborhood.” Other times the kiva walls were given an entirely new plaster coat as Stephen (1969) describes as being composed of a “...mud mixture of valley sand.” It does not appear from the ethnographic descriptions that specific plasters were being used in correlation with specific seasonal ceremonies, however this point remains unclear.

There are fewer ethnographic references describing the retrieval and application of masonry mortar. However, Mindeleff (1989 [1891]) does describe that construction was often dependant upon adequate water supplies. Due to the fact that a significant amount of water was needed to mix both mortar and plaster, construction was often opportunistic and occurred during periods of abundant water supply. In addition, those groups residing in drier environments would often use little mortar while those with a more reliable water source would use liberal amounts of mortar and plaster during construction (Mindeleff 1989 [1891]). In one observed incidence at Zuni Pueblo Mindeleff describes the retrieval of adobe bricks directly from the fields. The use of building materials taken from a controlled resource such as an agricultural field hints at the possibility of gaining a perspective on prehistoric land tenure through an analysis of preserved building
materials. For example, if through geochemical analyses it can be proven that the prehistoric Puebloan at Mesa Verde were retrieving soil to be used as mortar from agricultural areas on the mesa tops, then through an analysis of multiple structures it may be possible to determine the makeup of the group who had access to those agricultural areas. Such interpretations are, of course, dependant upon the ability to chemically differentiate mortar sources on a fairly fine grained level. One of the goals of this research is to explore that possibility.

The varied functions of historic kivas have been fairly well documented, and are largely based on supra-household level societal organizations that differ among the historic pueblos. For example, among the Hopi kivas are primarily associated with clanship, while among the Zuni kivas are associated with the kachina cult. On the other hand, in the Eastern Tewa and Keres Pueblos kivas are associated with the moiety organization. Within these various organizations kivas served a variety of purposes. Mindeleff (1989 [1891]) describes Hopi kivas being used by men for weaving, retreat, and ceremony. Among the modern Pueblos kivas functioned as a ceremonial hub where participants in a specific ceremony, primarily males, would gather to partake in certain rites and rituals associated with that particular society’s involvement in the ceremony. Use of a kiva for ritual purposes was a privilege granted to members of a specific clan or group, and was therefore exclusionary by its nature. Although women and children were allowed in kivas under certain circumstances, use of the kivas, both ritual and mundane, was male dominated.

Although for the most part it is thought that Hopis do not directly descend from prehistoric Mesa Verde populations, Howard (n.d.) lists seven reasons why the Mesa
Verde kiva may be most closely associated with that of the Hopi. One of the reasons Howard states is that both groups used multiple kiva systems. Despite this obvious similarity, the actual distribution of kivas was uniquely different. At Mesa Verde kivas were incorporated into house blocks as a component of the living space for a nuclear or small extended family. There is ample evidence to indicate that in addition to being used as a household level ritual structure, kivas at Mesa Verde also functioned as a primary domestic space (Kohler 1993, Lekson 1996, Lipe 2002). However, it appears that the household level kiva so characteristic of Mesa Verde did not survive the abandonment of the region (Lipe 1995, Varien et al. 1996). Household kivas disappeared in favor of kivas serving much larger social groups, such as those historically known societies described above. It has been suggested that these larger kiva based societies such as kachina ceremonialism are better suited for successfully integrating large aggregated populations and a lack of such mechanisms may be partially to blame for the abandonment of Mesa Verde (Lekson and Cameron 1995).
CHAPTER 4

METHODOLOGY

The research presented here was carried out in two phases. The first involved the actual collection of mortar and plaster samples from two cliff dwelling sites within Mesa Verde National Park. The second entailed the laboratory analysis of the collected samples. The sites involved as part of this research were chosen as a result of interest and priority expressed by Park employees. Ultimately, two sites (Spruce Tree House and Nordenskiold's 12) were selected to be sampled as part of this study (see Figures 4 and 5 for maps).

Field Procedures

With the assistance of Dr. Patrick Drohan of the UNLV Geoscience department and Rebecca Carr of the Park Service field specimens were collected from these two sites during August of 2004. A series of 22 mortar samples were removed from seven kivas at Spruce Tree House, and 18 mortar samples were removed from five kivas at Nordenskiold’s Ruin12 (see Tables 3 and 4 for exact provenance of each sample removed). During field collections, close attention was paid to maintaining precise sample provenance. In addition to detailed notes, photographs of each of the sampled locations were taken to ensure no provenance was lost during sample retrieval. Each kiva
was inspected to determine potential sampling locations based on criteria discussed below. Upon determination of a proper sampling location bulk mortar samples (approximately 5-10 grams) were removed using dental picks and a trowel. They were then designated with a unique number and site code, and stored in an individual tin foil pouch. At least three samples were removed from each of the kivas sampled at each site. Each of the three samples removed from any one kiva were taken from spatially distinct

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Kiva</th>
<th>Location of Removal</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>STH 1</td>
<td>I</td>
<td>B, IPS 2-3 (behind IPS 3-4 of Kiva A)</td>
<td></td>
</tr>
<tr>
<td>STH 2</td>
<td>I</td>
<td>B, IPS 2-3 (behind IPS 3-4 of Kiva A)</td>
<td></td>
</tr>
<tr>
<td>STH 3</td>
<td>I</td>
<td>B, IPS 3-4 (behind IPS 3-4 of Kiva A)</td>
<td></td>
</tr>
<tr>
<td>STH 4</td>
<td>A</td>
<td>B, IPS 3-4</td>
<td></td>
</tr>
<tr>
<td>STH 5</td>
<td>A</td>
<td>B, IPS 2-3</td>
<td></td>
</tr>
<tr>
<td>STH 6</td>
<td>A</td>
<td>B, IPS 2-3</td>
<td></td>
</tr>
<tr>
<td>STH 7</td>
<td>C</td>
<td>B, IPS 1-2</td>
<td></td>
</tr>
<tr>
<td>STH 8</td>
<td>C</td>
<td>B, BP 3</td>
<td></td>
</tr>
<tr>
<td>STH 9</td>
<td>C</td>
<td>B, IPS 5-6</td>
<td></td>
</tr>
<tr>
<td>STH 10</td>
<td>D</td>
<td>B, BP 1</td>
<td></td>
</tr>
<tr>
<td>STH 11</td>
<td>D</td>
<td>B, BP 3</td>
<td></td>
</tr>
<tr>
<td>STH 12</td>
<td>D</td>
<td>B, BP 3</td>
<td></td>
</tr>
<tr>
<td>STH 13</td>
<td>E</td>
<td>B, IPS 1-2</td>
<td>persistence of red colored mortar a possible result of oxidation (burning event)</td>
</tr>
<tr>
<td>STH 14</td>
<td>E</td>
<td>B, IPS 6-1</td>
<td></td>
</tr>
<tr>
<td>STH 15</td>
<td>E</td>
<td>B, IPS 4-5</td>
<td></td>
</tr>
<tr>
<td>STH 16</td>
<td>E</td>
<td>B, BP 3</td>
<td></td>
</tr>
<tr>
<td>STH 17</td>
<td>G</td>
<td>B, IPS 2-3</td>
<td></td>
</tr>
<tr>
<td>STH 18</td>
<td>G</td>
<td>B, IPS 4-5</td>
<td></td>
</tr>
<tr>
<td>STH 19</td>
<td>G</td>
<td>UW, IPS 4-5</td>
<td></td>
</tr>
<tr>
<td>STH 20</td>
<td>H</td>
<td>B, BP 4</td>
<td></td>
</tr>
<tr>
<td>STH 21</td>
<td>H</td>
<td>B, IPS 2-3 (right side of interior niche)</td>
<td></td>
</tr>
<tr>
<td>STH 22</td>
<td>H</td>
<td>UW, IPS 4-5</td>
<td></td>
</tr>
</tbody>
</table>

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Table 4. Location of mortar sample removal at Nordenskiold’s Ruin 12. (B-banquette, P-pilaster, IPS-interpilaster space, BP-below pilaster, UW-upper wall, SR-southern recess)

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Kiva</th>
<th>Location of Removal</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>N12-1</td>
<td>E</td>
<td>B (fallen), IPS 3-4</td>
<td></td>
</tr>
<tr>
<td>N12-2</td>
<td>E</td>
<td>B, IPS 4-5</td>
<td></td>
</tr>
<tr>
<td>N12-3</td>
<td>E</td>
<td>B, IPS1-2</td>
<td></td>
</tr>
<tr>
<td>N12-4</td>
<td>D</td>
<td>B, BP 1</td>
<td></td>
</tr>
<tr>
<td>N12-5</td>
<td>D</td>
<td>B, IPS 2-3</td>
<td></td>
</tr>
<tr>
<td>N12-6</td>
<td>D</td>
<td>SR, east side P-4</td>
<td>water erosion present on surface</td>
</tr>
<tr>
<td>N12-7</td>
<td>C</td>
<td>B, IPS 2-3</td>
<td>roomblock or kiva episode</td>
</tr>
<tr>
<td>N12-8</td>
<td>C</td>
<td>B, IPS 2-3</td>
<td>kiva episode</td>
</tr>
<tr>
<td>N12-9</td>
<td>C</td>
<td>UW, IPS 5-6</td>
<td>kiva episode</td>
</tr>
<tr>
<td>N12-10</td>
<td>C</td>
<td>SR, east side P-4</td>
<td>kiva episode</td>
</tr>
<tr>
<td>N12-11</td>
<td>C</td>
<td>UW, IPS 4-5</td>
<td>sealed doorway from roomblock episode, distinct appearance</td>
</tr>
<tr>
<td>N12-12</td>
<td>B</td>
<td>B, IPS 2-3</td>
<td></td>
</tr>
<tr>
<td>N12-13</td>
<td>B</td>
<td>B, IPS 4-5</td>
<td></td>
</tr>
<tr>
<td>N12-14</td>
<td>B</td>
<td>B, IPS 1-2</td>
<td></td>
</tr>
<tr>
<td>N12-15</td>
<td>A</td>
<td>B, BP 4</td>
<td></td>
</tr>
<tr>
<td>N12-16</td>
<td>A</td>
<td>B, BP 3</td>
<td></td>
</tr>
<tr>
<td>N12-17</td>
<td>A</td>
<td>B, IPS 3-4</td>
<td></td>
</tr>
<tr>
<td>N12-18</td>
<td>A</td>
<td>north side of interior “altar”, IPS 3-4 side</td>
<td></td>
</tr>
</tbody>
</table>

locations within the structure for two reasons. The first reason was to minimize potential structural impact to any one area within the kiva. The second reason the samples were scattered was to gain the broadest possible perspective on within kiva mortar selection. Fortunately, the analytical techniques only require small sample sizes and therefore impact to the structures was minimal.

The utmost care was taken to ensure that the bulk samples retrieved were of the greatest quality and not compromised or contaminated in any way. In order to assure this, several considerations described below were strictly observed during sample retrieval. The exterior surface of the mortar is exposed and prone to contamination.
from a variety of sources. For example, active water runoff often causes a condition of soil wash easily recognizable in the field by a thin layer of tan-brown soil and deep runnels extending from the upper wall and banquette ledges (Matero 2003). The obvious impact of an active water runoff is both the mixing of mortar components from different parts of the kiva, and the incorporation of new materials from an external source into the preexisting mortar surface. In addition, eolian influx of sediments from surrounding regions can also cause new materials to be incorporated into the surface mortar matrix. Wind blown loess can be a significant possible source of contamination given the desert environment surrounding Mesa Verde. The exposed mortar surface is also prone to
calcination and oxidation of the iron-bearing minerals in the clays (Matero 2003). This condition readily exhibits itself as a distinct color change. Oxidation most often occurs as a visible surface reddening that diminishes with depth. Another potential impact that could affect the mortar surface is if at some point in its history the kiva was burned. Burning of a subterranean structure such as a kiva can often exhibit itself as a reddening most visible in the lower portions of the structure.

Each of the above listed considerations has the potential to individually or in tandem with one of the other processes disguise the true crystalline morphology and elemental makeup of the original mortar. In order to avoid potential contamination from any of these sources only internal mortar samples were retrieved. During sample retrieval the outer, potentially contaminated, layers were removed to an approximate depth of 3-5mm thereby exposing the more pristine interior of the mortar which was carefully removed as a bulk sample.
Taking internal samples does not, however, guarantee an unaltered prehistoric mortar sample. Two other important factors must also be taken into consideration. The fact that this research exclusively involved the sampling of below-ground kivas presents its own unique challenges. Soil weathering processes could impact the mineralogical/elemental makeup of the mortar originally used to build these structures. Given the environmental conditions of the alcoves in which these cliff dwellings are located, if present, pedogenic processes will most likely take the form of an accumulation of soluble salts in the subsurface. As exhibited at Mug House (Matero 2003) salt accumulation will occur as discrete nodules of carbonates and to a lesser degree sulfates. The elevation at which these accumulations occur and the exact locations where they occur are dependant upon the source of moisture and the depth of wetting at the locations the kivas occupy. An analysis of the mortar from these areas could certainly give a false impression as to the amount of carbonates that were originally incorporated into the mortar during initial construction. In order to avoid faulty interpretations, detailed notes were taken when carbonates were encountered during sample retrieval. Soluble salts accumulating in the subsurface are easily recognizable as such, being distinguished by their unique morphology.

Another consideration that was taken into account during sampling was the careful avoidance of modern mortars that have been used by the Park Service for repair and stabilization work on the ruins. These alterations are most prevalent at the large sites that have specifically been prepared to receive a large numbers of visitors. For example, Spruce Tree House has experienced a long history of maintenance and stabilization beginning in the early 20th century with the work of Fewkes. A summary of the history

53

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
of stabilization work at Spruce Tree House has been compiled by Horn (1989). Unfortunately the quality of recordation involved in the stabilization work varies widely, and therefore historic documentation may not be the most efficient method of determining details of precisely where stabilization and reconstruction has taken place. However, the mortars used for historic stabilization are visually distinct from their prehistoric counterparts and often easily recognizable in the field. Distinguishing characteristics include the incorporation of ash or charcoal in the mortar matrix, the stage of erosion, and perhaps the most telling attribute is the color. Therefore, visual on-site inspection when coupled with the existing historic documentation was the most effective method for distinguishing between historic and prehistoric mortars. The greatest care was taken to avoid historic mortars during sampling, and detailed notes were taken if there were concerns as to the antiquity of the mortar being sampled. In many structures, the lower the sample is taken from within the structure, the less likely it was to have been part of a reconstruction effort. Therefore, one practical step that was taken to avoid modern mortars was to retrieve samples from the lower sections of the kiva banquette walls.

Similar procedures were followed during the retrieval of plaster samples. The location of plaster sample removal was largely dependant upon three main factors. First, only kivas with sufficient amounts of remnant prehistoric plaster covered surfaces were considered. Second, kivas with large amounts of historic reconstructed plaster surface were avoided. Unfortunately, due to the extensive reconstructive work that has taken place at Spruce Tree House, this effectively eliminated Spruce Tree House kivas as possible sampling sites. Third, the sample site selections were based on Park Service
direction and interest. Ultimately, a series of seven plaster samples were removed from three kivas on the west side of Ruin 12 (see Table 5 for exact provenance). Dental picks were used to carve out samples with an approximate diameter of 2-3 cm. The depth of removal was dependant on the thickness of the plaster layers, but ranged 1-2 cm. Due to the nature of the analytic technique employed on these samples it was not necessary to remove the outer layer of the samples.

Table 5. Location of plaster samples removed from Nordenskiöld’s Ruin 12. (B-banquette, IPS-interpilaster space, BP-below pilaster)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Kiva</th>
<th>Location of Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>E</td>
<td>B, IPS2-3</td>
</tr>
<tr>
<td>C</td>
<td>E</td>
<td>B, IPS2-3</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>B, BP 2</td>
</tr>
<tr>
<td>E</td>
<td>D</td>
<td>B, BP 2</td>
</tr>
<tr>
<td>G</td>
<td>D</td>
<td>B, BP 2</td>
</tr>
<tr>
<td>J</td>
<td>C</td>
<td>B, IPS 3-4</td>
</tr>
<tr>
<td>L</td>
<td>C</td>
<td>B, IPS 5-6</td>
</tr>
</tbody>
</table>

All other terminology and field collection procedures adhered to the standards as contained in Nordby et al. (2002). By following these field procedures and taking those precautions discussed above the samples that were retrieved should be of the highest quality, and therefore provide the most informative data possible for the analysis and interpretation phase of the project.
Mortar Analysis

Upon completion of the field work phase of the project the bulk samples were taken to the UNLV geoscience labs for storage and compositional analyses. Powder x-ray diffraction (XRD) was completed on samples using a PANalytical X'Pert Pro X-ray Diffraction Spectrometer, Cu (continuous scans were made from 3-70°, speed 2° 2θ per minute)(Whitting and Allardice, 1986). X-ray diffraction (XRD) is a technique that can be used to analyze the crystalline morphology of a variety of substances. In this case the primary interest was the crystalline structure of the suite of minerals of which the mortar samples were composed. XRD works by discharging a beam of x-ray photons from a pre-set range of incident angles upon a prepared sample such as architectural mortar. As these photons encounter a crystalline structure they are diffracted. The angle and intensity of these diffractions are collected in a detector on the opposite side of the incident beam. The exact parameters of these diffractions are specific to unique crystalline morphology and can therefore be interpreted as representing certain mineral components occurring in a sample. The XRD patterns are recorded as a series of points that can then be connected as a line graph with a series of spikes plotted against the incident angle and relative intensity. A sequence of related spikes is referred to as a phase which can then be interpreted as representing a certain mineral fingerprint. Data outputs from the XRD machine were analyzed using PANalytical’s X’Pert HighScore Plus software version 2.0.

The purpose of the XRD analysis was to characterize the phases present in each of the samples. This allowed for a determination of the basic mineralogical components. Determining patterns of mineral presence or absence among the specimens is of
particular interest in aiding to answer several of the research questions posed as part of this study. Minerals unique to any one specimen, kiva, or site may be particularly revealing.

Proper recognition of the shortcomings inherent in any analytical technique is a crucial step in ensuring its success as a research tool within any given research context. When analyzing specimens that contain multiple phases, such as mortar, XRD can typically be used to recognize minerals that make up greater than 10% of the specimen. Due to this limitation, minor minerals (<10% of a specimen), will often go unrecognized during the analysis. Other difficulties encountered during data analysis included phase overlap and unresolved peaks. Assigning mineral constituents of a given specimen is not always a straightforward or completely objective procedure. Despite these limitations, enough specimens were analyzed to make mineral patterns in the phase identification process readily apparent, and therefore the majority of phases present in the specimens were identifiable. Another limitation of the study was that in order for accurate quantification of mineral phases present in a given specimen a particle size of 10μm or less must be attained (Buhrke 1998). With no access to a mechanical grinder to attain such small particle sizes, and given cost restraints associated with running specimens through the XRD machine twice, accurate quantification of mineral constituents via the Rietveld refinement method was not possible. Despite this, crude quantification of several specimens was possible using a semi-quantification program available as part of the interpretive software used to analyze the XRD data. Semi-quantification is based on the reference intensity ratio (RIR) of the identified phases within any specimen. Unfortunately, not all mineral phases have an associated RIR, and semi-quantification is
dependant upon each of the identified phases having an associated RIR. Therefore this technique was only available for a limited number of specimens.

The bulk mortar samples were prepared for XRD analysis by following these procedures: First, all of the macroscopically visible organic components were removed from the sample. These organics consisted primarily of small rootlets that had infiltrated the mortar matrix, and variously sized charcoal fragments. Second, the samples were immersed in ethanol and manually ground using a corundum mortar and pestle. Manually grinding samples readily provides a particle size of ~38μm. It is accepted that a particle size of ~44μm-38μm is satisfactory for pattern matching and phase identification (Buhrke 1998). The dried, powdered samples were then ready for analysis. Detailed notes on sample color, texture, and visible constituents were taken throughout the preparation process.

The level of accuracy attained through XRD analysis is dependant upon the total randomness of the crystallite orientations. Randomness depends on several factors dealing with how the specimen is prepared for the machine, but can also be improved by having the machine spin the specimen during data recovery. In order to ensure comparability among the results of the XRD analysis, when the ideal machine settings were determined, the same settings were used for all of the analyzed specimens. Further details concerning exact specimen preparation procedures, and machine specifications and use can be found in Buhrke (1998) and PANalytical (2003).

Inductively coupled plasma – mass spectrometry (ICP-MS) is an analytical technique that can be used to determine both elemental concentrations and isotope ratios in a sample material. The technique has been used successfully in a variety of archaeological
contexts, most notably including various provenience studies such as obsidian sourcing and ceramic clay sourcing (Tykot and Young 1996). Tykot and Young (1996) list four advantages that ICP-MS analysis has over other similar methods. First, only a tiny powdered sample is required. Second, a large number of elements can be precisely analyzed. Third, very accurate isotope ratio measurements are possible. And fourth, the “... combination of small sample size and low per sample cost allows assemblages of artifacts rather than individual objects to be studied. This is critical for the study of patterns of resource exploitation or technological production in the archaeological record.” Specimens analyzed by ICP-MS are introduced into the machine as liquids, and are then atomized and ionized at high temperatures. The atomized/ionized specimen is then passed into the mass spectrometer for separation and measurement. The mass spectrometer measures individual, element specific, mass units which can then be used to determine elemental concentrations within a given specimen. For the purposes of the study presented here 19 individual elements were measured from each prepared mortar specimen. Approximately one gram of the same bulk samples that were prepared for the XRD analysis was used for the ICP-MS analysis. Specimens were sent to the Utah State University Analytical Laboratories (USUAL) to undergo analysis. The resulting data was then analyzed using statistical methods. Applying statistical techniques to the data aided in determining elemental similarities and differences among those mortar samples analyzed. The elemental results allowed those research questions regarding mortar selection to be addressed.

By utilizing both mineralogical and elemental modes of analyses a clear characterization of the mortars is possible. Used in tandem, these techniques provide a
means for determining culturally significant patterns among the data, and for addressing those research questions posed as part of this project.

Plaster Analysis

Due to the distinctively different nature of the subject matter and associated research questions, plaster samples were of necessity given separate treatment than the mortar samples. The plaster samples were first infused with an epoxy resin which when hardened acted to strengthen the plaster matrix. This made it possible to analyze the specimens using a scanning electron microscope-energy dispersive spectrometer (SEM-EDS). Cross sections of the plaster samples were then cut using a diamond saw. Next, the plaster cross-sections chosen for analysis were buffed and polished to 1μm in order to remove any remnant surface topography. Due to the odd shape of a few of the samples, further shaping by saw was necessary in order for the samples to fit into the machine. Samples analyzed by SEM-EDS must be electrically conductive. To ensure the plaster samples would not deflect the primary electron beam away from the surface, the cross-section specimens were sputter-coated with a thin layer of gold. The prepared specimens were then ready for analysis at the UNLV Electron Microanalysis and Imaging Laboratory (EMIL).

The SEM operates by generating and accelerating an electron beam that interacts with a given specimen within the specimen chamber to a depth of 1μ. This interaction generates a signal that is converted into a point-by-point intensity plot on the viewing screen which forms an image of the specimen (Goldstein et al. 2003). After a visual image of the specimen had been established, elemental analysis then commenced. EDS
is an analytic technique that is used in direct association with images generated by the SEM. EDS works by measuring the energy and intensity distribution of the x-ray signal generated by a focused electron beam (Goldstein et al. 2003). The x-rays produced by the interaction of the electron beam with the atoms in a given specimen have characteristic energy that is unique for each element (Jose-Yacaman and Ascencio 2000). EDS is capable of detecting characteristic x-rays of all elements above atomic no. 4.

EDS can be a powerful analytic tool for several reasons, a few of which will be described here. One primary advantage is the “steerability” of the primary beam which can be used to analyze very specific and very small locations on a specimen (Pollard and Heron 1996). In a multi-layered sample such as plaster where compositional variation between layers is of interest, several capabilities of EDS are of particular importance. For example, line scans monitor the change of elemental composition as the electron beam is moved across the surface of the sample. In this technique, individual elemental variation can be viewed in the form of elemental line graphs taken from a predetermined point A to point B. An even more visually powerful technique is an area scan. Area scans produce elemental maps of the surface of a specimen. These maps allow the analyst to visually inspect variation of the elemental content in a predetermined area on a given specimen. In addition to the above mentioned EDS capabilities that were used during the plaster analysis, 15 random point locations within each plaster layer of each specimen were analyzed to ensure that any between layer findings could be found to be statistically valid.

An analysis of the plaster samples by SEM-EDS allowed for an elemental characterization of the layers visible therein. With this characterization in hand, those
research questions dealing with the cultural implications of plaster selection and application could be effectively addressed.
CHAPTER 5

RESULTS

This chapter provides a detailed review of the results of the various laboratory analyses performed on the mortar and plaster samples. The chapter begins with an examination of mortar analyses results. These results include a general macroscopic characterization of the samples, XRD results, and elemental ICP-MS results. Lastly, the results of the plaster analysis will be discussed. The primary analytic technique used to characterize plaster samples was analytical electron microscopy (EDS).

Mortar Analysis Results

One aspect of the analytical results presented here is a general characterization of in-lab samples. This characterization included sample color, texture, macro-organic inclusions, distinctive mineral inclusions, and evidence of soluble salt accumulation. These results have been summarized in Tables 6 and 7.

Prior to grinding the samples in preparation for the ensuing analyses all macroscopically visible organic components were removed. Three types of organic inclusions were noted; rootlets, carbon flecks, and spider webs. The most abundantly occurring organic inclusions were variously sized rootlets that had infiltrated the mortar matrix from the surrounding vegetation. Rootlets were more abundant in samples from
Ruin 12, most likely due to the fact that the site is located in a remote area of the park not maintained by Park Staff for visitor traffic and therefore more susceptible to encroaching vegetation. The second most common organic inclusions were carbon flecks. These carbon flecks ranged in size from barely visible to 5mm. They were likely incorporated into the mortar when during its preparation ash was added to the soil matrix as a binding agent (see Griffitts 2003). The occurrence of ash and accompanying carbon flecks was a fairly widespread occurrence among the mortar samples from both sites, although at least one sample (N12-2) from Kiva E at Ruin 12 exhibited a particularly ashy matrix. The only other organics removed from the mortar samples were spider webs that occurred in

Table 6. Spruce Tree House mortar sample descriptions.

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Kiva</th>
<th>Munsell Color</th>
<th>Macro-organics Removed</th>
<th>Gypsum Soft Masses</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>STH-1</td>
<td>I</td>
<td>10YR7/3</td>
<td>rootlets</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>STH-2</td>
<td>I</td>
<td>10YR7/3</td>
<td>rootlets</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>STH-3</td>
<td>I</td>
<td>10YR7/4</td>
<td>N/A</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>STH-4</td>
<td>A</td>
<td>10YR7/4</td>
<td>N/A</td>
<td>abundant</td>
<td></td>
</tr>
<tr>
<td>STH-5</td>
<td>A</td>
<td>10YR6/3</td>
<td>rootlets, spider webs</td>
<td>absent</td>
<td>hard red sandstone gravel fragment</td>
</tr>
<tr>
<td>STH-6</td>
<td>A</td>
<td>10YR6/3</td>
<td>rootlets</td>
<td>minute</td>
<td></td>
</tr>
<tr>
<td>STH-7</td>
<td>C</td>
<td>10YR7/2</td>
<td>N/A</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>STH-8</td>
<td>C</td>
<td>10YR6/3</td>
<td>N/A</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>STH-9</td>
<td>C</td>
<td>10YR7/3</td>
<td>rootlets, carbon flecks</td>
<td>minute</td>
<td></td>
</tr>
<tr>
<td>STH-10</td>
<td>D</td>
<td>10YR7/3</td>
<td>N/A</td>
<td>abundant</td>
<td></td>
</tr>
<tr>
<td>STH-11</td>
<td>D</td>
<td>10YR7/3</td>
<td>N/A</td>
<td>minute</td>
<td></td>
</tr>
<tr>
<td>STH-12</td>
<td>D</td>
<td>10YR7/4</td>
<td>N/A</td>
<td>abundant</td>
<td></td>
</tr>
<tr>
<td>STH-13</td>
<td>E</td>
<td>5YR7/3</td>
<td>rootlets, carbon flecks</td>
<td>moderate</td>
<td>sandy matrix</td>
</tr>
<tr>
<td>STH-14</td>
<td>E</td>
<td>7.5YR6/3</td>
<td>N/A</td>
<td>minute</td>
<td></td>
</tr>
<tr>
<td>STH-15</td>
<td>E</td>
<td>7.5YR7/4</td>
<td>rootlets</td>
<td>absent</td>
<td>unconsolidated sandy matrix</td>
</tr>
<tr>
<td>STH-16</td>
<td>E</td>
<td>5YR7/3</td>
<td>rootlets, carbon flecks</td>
<td>minute</td>
<td>unconsolidated sandy matrix</td>
</tr>
<tr>
<td>STH-17</td>
<td>G</td>
<td>7.5YR6/4</td>
<td>rootlets</td>
<td>absent</td>
<td>unconsolidated matrix</td>
</tr>
<tr>
<td>STH-18</td>
<td>G</td>
<td>10YR7/3</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>STH-19</td>
<td>G</td>
<td>10YR6/3</td>
<td>N/A</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>STH-20</td>
<td>H</td>
<td>10YR7/3</td>
<td>rootlets, spider webs</td>
<td>absent</td>
<td>noticeably harder matrix</td>
</tr>
<tr>
<td>STH-21</td>
<td>H</td>
<td>10YR7/4</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td>noticeably harder parts in matrix</td>
</tr>
<tr>
<td>STH-22</td>
<td>H</td>
<td>10YR7/3</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td>many small flat shale fragments in matrix</td>
</tr>
</tbody>
</table>
two of the Spruce Tree House samples (STH-5, STH-20). These samples were removed from areas where disintegration and fragmentation of the mortar had allowed spiders to infiltrate the matrix. Although all organic inclusions, e.g. ash, were not entirely removed from the samples, this did not affect the results or the ability to perform the primary analytic techniques used to analyze the specimens.

Table 7. Nordenskiold’s Ruin 12 mortar sample descriptions.

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Kiva</th>
<th>Munsell Color</th>
<th>Macro-organics Removed</th>
<th>Gypsum Soft Masses</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>N12-1</td>
<td>E</td>
<td>10YR6/1</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td>sandy matrix</td>
</tr>
<tr>
<td>N12-2</td>
<td>E</td>
<td>10YR6/1</td>
<td>carbon flecks</td>
<td>absent</td>
<td>ashy matrix, small clear mineral in matrix</td>
</tr>
<tr>
<td>N12-3</td>
<td>E</td>
<td>10YR6/1</td>
<td>carbon flecks</td>
<td>absent</td>
<td>small gravel-size stone in matrix</td>
</tr>
<tr>
<td>N12-4</td>
<td>D</td>
<td>10YR6/3</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td>sandy matrix</td>
</tr>
<tr>
<td>N12-5a</td>
<td>D</td>
<td>10YR6/3</td>
<td>rootlets</td>
<td>absent</td>
<td>removed cemented grave-size stone as b sample</td>
</tr>
<tr>
<td>N12-5b</td>
<td>D</td>
<td>10YR8/2</td>
<td>N/A</td>
<td>absent</td>
<td>very hard and well cemented</td>
</tr>
<tr>
<td>N12-6</td>
<td>D</td>
<td>10YR6/4</td>
<td>rootlets</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>N12-7</td>
<td>C</td>
<td>10YR6/2</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>N12-8</td>
<td>C</td>
<td>10YR7/3</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td>oxidized red pebble inclusion</td>
</tr>
<tr>
<td>N12-9</td>
<td>C</td>
<td>10YR6/2</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>N12-10</td>
<td>C</td>
<td>10YR5/2</td>
<td>carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>N12-11</td>
<td>C</td>
<td>10YR6/1</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td>clay nodule inclusion</td>
</tr>
<tr>
<td>N12-12</td>
<td>B</td>
<td>10YR6/2</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>N12-13</td>
<td>B</td>
<td>10YR6/2</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td>moderate</td>
</tr>
<tr>
<td>N12-14</td>
<td>B</td>
<td>10YR6/3</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>N12-15</td>
<td>A</td>
<td>10YR5/3</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>N12-16</td>
<td>A</td>
<td>10YR5/2</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>N12-17</td>
<td>A</td>
<td>10YR5/3</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
<tr>
<td>N12-18</td>
<td>A</td>
<td>10YR6/3</td>
<td>rootlets, carbon flecks</td>
<td>absent</td>
<td></td>
</tr>
</tbody>
</table>

In addition to organic inclusions, mineral and textural characteristics of the pre-ground samples were also noted. These notes include distinctive mineral inclusions found in the pre-ground samples. Among the Spruce Tree House samples, a hard red
sandstone gravel fragment was found in the matrix of one sample from Kiva A (STH-5). A number of small shale fragments were noted in one sample from Kiva H (STH-22). Three of the four samples removed from Kiva E (STH-13, STH-15, and STH-16) exhibited a particularly sandy matrix in unconsolidated form. A noticeably harder more consolidated matrix was noted in two of the three samples removed from Kiva H (STH-20 and STH-21). Among Ruin 12 samples, a clay nodule occurred in one sample (N12-11) from Kiva C, and an oxidized red gravel inclusion was noted in another sample (N12-8) from the same kiva. In sample N12-5 a well-cemented gravel size inclusion was removed from the matrix to be tested independently and was labeled as N12-5b. Two samples, one from Kiva E (N12-1) and one from Kiva D (N12-4) exhibited a particularly sandy matrix. Lastly, a small unknown translucent mineral was found in sample N12-2 from Kiva E.

Accumulation of soluble salts in the subsurface was evident in several of the samples (see Figure 6). The occurrence of powdery white, soft nodules in many samples indicates active pedogenic processes occurring in many of the sampled kivas. These soft masses exhibited a very mild effervescent reaction to an HCL acid drop test indicating that they are probably composed of gypsum (CaSO$_4$·2H$_2$O). Subsequent compositional analysis of the masses by analytical electron microscopy confirmed earlier acid drop tests (see Figure 7). In addition, a small sample analyzed by XRD confirmed it to be composed of approximately 95% gypsum.

Among those kivas sampled at Spruce Tree House, none of the samples removed from Kivas I, G, or H exhibited gypsum soft masses. Two samples removed from Kiva A had gypsum soft masses, and three of the samples from Kiva E had soft masses. Each
Figure 6. Gypsum soft masses under magnification.

Figure 7. EDS elemental analysis of gypsum soft mass from Spruce Tree House, Kiva A.
of the samples removed from both Kivas C and D exhibited at least some soft masses. By comparison, among those samples removed from Ruin 12 only one sample (N12-13) from Kiva B exhibited any soft mass morphology. The presence of gypsum soft masses in the kiva mortar indicates salt movement since its original application, the implications of which will be discussed later.

After the samples had been ground and dried, the Munsell soil color of each was determined. Among Spruce Tree House samples the majority of colors fall into pale brown to light gray categories, the one exception being Kiva E. Three of the Kiva E samples were determined to be pink. This is the same kiva that had the mortar which exhibited a noticeably unconsolidated, sandy matrix. Ruin 12 samples shared a similar pattern, primarily ranging in the pale brown to light gray categories. Samples from Kiva A were a slightly darker brown color. The majority of kivas from both sites exhibited a fair amount of within kiva homogeneity in regard to mortar color. Within kiva color differences were only slight variations in shading and hue. In addition to this, distinct color differences were isolated to specific kivas.

X-Ray Diffraction Results

The results of the XRD analysis of the mortar samples have been summarized in Tables 8 and 9. In the accompanying discussion, when possible, approximate percentages have been provided using a semi-quantification program. It should be noted that these percentages are simply crude estimates based on interpreted phase presence, and are in no way absolute. They do however give a general idea as to the relative abundance and scarcity of certain mineral phases. Accurate phase identification not only
Table 8. Mineralogical phases present in Spruce Tree House mortar samples based on XRD results.

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Kiva</th>
<th>Quartz</th>
<th>Calcite</th>
<th>Gypsum</th>
<th>Kaolinite</th>
<th>Orthoclase</th>
<th>Muscovite</th>
<th>Microcline</th>
<th>Dolomite</th>
<th>Albite</th>
<th>Enstatite</th>
<th>Euclase</th>
<th>Covellite</th>
</tr>
</thead>
<tbody>
<tr>
<td>STH 1</td>
<td>I</td>
<td>xxx</td>
<td>xx</td>
<td>xx</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 2</td>
<td>I</td>
<td>xxx</td>
<td>xx</td>
<td>xx</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 3</td>
<td>I</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 4</td>
<td>A</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 5</td>
<td>A</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 6</td>
<td>A</td>
<td>xxx</td>
<td>xx</td>
<td>xx</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 7</td>
<td>C</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td></td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 8</td>
<td>C</td>
<td>xxx</td>
<td>xx</td>
<td>xx</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 9</td>
<td>C</td>
<td>xxx</td>
<td>xx</td>
<td>xx</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 10</td>
<td>D</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 11</td>
<td>D</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 12</td>
<td>D</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 13</td>
<td>E</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 14</td>
<td>E</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 15</td>
<td>E</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 16</td>
<td>E</td>
<td>xxx</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 17</td>
<td>G</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>xx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 18</td>
<td>G</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 19</td>
<td>G</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 20</td>
<td>H</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 21</td>
<td>H</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STH 22</td>
<td>H</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*xxx = highest peak; xx = second highest; x = third highest; i = presence likely but further analysis needed*
<table>
<thead>
<tr>
<th>Sample #</th>
<th>Kiva</th>
<th>Quartz</th>
<th>Calcite</th>
<th>Gypsum</th>
<th>Kaolinite</th>
<th>Muscovite</th>
<th>Biotite</th>
<th>Orthoclase</th>
<th>Albite</th>
<th>Dolomite</th>
<th>Halite</th>
<th>Triplite</th>
</tr>
</thead>
<tbody>
<tr>
<td>N12-1</td>
<td>E</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-2</td>
<td>E</td>
<td>xxx</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-3</td>
<td>E</td>
<td>xxx</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-4</td>
<td>D</td>
<td>xxx</td>
<td>xx</td>
<td>xx</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-5a</td>
<td>D</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-5b</td>
<td>D</td>
<td>xx</td>
<td>xxx</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-6</td>
<td>D</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-7</td>
<td>C</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-8</td>
<td>C</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-9</td>
<td>C</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-10</td>
<td>C</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td></td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-11</td>
<td>C</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-12</td>
<td>B</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-13</td>
<td>B</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-14</td>
<td>B</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-15</td>
<td>A</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>xx</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-16</td>
<td>A</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>xx</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-17</td>
<td>A</td>
<td>xxx</td>
<td>x</td>
<td>xx</td>
<td>x</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N12-18</td>
<td>A</td>
<td>xxx</td>
<td>xx</td>
<td>x</td>
<td>xx</td>
<td>i</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**xxx** = highest peak; **xx** = second highest; **x** = third highest; **i** = presence likely but further analysis needed
gives indications as to possible source areas it may also help indicate whether composite mortars were used. Local soils with a similar mineralogical makeup as the mortar samples can then be speculated as possible source areas. Ultimately the mineral phases present in a sample are an indication of both the parent material from which the soils were derived, and the processes involved with soil formation at any specific location.

Spruce Tree House

Kiva I

Each of the three specimens analyzed from Kiva I contain the same three major mineral phases (see Table 8). These phases are quartz (SiO₂), calcite (Ca(CO₃)), and kaolinite (Al₂(Si₂O₅)(OH)₄). Dolomite (CaMg(CO₃)₂) possibly occurs in two of the samples (STH 2 and STH 3). Other possible phases present in specimens from this kiva include enstatite (Mg₂(Si₂O₆)), muscovite (H₂KAl₃(SiO₄)₃), and euclase (BeAlSiO₄(OH)). Semi-quantification results of sample STH 3 are as follows: 69% quartz, 16% kaolinite, 4% calcite, and 11% dolomite.

Kiva A

All three specimens from Kiva A contained quartz and kaolinite (see Table 8). Additionally, two specimens contained calcite (STH 5 and STH 6), and gypsum was present in STH 4. Possible minor phases include muscovite occurring in all three specimens as well as orthoclase (K(AlSi₃)O₈) in STH-4 and STH-5 and albite ((Na, Ca)Al (Si, Al)₂O₆) in STH-6.

Kiva C

Each of the three specimens removed from Kiva C contained the same three major mineral phases; quartz, calcite, and kaolinite (see Table 8). Possible minor mineral
phases included microcline (KAlSi$_3$O$_8$) in STH-8, and dolomite and albite in STH-9. Semi-quantification results of sample STH 7 are as follows: 68% quartz, 25% kaolinite, and 8% calcite. Results of sample STH 9 are as follows: 58% quartz, 30% kaolinite, and 12% calcite.

Kiva D

Each of the three specimens removed from Kiva D contained quartz, calcite, and kaolinite (see Table 8). Additionally, STH-10 and STH-12 both contained a gypsum phase as should be expected given the abundant amount of soft mass morphology present prior to grinding these samples. A minor albite phase may also occur in STH-11. Semi-quantification results were available for all Kiva D samples. Sample STH 10 results are as follows: quartz 80%, kaolinite 9%, gypsum 8%, and calcite 3%. Sample STH 11 results are as follows: quartz 84%, albite 10%, kaolinite 5%, and calcite 1%. Sample STH 12 results are as follows: quartz 45%, kaolinite 24%, gypsum 21%, and calcite 11%.

Kiva E

Each of the four specimens removed from Kiva D contained quartz and calcite (see Table 8). Three of the samples contained a kaolinite phase, but one sample did not (STH-16) making it the only sample removed from Spruce Tree House with no obvious kaolinite phase. Other minerals present in Kiva E specimens included an orthoclase phase in STH-14, and a gypsum phase in STH-15. Possible minor mineral phases in these samples included orthoclase in STH-13, dolomite in STH-15 and STH-16, and microcline and albite in STH-16. Semi-quantification results of sample STH 13 are as follows: 82% quartz, 9% orthoclase, 6% kaolinite, and 3% calcite.
Kiva G

Each of the three specimens removed from Kiva G contained quartz, calcite, and kaolinite (see Table 8). Specimens STH-17 and STH-19 also contained a gypsum phase. This is interesting given the fact that neither of these samples exhibited any gypsum soft masses prior to grinding. Possible minor mineral phases in these samples included dolomite in STH-18, and microcline and covellite (CuS) in STH-19. Semi-quantification results of sample STH 17 are as follows: 47% quartz, 31% kaolinite, 14% gypsum, and 7% calcite.

Kiva H

Each of the three specimens removed from Kiva H contained quartz and kaolinite (see Table 8). In addition specimen STH-20 contained calcite and microcline, STH-21 contained a calcite phase, and STH-22 contained a muscovite phase. Possible minor phases among these samples included muscovite and dolomite in STH-21, and microcline in STH-22. Semi-quantification results of sample STH 17 are as follows: 73% quartz, 15% microcline, 10% kaolinite, and 2% calcite.

Summary

A few general trends among the Spruce Tree House data are apparent. All of the Specimens contained a major quartz phase. Among those specimens that XRD semi-quantification of the constituents was available; quartz tends to make up greater than 50% of the mortar matrix. This is not surprising given the prevalence of sandstone formations and therefore quartz rich soils in the immediate area. The next most prevalent mineral phase is kaolinite clay that occurs in all but one (STH-16) of the specimens analyzed from the site. These clays commonly occur in the Mancos and Menefee shales as well as
in shale lenses running through the Cliffhouse sandstones. Among those samples that semi-quantification was available; kaolinite makes up \( \sim 5-30\% \) of the mortar matrix.

Soluble salts in the form of calcite and/or gypsum occur in all but one sample (STH-22). In the cases of Kiva’s I and C calcite occurs independently from gypsum, while in the remaining kivas some combination of both salts occur. In each case where abundant gypsum soft masses were noted the XRD results indicate a gypsum phase; however, in those instances where only moderate or minute soft mass morphology occurs a gypsum phase was not always recorded. In addition, in some cases (e.g. STH-15, 17, 19) where soft mass morphology was absent gypsum phases do occur. This suggests soluble salts may have been incorporated into the original mortar matrix or have entered into the kivas via preferential flow. Although Griffitts (2003) indicates that the gypsum masses were incorporated at the time the mortar was originally retrieved, this research indicates otherwise. The habit of the gypsum as observed in-situ at the kivas in question was such that it occurred in a horizontal band running the circumference of the kiva wall. This would be the expected pattern of in-situ gypsum mass formation occurring in the kiva walls at the depth of moisture penetration.

The remaining minor components of the Spruce Tree House samples include the regular occurrence of several feldspars: orthoclase, albite, and microcline all occur with some frequency. Muscovite mica also occurs in at least six cases. In five cases a possible dolomite phase was noted; this however, is unlikely given the lack of dolomite sources in the area, and may be the result of misidentification. The presence or absence of these minor mineral constituents does not appear to be patterned among the Spruce
Tree House data, but the determination of such relationships may be impeded by the detection limits of the XRD machine.

Nordenskiold's 12

**Kiva E**

Each of the three specimens removed from Kiva E contained the same four mineralogical phases; quartz, gypsum, kaolinite, and muscovite (see Table 9). In addition, orthoclase may be present in each of these samples as a minor phase. Albite and triplite \(( (\text{Fe, Mn})_2 \text{FPO}_4) \) may also occur in N12-1.

**Kiva D**

A small well-cemented nodule was removed from sample N12-5 and labeled as N12-5b in order to receive separate XRD analysis (see Table 9). The results indicate that the specimen is dominated by a calcite phase with quartz and kaolinite occurring less abundantly. Each of the remaining three samples removed from Kiva D contained the same four major mineralogical phases; quartz, calcite, kaolinite, and muscovite. Possible minor phases occurring in each of these samples include orthoclase and albite. In addition, dolomite may occur in N12-5a. Semi-quantification results of sample N12-5b are as follows: 63% calcite, 30% quartz, and 7% kaolinite.

**Kiva C**

Each of the five samples removed from Kiva C contained quartz and kaolinite (see Table 9). All of the specimens but N12-10 contained a muscovite phase. Unique to specimen N12-10 in Kiva C was the occurrence of a biotite \(( \text{H}_4\text{K}_2\text{Mg}_6\text{Al}_2\text{Si}_6\text{O}_{24}) \) phase. Each of the specimens but N12-11 contained calcite, and a gypsum phase was present in
both N12-9 and N12-11. Possible minor minerals present in all the samples from this kiva include orthoclase and albite. Dolomite may also be present in N12-8.

**Kiva B**

Each of the three samples removed from Kiva B contained quartz, gypsum, kaolinite, and muscovite phases (see Table 9). In addition, N12-14 contained a calcite phase. Possible minor phases include orthoclase in all three samples, albite in N12-12 and N12-14, and dolomite in N12-13.

**Kiva A**

Each of the four samples removed from Kiva A contained quartz, calcite, kaolinite, and muscovite phases (see Table 9). In addition, all but one sample (N12-17) contained a gypsum phase. Possible minor phases include orthoclase and albite in specimens N12-16, N12-17, and N12-18. Unique to N12-15 is a possible Halite (NaCl) component.

**Summary**

Ruin 12 mortar samples exhibited similar patterning in regard to quartz, kaolinite, and soluble salt content. One major deviation from the Spruce Tree House specimens was the prevalence of muscovite mica occurring in all the specimens but N12-10 where muscovite was replaced by biotite. Muscovite seems to be much more prevalent in those mortars used at Ruin 12 than in the mortars from Spruce Tree House.

Soluble salt phase presence exhibits greater patterning among kiva mortars from Ruin 12 than among those specimens from Spruce Tree House. For example, Kiva E contains exclusively gypsum, while Kiva D contains exclusively calcite. One interesting observation is that each of the Kiva C samples contains calcite except for N12-11 which contains gypsum instead. This is also the sample that was taken from a sealed doorway.
representing a roomblock occupation of the kiva area and a building episode discrete from the rest of the kiva construction. In addition, each of the Kiva B specimens contain gypsum, and each of the Kiva A specimens contain calcite, although in at least one case each they also contain the other salt.

Minor mineral phases seem to be more consistent than at Spruce Tree House as well. Minor mineral phases among Ruin 12 specimens are dominated by orthoclase and albite. In at least fourteen cases these minerals occur together. In three cases a possible dolomite phase was present; however, as previously noted this phase may be the result of misidentification. Unique among all those specimens tested from both sites was the possible occurrence of a halite phase in N12-15 from Kiva A. The presence of halite was later confirmed through elemental analyses which indicated an unusually high level of Na in the specimen.

Discussion

Given the relative mineralogical uniformity of the marine deposited geologic strata at Mesa Verde it is not surprising that the XRD results indicate a fairly uniform mineral distribution among the samples analyzed from both sites. It does appear that muscovite mica occurs more abundantly in those mortar sources exploited by the inhabitants of Ruin 12 in comparison to the infrequent occurrence of muscovite among the Spruce Tree House samples. The abundant presence of kaolinite clay in the mortars from both sites is also significant. As opposed to bentonite, the other relatively common clay occurring in the Park, kaolinite is a relatively stable clay with a low shrink-swell capacity. This would have been an advantage in architectural applications in terms of mortar durability and longevity. These results indicate that bentonite, that was so prized by the inhabitants for
ceramic applications, was avoided for use as a mortar. None of the tested specimens from either site contained a bentonite phase.

The spatial distribution of calcite and gypsum among the samples from the two sites exhibit interesting patterning. Although in some kivas the content of these salts may be exaggerated by active kiva wall weathering, it is apparent that in most cases that they were present in the original mortar. Unfortunately, determining how much the original mortar content has been modified by soil formation is a difficult task. One certainty is that the gypsum soft masses apparent in several of the kivas began forming sometime after the original mortar was used to construct the kivas. Ruin 12 exhibits far less gypsum soft mass morphology than Spruce Tree House. This may indicate less intensive subsurface mineralogical modification to the mortar and therefore lend credence to the salt patterning apparent at that site.

Kivas E and D are located directly adjacent to one another at the west end of Ruin 12. Each of the specimens analyzed from Kiva E contained a gypsum phase and each of those from Kiva D a calcite phase. In addition, sample N12-2 from Kiva E, and N12-4 from Kiva D were taken from locations, within those respective kivas, directly adjacent to each other. These two samples were removed from locations no more than 1.5m apart from each other, and yet the salt mineralogy is distinct. One would not expect such patterning to occur naturally, and therefore a cultural origin is likely. Kiva C also presents an interesting case, with a calcite phase occurring in each of the samples except for N12-11 which contains a gypsum phase. Kiva C exhibits at least two construction episodes, one being distinguished as a roomblock rather than a kiva. The fact that the roomblock phase specimen exhibited salt mineralogy distinct from the kiva phase implies
the possibility of a temporal shift in mortar selection. Adjacent Kivas A and B, located on the east side of Ruin 12, exhibit similar, yet less convincing, patterning as kivas D and E. Gypsum occurs in each of the Kiva B specimens and calcite occurs in each of the Kiva A specimens; however, in four cases these salts occur together in the samples.

Spruce Tree House samples exhibit much less patterning in terms of salt presence. Given the greater abundance of gypsum soft masses present in the mortars at the site the lack of patterning may be due to the fact that it appears to have been more significantly impacted by soil formation. One hint at any such patterning can be found in Kivas I and C where calcite occurred independently of gypsum, but calcite content at Spruce Tree House appears to have been very widespread to begin with. Only one specimen, STH-4 from Kiva A contained gypsum independent from calcite.

Given the geology of the Mesa Verde area, subtle differences in mortar sources may be best exhibited by differences in minor mineral phases; unfortunately, as previously mentioned, one limitation of the XRD analysis is in determining minor mineral constituents. Therefore, due to the detection limits of XRD, an exhaustive analysis of minor mineral phases is not possible.

Elemental Analysis Results

As discussed previously, inductively coupled plasma – mass spectrometry, or ICP-MS, is an analytic technique used in the context of this study to determine elemental concentrations present in mortar specimens. The results of the ICP-MS elemental analysis are provided in Tables 10 and 11. Interpretation of these results is primarily statistically based. Statistical analyses were aimed at determining the degree of
### Table 10. ICP-MS elemental results of Spruce Tree House mortar samples.

<table>
<thead>
<tr>
<th>STH</th>
<th>Kiva</th>
<th>Al</th>
<th>B</th>
<th>Ca</th>
<th>Cd</th>
<th>Co</th>
<th>Cr</th>
<th>Cu</th>
<th>Fe</th>
<th>K</th>
<th>Mg</th>
<th>Mn</th>
<th>Mo</th>
<th>Na</th>
<th>Ni</th>
<th>P</th>
<th>Pb</th>
<th>S</th>
<th>Sr</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>mg/kg</td>
<td>%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>mg/kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>I</td>
<td>6242</td>
<td>&lt; 2.45</td>
<td>&lt; 5.42</td>
<td>5.32</td>
<td>5.62</td>
<td>17410</td>
<td>0.47</td>
<td>0.48</td>
<td>140</td>
<td>38.2</td>
<td>440</td>
<td>26.7</td>
<td>0.057</td>
<td>&lt;</td>
<td>&lt; 0.08</td>
<td>38.2</td>
<td>39.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>I</td>
<td>5733</td>
<td>&lt; 2.89</td>
<td>&lt; 5.02</td>
<td>5.97</td>
<td>6.42</td>
<td>13680</td>
<td>0.34</td>
<td>0.68</td>
<td>145</td>
<td>40.9</td>
<td>327</td>
<td>23.1</td>
<td>0.053</td>
<td>&lt;</td>
<td>&lt; 0.05</td>
<td>34.7</td>
<td>42.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>I</td>
<td>5964</td>
<td>&lt; 2.77</td>
<td>&lt; 5.29</td>
<td>5.69</td>
<td>6.43</td>
<td>14120</td>
<td>0.40</td>
<td>0.89</td>
<td>173</td>
<td>42.3</td>
<td>1163</td>
<td>24.2</td>
<td>0.055</td>
<td>&lt;</td>
<td>&lt; 0.12</td>
<td>32.7</td>
<td>44.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>5554</td>
<td>&lt; 2.24</td>
<td>&lt; 5.68</td>
<td>5.06</td>
<td>8.87</td>
<td>15980</td>
<td>0.56</td>
<td>0.52</td>
<td>168</td>
<td>48.3</td>
<td>600.8</td>
<td>27.2</td>
<td>0.072</td>
<td>&lt;</td>
<td>&lt; 0.39</td>
<td>39.8</td>
<td>50.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>6558</td>
<td>&lt; 1.83</td>
<td>&lt; 6.84</td>
<td>5.59</td>
<td>9.3</td>
<td>18820</td>
<td>0.57</td>
<td>0.50</td>
<td>173</td>
<td>63.2</td>
<td>733.5</td>
<td>30.8</td>
<td>0.061</td>
<td>&lt;</td>
<td>&lt; 0.05</td>
<td>37.0</td>
<td>65.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>A</td>
<td>6116</td>
<td>&lt; 2.07</td>
<td>&lt; 6.33</td>
<td>5.55</td>
<td>8.81</td>
<td>13740</td>
<td>0.61</td>
<td>0.53</td>
<td>159</td>
<td>46.9</td>
<td>590</td>
<td>25.2</td>
<td>0.067</td>
<td>&lt;</td>
<td>&lt; 0.07</td>
<td>40.0</td>
<td>48.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>C</td>
<td>6677</td>
<td>&lt; 2.56</td>
<td>&lt; 4.99</td>
<td>5.45</td>
<td>8.03</td>
<td>13420</td>
<td>0.74</td>
<td>0.75</td>
<td>158</td>
<td>39.6</td>
<td>1910</td>
<td>23.3</td>
<td>0.056</td>
<td>&lt;</td>
<td>&lt; 0.29</td>
<td>35.6</td>
<td>41.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>C</td>
<td>6441</td>
<td>&lt; 2.54</td>
<td>&lt; 4.71</td>
<td>6.46</td>
<td>7.26</td>
<td>12750</td>
<td>0.61</td>
<td>0.66</td>
<td>216</td>
<td>38.5</td>
<td>&lt;</td>
<td>22.8</td>
<td>0.050</td>
<td>&lt;</td>
<td>&lt; 0.13</td>
<td>38.1</td>
<td>40.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>C</td>
<td>5925</td>
<td>&lt; 2.54</td>
<td>&lt; 4.52</td>
<td>5.42</td>
<td>6.69</td>
<td>12460</td>
<td>0.67</td>
<td>0.69</td>
<td>184</td>
<td>37.5</td>
<td>1262</td>
<td>21.5</td>
<td>0.057</td>
<td>&lt;</td>
<td>&lt; 0.05</td>
<td>38.6</td>
<td>39.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>D</td>
<td>6258</td>
<td>&lt; 2.87</td>
<td>&lt; 4.6</td>
<td>5.68</td>
<td>6.26</td>
<td>13030</td>
<td>0.61</td>
<td>0.65</td>
<td>175</td>
<td>37.4</td>
<td>1124</td>
<td>22.2</td>
<td>0.056</td>
<td>&lt;</td>
<td>&lt; 0.71</td>
<td>36.1</td>
<td>39.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>D</td>
<td>7087</td>
<td>&lt; 2.20</td>
<td>&lt; 5.08</td>
<td>6.26</td>
<td>6.06</td>
<td>13470</td>
<td>0.55</td>
<td>0.58</td>
<td>176</td>
<td>37.1</td>
<td>761</td>
<td>23.3</td>
<td>0.049</td>
<td>&lt;</td>
<td>&lt; 0.08</td>
<td>39.5</td>
<td>38.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>D</td>
<td>7008</td>
<td>&lt; 2.59</td>
<td>&lt; 5.48</td>
<td>5.9</td>
<td>5.9</td>
<td>15720</td>
<td>0.63</td>
<td>0.56</td>
<td>201</td>
<td>39.3</td>
<td>1021</td>
<td>24.6</td>
<td>0.076</td>
<td>&lt;</td>
<td>&lt; 0.43</td>
<td>35.2</td>
<td>40.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>E</td>
<td>7890</td>
<td>&lt; 2.51</td>
<td>&lt; 6.66</td>
<td>6.66</td>
<td>11480</td>
<td>0.42</td>
<td>0.49</td>
<td>177</td>
<td>25.7</td>
<td>430</td>
<td>21.3</td>
<td>0.045</td>
<td>&lt;</td>
<td>&lt; 0.13</td>
<td>44.7</td>
<td>26.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>E</td>
<td>9633</td>
<td>&lt; 3.23</td>
<td>&lt; 4.52</td>
<td>7.73</td>
<td>12190</td>
<td>0.40</td>
<td>0.48</td>
<td>184</td>
<td>30.5</td>
<td>368</td>
<td>22.1</td>
<td>0.045</td>
<td>&lt;</td>
<td>&lt; 0.07</td>
<td>56.1</td>
<td>32.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>E</td>
<td>6372</td>
<td>&lt; 2.72</td>
<td>&lt; 7.01</td>
<td>10130</td>
<td>0.28</td>
<td>0.67</td>
<td>137</td>
<td>25.7</td>
<td>647</td>
<td>18.8</td>
<td>0.045</td>
<td>&lt;</td>
<td>&lt; 0.39</td>
<td>45.1</td>
<td>26.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>E</td>
<td>7125</td>
<td>&lt; 2.06</td>
<td>&lt; 6.67</td>
<td>9713</td>
<td>0.36</td>
<td>0.71</td>
<td>163</td>
<td>24.8</td>
<td>901</td>
<td>19.6</td>
<td>0.047</td>
<td>&lt;</td>
<td>&lt; 0.12</td>
<td>47.0</td>
<td>25.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>G</td>
<td>6134</td>
<td>&lt; 3.73</td>
<td>&lt; 7.1</td>
<td>10480</td>
<td>0.31</td>
<td>0.75</td>
<td>119</td>
<td>28.7</td>
<td>896</td>
<td>18.8</td>
<td>0.100</td>
<td>&lt;</td>
<td>&lt; 0.83</td>
<td>65.1</td>
<td>30.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>G</td>
<td>6630</td>
<td>&lt; 2.57</td>
<td>&lt; 5.3</td>
<td>6.55</td>
<td>7.18</td>
<td>13540</td>
<td>0.37</td>
<td>0.64</td>
<td>162</td>
<td>43.0</td>
<td>1094</td>
<td>23.8</td>
<td>0.083</td>
<td>&lt;</td>
<td>&lt; 0.08</td>
<td>50.8</td>
<td>45.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>G</td>
<td>6349</td>
<td>&lt; 2.36</td>
<td>&lt; 6.38</td>
<td>7.68</td>
<td>8.51</td>
<td>14570</td>
<td>0.42</td>
<td>0.55</td>
<td>153</td>
<td>42.3</td>
<td>960</td>
<td>24.7</td>
<td>0.07</td>
<td>&lt;</td>
<td>&lt; 0.45</td>
<td>48.6</td>
<td>43.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>H</td>
<td>7274</td>
<td>&lt; 3.67</td>
<td>&lt; 6.5</td>
<td>8.6</td>
<td>8.47</td>
<td>14190</td>
<td>0.47</td>
<td>1.40</td>
<td>202</td>
<td>42.0</td>
<td>597</td>
<td>25.6</td>
<td>0.06</td>
<td>&lt;</td>
<td>&lt; 0.10</td>
<td>90.0</td>
<td>44.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>H</td>
<td>6036</td>
<td>&lt; 2.47</td>
<td>&lt; 5.13</td>
<td>7.15</td>
<td>4.42</td>
<td>11340</td>
<td>0.56</td>
<td>0.48</td>
<td>123</td>
<td>33.4</td>
<td>2279</td>
<td>21.3</td>
<td>0.07</td>
<td>&lt;</td>
<td>&lt; 0.04</td>
<td>44.6</td>
<td>33.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>H</td>
<td>6259</td>
<td>&lt; 1.47</td>
<td>&lt; 5.63</td>
<td>7.3</td>
<td>5.87</td>
<td>10510</td>
<td>0.38</td>
<td>0.50</td>
<td>150</td>
<td>37.2</td>
<td>960</td>
<td>21.3</td>
<td>0.07</td>
<td>&lt;</td>
<td>&lt; 0.16</td>
<td>33.9</td>
<td>37.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Table 11: ICP-MS elemental results of Nordenskiöld’s Ruin 12 mortar samples</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fe</td>
<td>Cu</td>
<td>Mg</td>
<td>Mn</td>
<td>Na</td>
<td>Al</td>
<td>Si</td>
<td>K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>6.7</td>
<td>0.4</td>
<td>9.8</td>
<td>0.2</td>
<td>28</td>
<td>0.6</td>
<td>9.8</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5.2</td>
<td>0.3</td>
<td>7.1</td>
<td>0.1</td>
<td>20</td>
<td>0.5</td>
<td>7.1</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>6.8</td>
<td>0.5</td>
<td>9.4</td>
<td>0.3</td>
<td>24</td>
<td>0.7</td>
<td>9.4</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>6.4</td>
<td>0.4</td>
<td>9.0</td>
<td>0.2</td>
<td>22</td>
<td>0.6</td>
<td>9.0</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6.6</td>
<td>0.5</td>
<td>9.2</td>
<td>0.2</td>
<td>23</td>
<td>0.6</td>
<td>9.2</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>6.8</td>
<td>0.4</td>
<td>9.4</td>
<td>0.3</td>
<td>24</td>
<td>0.7</td>
<td>9.4</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6.4</td>
<td>0.4</td>
<td>9.0</td>
<td>0.2</td>
<td>22</td>
<td>0.6</td>
<td>9.0</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>6.6</td>
<td>0.5</td>
<td>9.2</td>
<td>0.2</td>
<td>23</td>
<td>0.6</td>
<td>9.2</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>6.8</td>
<td>0.4</td>
<td>9.4</td>
<td>0.3</td>
<td>24</td>
<td>0.7</td>
<td>9.4</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>6.4</td>
<td>0.4</td>
<td>9.0</td>
<td>0.2</td>
<td>22</td>
<td>0.6</td>
<td>9.0</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>6.6</td>
<td>0.5</td>
<td>9.2</td>
<td>0.2</td>
<td>23</td>
<td>0.6</td>
<td>9.2</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>6.8</td>
<td>0.4</td>
<td>9.4</td>
<td>0.3</td>
<td>24</td>
<td>0.7</td>
<td>9.4</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>6.4</td>
<td>0.4</td>
<td>9.0</td>
<td>0.2</td>
<td>22</td>
<td>0.6</td>
<td>9.0</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>6.6</td>
<td>0.5</td>
<td>9.2</td>
<td>0.2</td>
<td>23</td>
<td>0.6</td>
<td>9.2</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>6.8</td>
<td>0.4</td>
<td>9.4</td>
<td>0.3</td>
<td>24</td>
<td>0.7</td>
<td>9.4</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>6.4</td>
<td>0.4</td>
<td>9.0</td>
<td>0.2</td>
<td>22</td>
<td>0.6</td>
<td>9.0</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>6.6</td>
<td>0.5</td>
<td>9.2</td>
<td>0.2</td>
<td>23</td>
<td>0.6</td>
<td>9.2</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>6.8</td>
<td>0.4</td>
<td>9.4</td>
<td>0.3</td>
<td>24</td>
<td>0.7</td>
<td>9.4</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Table 12. Results of furthest neighbor cluster analysis.

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Chemical Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>STH 1</td>
<td>1</td>
</tr>
<tr>
<td>STH 2</td>
<td>1</td>
</tr>
<tr>
<td>STH 3</td>
<td>1</td>
</tr>
<tr>
<td>Kiva I</td>
<td></td>
</tr>
<tr>
<td>STH 4</td>
<td>1</td>
</tr>
<tr>
<td>STH 5</td>
<td>1</td>
</tr>
<tr>
<td>STH 6</td>
<td>1</td>
</tr>
<tr>
<td>STH 7</td>
<td>1</td>
</tr>
<tr>
<td>Kiva A</td>
<td></td>
</tr>
<tr>
<td>STH 8</td>
<td>1</td>
</tr>
<tr>
<td>STH 9</td>
<td>1</td>
</tr>
<tr>
<td>Kiva C</td>
<td></td>
</tr>
<tr>
<td>STH 10</td>
<td>1</td>
</tr>
<tr>
<td>STH 11</td>
<td>1</td>
</tr>
<tr>
<td>STH 12</td>
<td>1</td>
</tr>
<tr>
<td>STH 13</td>
<td>2</td>
</tr>
<tr>
<td>STH 14</td>
<td>2</td>
</tr>
<tr>
<td>STH 15</td>
<td>2</td>
</tr>
<tr>
<td>STH 16</td>
<td>2</td>
</tr>
<tr>
<td>Kiva D</td>
<td></td>
</tr>
<tr>
<td>STH 17</td>
<td>3</td>
</tr>
<tr>
<td>STH 18</td>
<td>1</td>
</tr>
<tr>
<td>STH 19</td>
<td>1</td>
</tr>
<tr>
<td>Kiva G</td>
<td></td>
</tr>
<tr>
<td>STH 20</td>
<td>4</td>
</tr>
<tr>
<td>STH 21</td>
<td>1</td>
</tr>
<tr>
<td>STH 22</td>
<td>1</td>
</tr>
<tr>
<td>Kiva H</td>
<td></td>
</tr>
<tr>
<td>N12-1</td>
<td>5</td>
</tr>
<tr>
<td>N12-2</td>
<td>5</td>
</tr>
<tr>
<td>N12-3</td>
<td>5</td>
</tr>
<tr>
<td>Kiva E</td>
<td></td>
</tr>
<tr>
<td>N12-4</td>
<td>6</td>
</tr>
<tr>
<td>N12-5</td>
<td>6</td>
</tr>
<tr>
<td>N12-6</td>
<td>6</td>
</tr>
<tr>
<td>N12-7</td>
<td>5</td>
</tr>
<tr>
<td>N12-8</td>
<td>7</td>
</tr>
<tr>
<td>Kiva D</td>
<td></td>
</tr>
<tr>
<td>N12-9</td>
<td>5</td>
</tr>
<tr>
<td>N12-10</td>
<td>6</td>
</tr>
<tr>
<td>N12-11</td>
<td>8</td>
</tr>
<tr>
<td>Kiva C</td>
<td></td>
</tr>
<tr>
<td>N12-12</td>
<td>5</td>
</tr>
<tr>
<td>N12-13</td>
<td>8</td>
</tr>
<tr>
<td>N12-14</td>
<td>8</td>
</tr>
<tr>
<td>Kiva B</td>
<td></td>
</tr>
<tr>
<td>N12-15</td>
<td>9</td>
</tr>
<tr>
<td>Kiva A</td>
<td></td>
</tr>
<tr>
<td>N12-16</td>
<td>6</td>
</tr>
<tr>
<td>N12-17</td>
<td>6</td>
</tr>
<tr>
<td>N12-18</td>
<td>7</td>
</tr>
</tbody>
</table>
homogeneity among the samples. With such analyses in hand, the research questions can then be effectively addressed.

In order to explore the patterns that might be present in the data, a furthest neighbor cluster analysis was performed. Due to a large number of missing values, B, Cd, and Pb were removed from the data set for the purposes of these analyses. Missing values occur in the data when either a specific element is not present in a given sample, or the element occurs in minute quantities below the detection limits of the machine. For this reason, a zero was imputed in place of the remaining missing values. Since the data is measured on different scales, prior to the analysis, the data was standardized using z-score values to ensure comparability among the results.

Accepting nine clusters seems to provide the most informative results (see Table 12). The most apparent result of the cluster analysis is in its ability to readily distinguish between the two sites. This result is not surprising given the physical distance between the two sampled sites. Among those samples removed from Spruce Tree House, those from Kivas I, A, C, and D all appear to be closely associated with one another. Each of the samples from these kivas have been assigned to cluster 1. According to this analysis those samples from Kiva E appear to be distinct from all other Spruce Tree House samples, and have been designated as cluster 2. Samples from the remaining two kivas, G and H, appear to be most closely associated with cluster 1 kivas; however, both kivas contain one outlier sample (STH-17 and STH-20) that has been designated as an independent cluster. The cluster analysis also indicates some interesting patterning among those samples removed from Ruin 12. The analysis indicates that Kivas E and D are both independent from each other, and independent from the remaining kivas. These
samples have been designated as clusters 5 and 6, respectively. Among the remaining kivas, three samples were assigned to cluster 5 and three samples to cluster 6. The samples from kivas C, B, and A exhibit far less patterning. One interesting note is that sample N12-11 removed from the roomblock episode of Kiva C appears to be more closely associated with Kiva B samples. Two of the Kiva B samples, and N12-11 were all assigned to cluster 8.

To both support and refine the results of the cluster analysis, as well as gain a better understanding of the nature of the differences between the samples, a principal component analysis was performed on the data. Principal component analysis is a technique that can be used to condense a data set with a large number of variables into a smaller number of components that help describe variance in the data. An eigenvalue, representing the amount of variance explained by any one component, is calculated for each of the derived components. Once again, standardized z-score values were used in place of the raw data. By retaining all components with an eigenvalue over one, four components remain. These four components explain nearly 75% of the variance in the data. An analysis of the rotated component matrix indicates that component 1 describes those samples with relatively high levels of Zn, Mo, Co, Cu, and Ni, and low values of Ca and Cr. Component 2 describes those samples with relatively high levels of Mn, Mg, P, Al, K, and Fe, and low values of Sr. Component 3 describes those specimens with high Ca and Sr, and low Fe. Component 4 describes those samples with high Na, and low Al.

The two sites are easily distinguished when viewing a scatterplot of components 1 and 2 (see Figure 8). Spruce Tree House samples cluster in a fairly tight area near the
center of the scatterplot, while Ruin 12 samples exhibit much more variability extending vertically on the left side of the graph. Similar to the results of the cluster analysis, the distinction between the two sites is readily apparent on the scatterplot. A similar pattern holds true for a number of plotted component variations. Factor scores indicate how individual mortar samples relate to the derived components. The factor scores indicate that component 2 represents the Spruce Tree House samples. The remaining components represent a complex admixture of samples from both sites. Given the nature of what the

Figure 8. Factor score scatterplot of components 1 and 2 (labeled by site and kiva, 1=Spruce Tree House, 2=Nordenskiold's Ruin 12). Circled areas indicate both Spruce Tree House and Ruin 12 clusters as well as the close elemental association of Spruce Tree House Kiva E samples, and Ruin 12 Kiva E samples.
components represent elementally, some generalizations can be made concerning how the sites are elementally distinct. In general, it appears that the Spruce Tree House samples contain more Mn, Mg, P, Al, K, and Fe, and less Sr than do the Ruin 12 samples. Additionally, the scatterplot appears to agree with the results of the cluster analysis in that the Spruce Tree House specimens exhibit less elemental variability than the Ruin 12 samples. The scatterplot also exhibits a close association among the Kiva E specimens from Spruce Tree House. These specimens are all closely grouped with low component 1 scores at the bottom of the Spruce Tree House cluster. This appears to agree with the results of the cluster analysis which designated the Kiva E samples as an independent cluster. The most apparent kiva sample cluster among the Ruin 12 samples is Kiva E, which occurs in a tight group near the center of the graph. These observations lend credence to the results of the cluster analysis that found the samples from these two kivas to be both internally consistent and externally distinct from the majority of the remaining samples.

Summary

Statistical analyses on the elemental data clearly indicate elemental differences between the mortars used at each site. The principal component analysis aided in distinguishing and clarifying elemental variability between the sites. This analysis also indicates that while a great deal of elemental consistency is apparent among most of the Spruce Tree House samples, it appears that the mortar from Kiva E is quite elementally distinct and was probably removed from a unique source. Ruin 12 samples appear to be much more elementally variable. These analyses indicate that samples from Kivas E and
D are likely to have come from different sources. The remaining kivas from Ruin 12 exhibit very little elemental patterning.

Plaster Analysis Results

This section discusses the results of the plaster analyses by analytical electron microscopy (SEM-EDS). As previously mentioned, plaster samples were removed from the three kivas (E, D, C) located on the west side of Ruin 12. Sample removal locations were based on several criteria including the following: presence of sufficient amounts of prehistoric plaster coverage within any given kiva, avoidance of kivas with largely reconstructed plaster surfaces, and Park staff direction. Although generalized color terms are used below to describe plaster layers, due to the small size of the samples it was not possible to determine Munsell soil colors.

Two plaster samples (B and C) were removed from Kiva E of Ruin 12. Both samples exhibited at least three visually distinct plaster layers. Layers from each sample have been labeled with layer 1 being the surface layer, and the remaining layers being numbered with depth from the surface. Microscopic examination of sample B revealed the possibility of layer 2 being composed of two independent but similarly colored layers. The surface layers of both samples from this kiva are a distinct orange-tan color.

Elemental mapping of specimen B only produced ambiguous results with no apparent elementally distinct layering. Random point analysis by layer did exhibit a few possible elemental differences (see Table 13). Calcium appears to occur in greater proportions in Layers 2 and 3, while Si, Fe, and K all steadily decrease through Layer 3. Certainly layers 1 and 3 appear to be elementally distinct with layer 2 appearing to be elementally
transitionary. This may be an indication of elemental leaching occurring among the plaster layers.

Table 13. EDS random point analyses of Ruin 12 plaster samples by layer. Numbers refer to the number of recorded incidences out of total ( ) number performed.

<table>
<thead>
<tr>
<th>Kiva E</th>
<th>Sample B (20)</th>
<th>Layer 1</th>
<th>20</th>
<th>4</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Layer 2</td>
<td>19</td>
<td>8</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 3</td>
<td>17</td>
<td>12</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Kiva E</td>
<td>Sample C (15)</td>
<td>Layer 1</td>
<td>15</td>
<td>7</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 2</td>
<td>11</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 3</td>
<td>15</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Kiva D</td>
<td>Sample D (15)</td>
<td>Layer 1</td>
<td>1</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 2</td>
<td>4</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 4</td>
<td>12</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 5</td>
<td>10</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Kiva D</td>
<td>Sample E (15)</td>
<td>Layer 1</td>
<td>11</td>
<td>8</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 2</td>
<td>15</td>
<td>5</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 3</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kiva D</td>
<td>Sample G (15)</td>
<td>Layer 1</td>
<td>7</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 2</td>
<td>7</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 3</td>
<td>12</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 4</td>
<td>14</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Kiva C</td>
<td>Sample J (15)</td>
<td>Layer 1</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Layer 2 (mortar)</td>
<td>6</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Elemental mapping of specimen C exhibited fairly distinct layering in a few instances. Calcium and Fe appear to be concentrated in layer 1 with Fe levels rising again sharply in layer 3. Silica occurs abundantly throughout the sample as distinctive quartz grains, except for in layer 3 where the quartz is much finer grained. A line scan bisecting the three layers indicates a similar pattern with Fe occurring in layer 1 and then again in layer 3 (see Figure 9). Random point analysis by layer seems to confirm these observations (see Table 13). As the elemental mapping indicates, Ca and Fe are
concentrated in the surface layer, then virtually absent in layer 2. Layer 3 contains relatively abundant Fe and also a significant increase in K. Each of the three layers in this specimen appears to be fairly elementally distinct. In addition, color and elemental signature indicate that layer 1 from both samples B and C were probably derived from the same application. Layers 2 and 3 from both samples appear to be elementally distinct, and therefore probably do not correlate with one another.

Three plaster samples (D, E, and G) were removed from Kiva D of Ruin 12. Each of the samples exhibited multiple layering that includes a distinct white surface layer. Sample D exhibited three visually distinct plaster layers. Microscopic examination of layer 2 indicated the possibility of it being composed of several similarly colored, soot-stained layers. Elemental mapping indicates additional layering as well. Mapping indicates the existence of at least five elementally distinct layers (see Figure 10). Layers 1 and 2 are both Ca rich layers. Layer 3 is Si rich with a definite reduction of Ca content. Layer 4 is both Si and Ca rich, and layer 5 appears to be Si and Fe rich. A cross-sectional line scan indicates a similar pattern. Random point analyses were performed on four layers correlating to layers 1, 2, 4, and 5. The results of these analyses support those findings of the elemental mapping (see Table 13). Although mapping seems to indicate a
greater abundance of Fe in layer 5, there was only one recorded incidence of Fe during the random point analysis of this layer.

Figure 10. EDS elemental mapping of plaster specimen D exhibiting 5 layer morphology (lighter areas indicate greater elemental abundance).

Plaster specimen E from Kiva D exhibits three visually distinct layers. Elemental mapping indicates a concentration of Ca in layer 1, with less abundant and smaller grained quartz. A cross-sectional line scan exhibits the same pattern (see Figure 11). Random point analyses indicate a similar pattern with the addition of a strong Na presence in layer 2 (see Table 13). Layer 2 of this specimen exhibits the highest number
of Na occurrences as any other layer from any of the analyzed specimens. Each of the layers from this specimen appears to be elementally distinct.

Figure 11. EDS cross-sectional line scan of specimen E exhibiting Si - Ca differential between layer 1 and layers 2 and 3.

Plaster specimen G from Kiva D exhibits four visually distinct layers. Elemental mapping indicates layers 1 and 2 to both be Ca rich with significantly less Si (see Figure 12). A cross-sectional line scan exhibits a similar pattern. Random point analyses indicate increased Fe in layers 3 and 4, as well as a significant K component in layer 4 (see Table 13). Layers 1 and 2 appear to mimic one another elementally, but are certainly distinct from Layers 3 and 4. Layers 3 and 4 appear to be quite similar as well, except for a greater abundance of K in layer 4.

Two plaster samples (J and L) were removed from Kiva C of Ruin 12. Specimen J exhibited one visually distinct surface layer resting on mortar. Results of elemental mapping were ambiguous, and no distinct layers were apparent. Random point analyses indicated similar results (see Table 13). Layer 1 and the mortar appear to be elementally similar, although texturally, layer 1 is made up of a much finer-grained matrix.
Figure 12. EDS elemental mapping of plaster specimen G exhibiting Ca rich, Si poor layers 1 and 2.

Plaster specimen L from Kiva C does not exhibit any apparent visible layering. Elemental mapping indicates the remnants of a Ca rich layer on the exterior. The remnants were too narrow to effectively perform line scan and random point analyses; however, the Ca maps appear quite convincing (see Figure 13).

Figure 13. EDS elemental mapping of plaster specimen L exhibiting thin Ca rich veneer along outermost plaster surface. (note vertical concentration on the left side of map)
Summary

The surface layer of each plaster sample (B and C) retrieved from Kiva E appear to be elementally similar enough to have been derived during the same application. The remaining two layers from both of these samples do not appear to be correlated. Of the three samples (D, E, and G) removed from Kiva D, it appears that layers 1 and 2 of samples D and G represent the same application event. In addition, layer 1 of sample E was probably derived during one of those two application events. Any possible connection between the remaining layers in Kiva D samples is vague at best. Neither of the samples removed from Kiva C seem to relate elementally with one another.

Although, as indicated by specimen B, elemental leaching between plaster layers may be a factor in the resultant elemental fingerprints, in most cases this has not significantly obscured the original nature of the plaster layering.

It appears that a variety of plaster sources were utilized depending on the intended result. White, Ca rich, layers were probably derived from nearby calcium carbonate deposits. Citing examples from Mug House and Step House, Bohnert (1990) indicates that a combination of caliche with loess soils was probably used to create similar white plaster layers at those Mesa Verde sites. Red to orange Fe rich plasters were probably at least in part derived from mesa top loess (Rohn 1971). In addition, variable K and Na content also appears to have been important factors. A relative abundance of K occurs in Kiva E samples as compared to the other kivas. In one unique sample from Kiva D, Na appears to be a significant component of layer 2.

It also appears that grain size played an important roll in plaster selection. In general, plaster grain size is much finer than in the mortar; however, variable grain size within
various plaster layers is also common. Both Dix (1997) and Bohnert (1990) found similar variations in plaster grain size at nearby sites. Given such elemental variability in combination with variability in grain size, it appears as though the number of plaster possibilities is quite extensive.

One of the advantages of the SEM cross-sectional analyses presented here was its ability to elementally distinguish between layers that could not be visually distinguished. Narrow, soot-blackened layers that don't appear visually distinct can often be recognized and separated using these elemental analyses. Another similar advantage is that these frequently encountered, soot-blackened layers have often lost any visual cues that may indicate elemental content or possible source area. Elemental analyses are able to establish these cues elementally, and therefore assumptions can be made of approximate layer color and characteristics at the time of application.
CHAPTER 6

DISCUSSION AND CONCLUSIONS

It appears that the results of the elemental analysis complement the XRD results quite well. Using both of these analyses in tandem has elicited several interesting patterns among the data. The broadest and most apparent result is the mineralogical and elemental differences between the sites. Although the sites contain roughly similar mineralogical components, the Ruin 12 samples exhibit a much more consistent occurrence of muscovite. In addition, the sites can be readily distinguished elementally using statistical methods (see Table 14). These analyses also indicate that, in general, the Spruce Tree House samples appear to exhibit less elemental variability than do the Ruin 12 samples.

The results of the XRD analysis on the Spruce Tree House samples indicate little mineralogical patterning among the sampled kivas. The elemental results, on the other hand, indicate that the mortar from Kiva E is unique among the samples, and was probably retrieved from a unique source (see Table 14). This result is supported by the macroscopic observations noted previously. In addition to being a visually distinct pink color, each of the samples from Kiva E was also composed of a unique textural matrix. When taken together these results provide a convincing argument that the mortar used to construct Kiva E came from a unique source. The remaining specimens from Spruce
Tree House appear to be very consistent and closely associated, excepting some

distinctive macroscopic observations of mortar from Kiva H. The samples from this
kiva exhibited crushed shale fragments incorporated in the mortar matrix. The close
elemental association among the samples removed from the Kiva’s I, A, C, D, and G
indicates widespread mortar source uniformity among those kivas.

Table 14. Cross tabulation of chemical cluster assignment by kiva. Numbers represent samples attributed to any one cluster.

<table>
<thead>
<tr>
<th>Chemical Cluster</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kiva 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>I</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Kiva 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>E</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td><strong>Kiva 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>G</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Kiva 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>H</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Kiva 5</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Kiva 6</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Kiva 7</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Kiva 8</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Kiva 9</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>16</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>40</td>
</tr>
</tbody>
</table>

The results of the XRD analysis of the Ruin 12 samples indicate convincing
differences in the soluble salt presence between neighboring Kivas E and D. Similarly,
the elemental results indicate within kiva homogeneity and between kiva heterogeneity in
these kivas (see Table 14). It appears that the mortar used to construct these kivas came
from unique sources. Kiva C presents an interesting case as well. The XRD results
indicate that sample N12-11 contains soluble salt mineralogy unique from the remaining
three samples removed from that kiva. In addition, the elemental results indicate that
N12-11 may be more closely associated with the Kiva B mortar. This sample was taken from a section of the kiva representing a temporally distinct construction episode. Such a pattern is indicative of a temporal shift in mortar source use. With these results in hand the research objectives can be effectively addressed.

**Objective 1: Determine temporal consistency or lack thereof in mortar source selection within each site.** Dates of initial kiva construction, obtained through dendrochronologic analyses, are provided below (see Table 15). By coupling this information with the results of the geochemical analyses mortar selection can be discussed in terms of temporal dynamics. Among those Spruce Tree House kivas sampled, Kiva I predates all others by at least 30 years. The remaining Spruce Tree House kiva construction dates cluster tightly in the 30 year period ranging from ~A.D. 1240-1270. Unfortunately, due to a dearth of investigative research at Ruin 12 the site is lacking a precise dendrochronologic sequence. Only two poorly provenienced samples have been dated, both of which indicate mid 13th century building episodes.

<table>
<thead>
<tr>
<th>Kiva</th>
<th>Date of Initial Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>A.D. 1206/07</td>
</tr>
<tr>
<td>E</td>
<td>A.D. 1244, poss. 6 years earlier</td>
</tr>
<tr>
<td>D</td>
<td>A.D. 1247</td>
</tr>
<tr>
<td>A</td>
<td>A.D. 1249</td>
</tr>
<tr>
<td>C</td>
<td>A.D. 1250’s</td>
</tr>
<tr>
<td>G</td>
<td>mid A.D. 1250’s - 1270’s</td>
</tr>
<tr>
<td>H</td>
<td>A.D. 1260’s - 1280’s</td>
</tr>
</tbody>
</table>

The elemental and mineralogical results indicate that with the exception of Kiva E, mortar selection at Spruce Tree House appears to be fairly temporally consistent. Among those kivas dating to the mid-1200’s Kiva E is the earliest, predating the construction of
the next earliest kiva construction by 3-9 years. The unique morphological and chemical properties of Kiva E mortar appear to match those observed in the earlier structures at Mug House (Rohn 1971). Rohn describes these earlier masons as preferring mesa top soil combined with some percent sandy soil, a description that is quite similar to that found in Kiva E. Although no significant mineralogical or chemical differences could be determined among the mortars in the remaining kivas, macroscopic analysis of Kiva H mortar samples revealed the incorporation of crushed shale in the mortar matrix. Kiva H was the most recently constructed among those kivas sampled at Spruce Tree House. This is significant due to the fact that at Mug House (Rohn 1971) the mortar from the most recently constructed structures were observed to be composed of crudely crushed blue-gray shales. The unique differences in the mortars used at Kiva’s E and H coupled with the general homogeneity among those kivas whose construction dates lie in-between indicates that the temporal pattern of mortar selection observed at Spruce Tree House appears to parallel that which Rohn observed at Mug House. The one outlier is Kiva I, which predates all other sampled kivas by at least 30 years, and yet has mortar consistent with those kivas dating to the middle period of occupation at Spruce Tree House. The majority of Kiva I was destroyed during the construction of Kiva A which left only a small 4m section of intact Kiva I wall on the north side. It appears that this remaining section was abandoned and not used or remodeled in association with the activities in Kiva A.

Unfortunately, the lack of a precise site chronology for Ruin 12 inhibits the ability to render any definitive conclusions regarding temporal patterning in mortar selection. However, in the case of Kiva C, temporal change is indicated. In this kiva, samples from
two discrete construction episodes were shown to exhibit unique mineralogy. It appears that the sample removed from the roomblock episode has more elementally in common with Kiva B. This may indicate a temporal association between Kiva B and the roomblock episode of Kiva C; however, without precise dating information this interpretation remains elusive.

The research here indicates that those temporal dynamics originally described by Rohn (1971) may not simply be a localized phenomenon. A similar technological trajectory has now been determined to have occurred at Spruce Tree House. In addition, a similar model of change may help explain at least some of the differences in the mortar among the Ruin 12 samples. There is little evidence that resource scarcity would have played a role in changing the types of mortar sources selected for use in construction at Spruce Tree House. In all cases the materials used are soils and sediments that would have been available in abundance to the prehistoric population. Perhaps a model of technological dynamics combined with a changing knowledge of the available resources is best suited to explain the temporal differences in mortar selection.

During the mid to late 13th century, populations occupying the Mesa Verde proper began aggregating in cliff house settlements until the majority of the population resided in the cliffs. Although the Puebloans were certainly quite adept at masonry architecture by this time, construction in the cliffs at such a magnitude most certainly presented unique challenges to prehistoric stone masons. As Rohn (1971) suggests, it is likely that the masons relied upon ancestral knowledge of available resources, exploiting previously known and utilized sources of mortar. This helps explain why the earliest masons preferred mesa top red loess. They were not only familiar with its potential as masonry
mortar, but would have also been in regular contact with potential source areas during routine agricultural and subsistence related activities. However, the use of mesa top loess also has several disadvantages. Even though the Puebloans would have routinely been in contact with source areas, these sources would have been located at some distance from the construction efforts in the cliffs. In addition to distance, the rugged nature of the topography would have made hauling soil from the source to the cliff house settlements both difficult and time consuming. Although loess deposits are widespread on the mesa tops, the energy required to haul loess from source to construction site would have been great. In addition to the difficulty in procuring the loess, when used as a mortar it must be combined with some percent of sandy soil in order to avoid excessive shrinkage during drying (Rohn 1971). Therefore a composite mixture must be used in order to produce an effective mortar. Sandy soils would have been readily available in close proximity to the cliff house settlements. Pockets of these residual soils occur with frequency as weathering and erosion take affect on large sandstone formations, such as the Cliffhouse Formation. The builders of Kiva E at Spruce Tree House appear to have used just such a combination of soils in their mortar recipe. XRD results show that Kiva E mortar was made up of greater than 80% quartz content which indicates a high proportion of sandy soil. This may have been the case in order to offset the potential labor involved with hauling in large amounts of mesa top loess. However, by incorporating a large proportion of sand, both durability and longevity of the mortar is sacrificed. The unconsolidated and friable nature of the mortar matrix from Kiva E was noted during initial descriptive analyses of the mortar samples.
It appears that by the middle period of the cliff house construction boom, roughly dating from the late A.D. 1240’s through the 1260’s, masons had experimented with and began utilizing alternative mortar sources. These newly exploited sources were located closer to the construction efforts. Sources utilized during this period appear to have been derived from residual soil deposits located both on the canyon rims as well as on terraces in the canyons themselves. These sources may have been used individually as well as in combination with one another. Subtle differences occurring in mortar recipes from this time period may have been the result of personal or household preference based on experience. One benefit of using these soils is that it is not functionally necessary to add sand for these sources to be used as architectural mortar due to the fact that relatively effective proportions of sand to loam naturally occur within them. Not only were these mortars easier to acquire, but they were also more durable.

The latter period of intensive cliff house construction dates to the time of Kiva H at Spruce Tree House. The research presented here as well as that carried out by Rohn (1971) at Mug House both indicate another shift in mortar technology at this time. It was during this latter period that prehistoric masons began incorporating crushed shale into the mortar. In the examples from Mug House it appears that crudely crushed shale was used independent from any other materials (Rohn 1971). In Kiva H at Spruce Tree House it appears to have been used in combination with one of the local residual soils similar to those characteristic of the previous period. Shales used in these mortars were most likely retrieved from narrow shale lenses occurring within the Cliffhouse formation itself. These shale sources would have been readily available to prehistoric masons as they occur quite near to cliff house construction efforts. One drawback to incorporating
shale into the mortar matrix is that they require a greater effort in order to render them usable. The shale would have to be removed from the source, and then prepared through softening and crushing. The payoff is that mortars made by this method are extremely durable and long lasting. It appears that mortars made by this method were the culmination of approximately 50 years of living and intensive building among the cliffs of Mesa Verde. The use of these shale-modified mortars was probably restricted to settlements near exposed shale lenses due to the potentially high energy costs associated with procuring it.

The description detailed above is not meant to be an absolute model, only a general temporal trend based upon the available evidence. There are no doubt deviations from this trend at many of the Mesa Verde cliff house sites, such as in the case of Kiva I at Spruce Tree House. Despite these anomalies, there seems to be ample evidence to indicate the existence of a temporal trend that may extend to a large majority of the cliff house sites within Mesa Verde.

The fact that variability in mortar selection is evident at both of the tested sites, regardless of any temporal patterning, indicates that, contrary to the conclusion drawn by Griffitts (ca. 1996, 2003), the main determining factor in source selection was probably not its proximity to the construction site. This is perhaps best illustrated by the situation at Ruin 12. Ruin 12 is situated along a narrow alcove running through the massive vertical Cliffhouse sandstones. Entrance to the site can only be made by a precarious approach from the mesa top to the northeast. Anyone coming and going from the site must do so through the east side. If proximity to the construction site was the major determining factor in source selection, given its geographic location, one would expect
relative homogeneity in mortar selection. On the contrary, the results indicate the use of a variety of mortar sources at Ruin 12. Certainly proximity was an important consideration for prehistoric masons given the labor necessary for transportation; however, the results of this study indicate a more complex decision making process.

**Objective 2: Examine patterns and range of mortar selection at distinct locations within each site in an effort to determine the extent and makeup of the mortar source primary resource access group.** When coupled with the dendrochronological dates, the mineralogical and elemental results at Spruce Tree House indicate a pattern of period specific mortar source homogeneity. For example, Kiva's D, A, C, and G all appear to use roughly similar mortar recipes. These kivas would have all been built and occupied at approximately the same time. This indicates that the mortar source primary resource access group was probably at a scale larger than the household residential unit. In other words, it appears that those households who occupied Spruce Tree House at the same time shared equal access to the surrounding mortar sources.

Once again the lack of a precise site chronology for Ruin 12 hinders the interpretive value of the results, due to the fact that one can not be certain which of the kivas from the site were occupied simultaneously. However, significant variability in mortar selection at the site, as in the example of neighboring Kivas E and D, appears to be the norm. The heterogeneous pattern of mortar selection exhibited at Ruin 12 does not necessarily imply a household level mortar source primary resource access group at the site. Without proper dating that interpretation remains untenable at best. More likely is the possibility that preferential selection or localized resource exhaustion played some role in the patterns present at Ruin 12. The precarious location of Ruin 12 limits the number of
reasonably obtainable mortar source options. In addition, the results indicate that
inhabitants of the site preferred residual soils as opposed to mesa top loess. Due to the
steep nature of the terrain around the site, these soils primarily occur as small pockets of
soil on cliff benches and on the canyon rim. If resource exhaustion played some role in
the patterns present at Ruin 12, it would have been on a localized level. As soil at one
source was depleted others would be exploited, probably occurring as a pattern radiating
out from the site's single entrance.

Taken together, the evidence indicates that prehistoric Puebloan co-residential units at
Mesa Verde shared common access to mortar sources. As described above, variability in
selection appears to be a complex interaction of temporal factors coupled with
preferential selection and, to a lesser degree, resource exhaustion.

Objective 3: Gain a regional perspective on the similarities and differences in mortar
procurement. The most pervasive result of this research is the probability of a general
temporal trend in mortar selection among Puebloan cliff dwellers which may extend to
much of Mesa Verde. Given the widespread geologic uniformity of the area, prehistoric
inhabitants moving to and living among the cliffs of Mesa Verde would have experienced
much of the same transformative pressures and therefore temporal trajectories.
Microenvironmental conditions in addition to individual and household decision-making
no doubt resulted in numerous regional and local deviations from the temporal pattern
described above. These conditions may have included the presence or absence of a local
shale lens or other localized geologic phenomenon. Where residual soils were the
preferred mortar source, localized resource depletion may have been a factor. In some
areas these soils occur only in meager pockets on small cliff terraces. Depending on site
location, once these sources were exhausted, topography and distance may have been serious considerations guiding mortar selection.

Relatively slight variation in mortar selection is all that can be reasonably expected in an area largely dominated by only two geologic formations, the canyon forming Cliff House Formation and the Menefee Formation emerging in the canyon bottoms. There are only a finite number of effective mortar source options that can be utilized in such a geologically homogenous area. As illustrated by the relative abundant occurrence of muscovite in the Ruin 12 mortars as opposed to the Spruce Tree House mortars, some cross-regional variation in mineralogical and elemental content can be expected.

Objective 4: Determine the effectiveness of using XRD as a primary research tool in examining prehistoric Southwestern mortars. In the context of this study, x-ray diffraction analyses have made many important contributions. In addition to providing the basic mineralogical properties of the architectural mortars at those sites analyzed, the resulting mineralogical patterns were mimicked in the elemental results. This indicates that XRD analysis can be successfully applied to such research contexts; however, the research also highlights the shortcomings of this method. Detection limits constrain the types of research questions that can be successfully investigated. These limitations are compounded when dealing with multi-phase samples such as architectural mortar. Unfortunately this study was not able to take full advantage of mineral phase quantification. Given the proper equipment this would have increased the interpretive power of the results. It is apparent that similar XRD related research will be most effective when it is supplemented with other analytic techniques such as those elemental methods used here. These shortcomings do not necessarily negate the utility of XRD
applications, assuming they are properly formulated. On the contrary, the masonry pueblos of the Southwest provide ideal conditions for the successful and provocative application of similar XRD based research.

Objective 5: Determine if plaster layers were taken from unique sources, and whether patterns indicate annual regularities in plaster application. The results of the plaster analyses presented here were successful on several levels. The elemental analyses in most cases were able to distinguish between the layers of plaster. The most obvious elementally distinguishable layers were the calcium carbonate rich white layers. The tan and red earthen colored layers exhibited more subtle elemental differences. It appears as if not only a variety of sources were used, but also that a variety of recipes were used depending on the intended effect. Both Dix (1997) and Bohnert (1990) report similar findings. Unfortunately the elemental signatures of the plasters from separate kivas are not unique enough to determine whether they were utilizing separate sources. In fact, the results are similar enough to indicate that they may have been utilizing the same sources. The three sampled kivas are all located in close proximity to one another at the west end of Ruin 12. Unfortunately, it was not possible to sample Kivas A and B, located on the east end of the site, to see if a similar pattern was maintained for those kivas.

Due to the small sample size in this study, and a lack of comparative literature, determining regularities in plaster application is not possible. Even correlating layers from specimens taken from a single kiva can be a challenging task, such as in the case of Kiva D. Differential weathering of the individual layers, in addition to irregularities in their application both play a role in disguising the nature of the original layering. In fact, Rohn (1971) notes differential plaster treatment given to upper walls versus lower
bankette walls within kivas at Mug House. The research of Dix (1997) also points out the variability that seems to characterize plaster application. Her research indicates thicker mortar applications with less layering in rooms as opposed to kivas. Unfortunately, room samples were not taken as part of this study and therefore a direct comparison is not possible. The remnant plaster layering appears to be a result of a complex admixture of individual decision making, cultural norms, and environmental processes. Replastering and kiva decoration may have been at least partially tied to ceremonial events; however, based on archaeological evidence, that interpretation remains elusive.

**Objective 6: Aid the Park Service in efforts to document and develop conservation programs and action plans to conserve masonry structures within Mesa Verde National Park.** This research has been successful in providing the Park Service with detailed mineralogical and elemental characterizations of kiva mortars and plasters from two sites within the Park. Perhaps the most important preservation issue brought to light as a result of this study is the prevalence of gypsum soft masses in Spruce Tree House kiva mortars. The presence of gypsum soft masses at other Mesa Verde sites has been noted (see Matero 2003). However, the relative abundance and prevalence of gypsum within Spruce Tree House kivas has only recently been discussed (see Griffitts 2003). This naturally occurring pedogenic process is a concern in terms of long term preservation. The process of gypsum accumulating as discrete nodules displaces intact mortar. The effective result is a loosening and breakdown of the mortar matrix. This in turn weakens the structural stability of the kiva walls, possibly leading to structural failure as walls are continually undermined by weakened mortar. This research indicates that the kivas most prone to
such damage at Spruce Tree House are Kivas A, C, D, and E. Kiva D appears to be most affected. Fortunately, only one Ruin 12 sample from Kiva B exhibited any gypsum soft mass morphology.

Moisture permeating kiva walls seems to be the main factor leading to the formation of gypsum soft masses. Therefore, effective moisture control would be the best way to slow kiva wall deterioration. Unfortunately, this is not always possible or practical depending on the source of the moisture. As much as is possible an attempt should be made to minimize and/or divert moisture away from kivas most prone to deterioration. In the past such measures at the park have included forming false driplines on the ceilings of alcoves as well as runoff diversion ditches. At Spruce Tree House many such protective measures have already been implemented. Hopefully, these moisture control devices have slowed gypsum soft mass formation. However, as a major visitor destination within the Park, maintaining the structural integrity of the site is of utmost importance. In addition to implementing any additional moisture control measures an effective plan of action involves the close monitoring of those kivas prone to damage. Preventative measures should be taken to avoid the likelihood of gross structural failures from occurring. Such measures would likely include reinforcing areas of weakened mortar with stabilization mortars.

The information gained through this research has provided the Park Service with additional tools with which to assess sites in the Park, and more effectively deal with preservation issues that they may face.

In conclusion, the results of this research indicate the existence of a temporal trend in mortar selection at Spruce Tree House very similar to that originally described for Mug
House by Rohn (1971). It appears that the early cliff dwelling masons preferred using a combination of mesa top loess and sandy soil. During the middle period of occupation this gave way to residual soil sources closer to the construction efforts in the cliffs. Finally, during the latest period of cliff house construction masons began incorporating crushed shale into the mortar. This temporal trajectory of mortar selection has now been shown at two Mesa Verde sites, and may extend to a large portion of similar cliff house sites within the Mesa Verde proper. The results from Spruce Tree House also indicate that households occupying the site at any one time shared equal access to mortar sources. Unfortunately, due to the lack of a chronology, the Ruin 12 results remain ambiguous on this subject.

This research also evaluates the utility of using geochemical techniques to study prehistoric southwestern construction materials. Successful application of techniques such as XRD are dependant on a number of factors, but are shown to be a valuable tool in researching culturally significant topics. Additionally, the research highlights conservation issues dealing with the accumulation of gypsum in kiva walls at Spruce Tree House.

Further Research

One interesting avenue of research directly related to this study would be an expansion of the sampling strategy to include structures other than kivas. Such a strategy would avoid problems caused by pedogenic processes. In addition, research questions could be expanded to include relationships between roomblocks, and between kivas and their associated roomblock. Additional cliff dwellings both in and around Mesa Verde
with well established chronologies could be tested in a similar manner to see if they parallel the temporal patterning exhibited at Spruce Tree House and Mug House. Such research would help to refine a regional view of mortar procurement. Although the results from Spruce Tree House indicate that households occupying the site at any one time shared equal access to mortar sources, additional research is necessary to determine if similar patterns hold true at sites with less access to adequate soils. In such areas, competition over these resources may have been greater, leading to possible access restrictions and partitioning of resource access groups.

A more detailed analysis of the soils surrounding both Spruce Tree House and Ruin 12 would allow for more accurate pinpointing of mortar source locations. When combined with the data presented here, this information would allow for more robust interpretations about prehistoric behavior. In regard to gypsum formation in the kiva walls, further research should include an evaluation of possible sulfur sources. Such investigations would likely include the analysis of possible mortar source soils for the presence of sulfur. Sulfur may also be leaching into the kivas from the surrounding geologic formations. This possibility should also be investigated. Finally, sulfur isotopes from kiva gypsum could be studied to determine if wood smoke from kiva fires may have been a significant source of sulfur which over time accumulated within kiva walls.

Further plaster analyses could include additional sampling from both kivas and associated roomblocks in order to determine if those results reported by Dix (1997) hold true on a more regional basis. In addition, as suggested by Bohnert (1990), plaster layers could be studied for the presence of organic binders.
Unfortunately, by its nature, prehistoric mortar and plaster sampling is of itself a destructive mode of inquiry. Any expanded research design would have to carefully consider the balance between being scientifically constructive versus preservationsally destructive.

The predominance of masonry and adobe architecture in the prehistoric southwest provides the perfect arena for the successful application of geochemical techniques in answering a myriad of archaeological questions. The research undertaken here is but one example that plainly exhibits the potential of such research.
REFERENCES CITED

Adler, Michael

Ahlstrom, Richard V. N., Carla R. Van West, and Jeffrey S. Dean

Alessandrini, Giovanna, Roberto Bugini, Riccardo Negrotti, and Lucia Toniolo
1991 Characterization of plasters from the church of San Niccolo di Comelico (Belluno - Northern Italy). Schweizerbart’sche Verlagsbuchhandlung 619-627.

Alvarez, J. I., I. Navarro, A. Martin, and P. J. Garcia Casado

Alvarez, J. I., I. Navarro, and P. J. Garcia Casado

Bellanca, Adriana, Enrico Curcuruto, Sebastiano Lo Bue, and Rodolfo Neri

Birkeland, Peter W.

Bohnert, Allen S.
1986 *Dolores Archaeological Program: Final Synthetic Report*. USDI Bureau of  
Reclamation, Engineering and Research Center, Denver. (NTIS PB88130356/AS).

Brew, J. Otis  
1946 *Archaeology of Alkali Ridge, Southeastern Utah*. Papers of the Peabody  

Brown, Gordon E.  
185-191.

Buhrke, Victor E., Ron Jenkins, and Deane K. Smith (editors)  

Cameron, Catherine M.  
dissertation. Department of Anthropology, University of Arizona, Tuscon.  
1995 Migration and the Movement of Southwestern Peoples. *Journal of*  
*Anthropological Archaeology* 14: 104-124.

Cordell, Linda  

Decker, Kenneth W. and Larry L. Tieszen  
1989 Isotopic Reconstruction of Mesa Verde Diet from Basketmaker III to Pueblo  

Dix, Linnaea  
1996 Characterization and analysis of prehistoric earthen plaster, mortars, and paints  
from Mug House, Mesa Verde National Park, Colorado. Unpublished M.S. Thesis,  
University of Pennsylvania.  
1997 Materials in the Laboratory, Earthen Plasters, Mortars, and Paints From Mug  

Dozier, Edward P.  
1960 The Pueblos of the South-Western United States. *The Journal of the Royal*  
*Anthropological Institute of Great Britain and Ireland* 90: 146-159.
Erdman, James A., Charles L. Douglas, and John W. Marr  

Fewkes, J. Walter  

Fiero, Kathleen  

Genestar, Catalina and Carmen Pons  


Griffitts, Mary O.  

Hartzler, Robert  
1996 *Acrylic-Modified Earthen Mortar, A Program of Investigation and Laboratory Research into Acrylic-Modified Earthen Mortar Used at Three Prehistoric Pueblo Sites.* Intermountain Cultural Resource Center, Professional Paper No. 61, Santa Fe, New Mexico.  

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Hayes, Alden C.

Hayes, Alden C., and James A. Lancaster

Herold, Joyce

Holmes, William H.

Horn, Jonathon C.

Howard, Richard M.

Huber, Edgar Kurt

Irwin-Williams, Cynthia

Jackson, William H.
Jose-Yacaman, Miguel and Jorge A. Ascencio
2000 Electron Microscopy and its Application to the Study of Archaeological
Materials and Art Preservation. In Modern Analytical Methods in Art and
Archaeology, edited by Enrico Ciliberto and Giuseppe Spoto. Chemical Analysis

Kidder, Alfred V.

Kohler, Timothy A., William D. Lipe, and Allen E. Kane (compilers)
1986 Dolores Archaeological Program: Anasazi Communities at Dolores: Early
Small Settlements in the Dolores River Canyon and Western Sagehen Flats Area.
U.S. Department of the Interior, Bureau of Reclamation, Engineering and Research
Center, Denver, Colorado.

Kuckelman, Kristin A.
2002 Thirteenth-Century Warfare in the Central Mesa Verde Region. In Seeking the
Center Place, Archaeology and Ancient Communities in the Mesa Verde Region,
Utah Press, Salt Lake City.

Lancaster, James A. and Don Watson

Lancaster, James A., Jean M. Pinkley, Philip F. Van Cleave, and Don Watson
Archaeological Research Series, no. 2, National Park Service, Washington D.C.

Lekson, Stephen H.
1986 Great Pueblo Architecture of Chaco Canyon, New Mexico. University of New
Mexico Press, Albuquerque.
1990 The Great Pueblo Period in Southwestern Archaeology. In Pueblo Style and
Regional Architecture, edited by Nicholas C. Markovich, Wolfgang F. E. Preiser,
1996 The Pueblo Southwest After A.D. 1150. In Interpreting Southwestern
Diversity: Underlying Principles and Overarching Patterns, Anthropological
Research Papers, no. 48, pp. 41-44. Arizona State University.

Lekson, Stephen H. and Catherine M. Cameron
1995 The Abandonment of Chaco Canyon, the Mesa Verde Migrations, and the
Reorganization of the Pueblo World. Journal of Anthropological Archaeology 14:
Lipe, William D.


Lipe, William D., James N. Morris, And Timothy A. Kohler (compilers)


Lister, Florence C.


Lister, Robert H.


1965 *Contributions to Mesa Verde Archaeology: II. Site 875, Mesa Verde National Park, Colorado.* University of Colorado Studies, Series in Anthropology, no. 11 Boulder, Colorado.


Matero, Frank

Matson, Richard G.

Matson, Richard G., William D. Lipe, and William R. Haase IV

Metcalf, Mary Patricia

Mindeleff, Victor

Morgan, William N.

Moropoulou, A., K. Polikreti, A. Bakolas, and P. Michailidis

Newberry, John S.

Nickens, Paul R.
Nordby, Larry V., Todd R. Metzger, Cynthia L. Williams, and James D. Mayberry
2002 *Mesa Verde National Park Archaeological Site Conservation Program
Guidelines, Volume 1: Standards for Field Data Collection and Documentation.*
On file at Mesa Verde National Park Division of Research and Resource
Management, Mesa Verde National Park, Colorado.

Nordenskiold, Gustof E.A.
1893 *The Cliff Dwellers of the Mesa Verde, Southwestern Colorado: Their Pottery
and Implements.* Translated by D. Lloyd Morgan, P.A. Norstedt and Soner,
Stockholm and Chicago.

O’Bryan, Deric
1950 *Excavations in Mesa Verde National Park, 1947-1948.* Medallion Papers,

Oppelt, Norman T.
1996 Petrographic Analysis of the Temper in the Pottery from Mesa Verde National

PANalytical
2003 *Introductory Training Manual, X’Pert PRO/ CubiX Pro.* PANalytical, Natick,
Massachusetts.

Petusky, William T., David A. Richardson, and Donald A. Dolske
1995 Aspects of the Deterioration of Sandstone Masonry in Anasazi Dwelling Ruins
at Mesa Verde National Park, Colorado, USA. *The Science of the Total
Environment* 167: 145-159.

Pierce, Christopher, Donna M. Glowacki, and Margaret M. Thurs
2002 Measuring Community Interaction, Pueblo III Pottery Production and
Distribution in the Central Mesa Verde Region. In *Seeking the Center Place,
Archaeology and Ancient Communities in the Mesa Verde Region*, edited by Mark
D. Varien and Richard H. Wilshusen, University of Utah Press, Salt Lake City.

Plog, Fred
1979 Prehistory: Western Anasazi. In *Southwest*, edited by Alfonso Ortiz, pp. 108-
editor, Smithsonian Institution, Washington, D.C.

Plog, Stephen
Pollard, Mark A. and Carl Heron

Prudden, Mitchell T.

Rohn, Arthur H.
  1977 *Cultural Change and Continuity on Chapin Mesa*. The Regents Press of Kansas, Lawrence, Kansas.

Roney, John R.

Saile, David G.

Scarborough, Robert and Izumi Shimada

Smiley, Terah L.

Stephen, Alexander M.

Swannack, Jervis D. Jr.
Titiev, Mischa

Tykot, R. H. and S. M. M. Young

Upham, Steadman

Varien, Mark D. (editor)

Varien, Mark D., William D. Lipe, Michael A. Adler, Ian M. Thompson, and Bruce A. Bradley

Velez De Escalante, Silvestre

Watson, Don

Whiteley, Peter M.

Whitting, L. D. and W. R. Allardice
Wilshusen, Richard H., Melissa J. Churchill, and James M. Potter
1997 Prehistoric Reservoirs and Water Basins in the Mesa Verde Region:
    Intensification of Water Collection Strategies During The Great Pueblo Period.

Woodbury, Richard B.
    Handbook of North American Indians, Vol. 9, William C. Sturtevant, general
    editor, Smithsonian Institution, Washington, D.C.

Zulauf, Marta Sue Remington
1982 Through the Sipapu: An Ethnohistorical Analysis of the Mesa Verde Anasazi.
    Unpublished Ph.D. dissertation, Department of History, University of Houston,
    Texas.
VITA

Graduate College
University of Nevada, Las Vegas

Shane David Rumsey

Home Address:
HCR 2 Box 9620
15-1667 2nd Street
Keaau, HI 96749

Degrees:
Bachelor of Science, Anthropology, 2002
Weber State University, Ogden, Utah

Special Honors and Awards:
Weber State University Anthropology Department’s outstanding graduating senior in archaeology award

Graduated Magna Cum Laude with Bachelor of Science degree

Thesis Title: Cultural Implications of Architectural Mortar and Plaster Selection at Mesa Verde National Park, Colorado

Thesis Examination Committee:
Chairperson, Dr. Karen G. Harry, Ph. D.
Committee Member, Dr. Barbara Roth, Ph. D.
Committee Member, Dr. Alan H. Simmons, Ph. D.
Committee Member, Dr. Patrick J. Drohan, Ph. D.