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Characterization, Analysis and Interpretation of the Surface Finishes of Kiva E, Long House, Mesa Verde National Park

Lauren Reynolds Hall
University of Pennsylvania

A Thesis in Historic Preservation Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for the Degree of Master of Science in Historic Preservation 2007.
Advisor: Frank G. Matero

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In

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MASTER OF SCIENCE
IN HISTORIC PRESERVATION

2007

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CHAPTER 1

1.0 INTRODUCTION

This thesis investigates the interior architectural surface finishes within Kiva E, a ceremonial chamber in the western portion of Long House at Mesa Verde National Park, and attempts to analyze them and interpret the succession of interior schemes. Kiva E contains significant surface finishes, unique in their applied design, that record a sequence of symbolic and stylistic changes. Study of these elements is critical for the interpretation of this important space and Long House in general while their preservation is fundamental to allow future studies and investigations.

A comparative investigation of kiva construction, design and finish treatment, particularly at Mesa Verde and elsewhere in the Four Corners region enable architectural comparison while a study of Pueblo pottery designs and symbolism extends interpretation of the schemes and embellishments such as those found in Kiva E. On-site observation and recording of architectural surface finishes, cross section analysis, and iconographic research of Ancestral Puebloan creative practices facilitate the development of a conjectural schematic visualization of Kiva E, illustrating what the space may have looked like and its evolution over time.

Three principle research objectives are addressed. Compositional analyses of earthen finishes in Kiva E for the identification of possible raw materials of the finishes, their use, placement and appearance over time. Relationships between pottery design, kiva construction and applied architectural embellishment based on Pueblo practice and symbolism are studied. Various finish schemes are identified and subsequent hypothetical illustrations of the interior of Kiva E, its embellishments and finish sequence created.

General research methodology includes the study of archival documentation for Wetherill Mesa and Long House in particular. A catalog of previous research findings at Mesa Verde National Park was compiled including geologic and soil surveys and analyses of architectural surface finishes. Methods of research and analysis applied in former investigations to similar sites are similarly applicable in the examination Kiva E. Representative samples from designated areas within Kiva E were collected for characterization and analysis. Investigative methods include optical microscopy such as thin and cross section analysis, Fourier Transform Infrared Spectroscopy, and scanning electron microscopy with x-ray spectroscopy, as well as micromorphological studies laboratory methods of chemical analysis. Evaluation and visualization of the findings (field and lab data and speculative schemes) constitute a series of conjectural graphic representations of the information.

The plaster finishes at Long House represent some of the most exceptional extant surfaces found park-wide, especially considering the elaborate design along the east wall of Kiva E. Knowledge of plaster composition and methods of application may contribute to the formulation of potentially compatible treatment options in comparable spaces. Visual investigation and cross section analysis identify the number and type of applied layers, facilitating the identification of various schemes and present further insight to ancestral Puebloan architecture and cultural practice. Through analyses, investigation, and interpretation the value of these sites will be sustained while the development of compatible treatments will contribute to preserve their integrity.

2.0 SITE HISTORY AND DESCRIPTION

2.1 Wetherill Mesa

Designated by Swedish amateur-archaeologist Gustav Nordenskiöld, 'Wetherill's Mesa' commemorated the Wetherill family's contribution to the discovery of many of the architectural ruins of Mesa Verde, principally due to their friendly rapport with the Ute Indians that occupied the region. Nordenskiöld's 1893 publication, *The Cliff Dwellers of Mesa Verde*, remained the singular account of the vestiges of Wetherill Mesa until 1964.

Wetherill Mesa, a sandstone and shale geologic formation, is flanked by Long Canyon to the east and Rock Canyon to the west and serves as the western boundary of Mesa Verde National Park. Marked by a ridge, Long Spur, along its narrow north rim, Wetherill Mesa rises nearly 2,614 meters (8,575 feet) and slopes gently down towards the south.[1] The mesa-top widens to approximately 1 ½ kilometers (nearly 1 mile) and is covered by a red loess soil near its center. Along the broader section of the mesa, the cliffs are sheer and steep ranging from 15 to 30 meters (50 - 100 feet) deep.[2] Most recently affected by the Wildhorse Fire in 1934, the Rock Springs Fire of 1972, the first Long Mesa Fire of 1989 and the Pony Fire of 2000, much of the mesa today appears barren and charred.

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[1] Hayes, Alden C., and Douglas Osborne, *The Archeological Survey of Wetherill Mesa, Mesa Verde National Park—Colorado*. Archeological Research Series Number Seven—A. National Park Service. 1964. Online version. <http://www.cr.nps.gov/history/online_books/meve/7a/contents.htm> (17 February 2007).
[2] Hayes. Online version.

CHAPTER 2

Figure 2.1. North Scarp of Wetherill Mesa, Long Spur to the right (Hayes).

The Wetherill Mesa Project

The Wetherill Mesa Project emerged amidst the introduction of Mission 66, a program directed towards the revitalization of park facilities, as the second major undertaking to generate progressive change at Mesa Verde. Initiating a full-scale archaeological excavation after 40 years of quiet, the project reestablished Mesa Verde as a leader in prehistoric excavation.[3] The National Geographic Foundation provided supplementary funding to that of Federal monies with the endowment of four grants in 1958, totaling $200,000, and enabling preliminary excavations of Long House in the fall of that year.[4] The summer of 1961 proved the most productive and by the end of the second season approximately 800 sites had been discovered.

The initiative was a binary operation, its dual objectives focused on research and new exhibits and later, the introduction of a transit system on Wetherill Mesa. Park officials were hopeful that additional sites open for visitation would both benefit the public and alleviate tourist traffic straining the over-crowded sites of Chapin Mesa during peak season.

Representing the most comprehensive archaeological program at Mesa Verde, the Wetherill Mesa Project was responsible for the renewed popularity of the Park. This along with improved highway systems enabled more extensive travel out west. By 1965, Wetherill Mesa was ready for visitation, but a transportation infrastructure was still in the works.

Wetherill Mesa finally opened to the public in 1973, but remained largely underutilized by the visiting population. Insufficient transit systems, hazardous roads and rock slides presented frequent problems. In efforts to promote interest and increase

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[3] Smith, Duane A., *Mesa Verde National Park, Shadows of the Centuries* (Lawrence, Kansas: University of Kansas Press, 1988) 160.
[4] Smith 160.

accessibility, improvements were made to the roads and exhibits, and by 1987 visitors were permitted to drive their private cars out the mesa.

2.2 Long House

Figure 2.2. Plan of Long House (Cattanach 1980).

Long House is the second largest alcove site in Mesa Verde National Park, behind the Park's most widely recognized and visited alcove site Cliff Palace, with an estimated 150 rooms, 21 kivas and a large ceremonial plaza in the eastern portion of the site. Long House is located along the western side of Wetherill Mesa overlooking Rock Canyon to the south, nestled in the cliff approximately 30 meters (100 feet) below the rim rock at an elevation of 2,128 meters (6,983 feet.) above sea level.[5]

Sheltered by the alcove wall, Long House is constructed of sandstone masonry and adobe and covered in earthen plasters, remnants of which remain on elements of original construction and are especially intact in the eastern half of the site where the architecture is better protected by the alcove. A seep at the rear of the alcove in the east half of the site once provided water to the extensive pueblo, now evident by a small pool of standing water surrounded by abundant vegetation. Varied styles and structures account for the irregular topography of the site as well as its history of use and occupation. Several periods of occupation are represented in the architecture at Long House with evidence of alterations through episodes of abandonment, reoccupation and reconstruction. Two phases of

[5] Cattanach, George S. Jr., *Long House Mesa Verde National Park, Colorado*, Publications in Archaeology 7H, Wetherill Mesa Studies (Washington, DC: National Park Service, U.S. Dept. of the Interior, 1980) 1.

Figure 2.3. View of Long House taken from the eastern portion of the site looking west (August 2006).

inhabitance have been identified at Long House with occupancy during the Basketmaker III period, from approximately 648 C.E., and the late Pueblo III period, its age of major occupation dating from 1200 to 1280 C.E.[6] Dates were ascertained by performing dendrochronology on roofing timbers, or *vigas*, from early Pithouses and later rooms and kivas.

[6] Cattanach 3.

Inscriptions on the rock face and elsewhere in the site attribute the discovery and naming of Long House to the Wetherill brothers and their brother-in-law Charlie Manson, presumably in the winter of 1890. Introduced to the site by the Wetherills, Nordenskiöld assigned Long House "No. 15", carved in bedrock at the rear of the cave, for the purposes of his records and investigations. Long House was the first alcove site excavated during the Wetherill Mesa Project beginning in October of 1958.

2.3 Excavation and Stabilization History

The first formal excavations at Long House were executed by Gustav Nordenskiöld and John Wetherill between July 14 and August 14, 1891. Not generating "any particularly good results", Nordenskiöld moved his efforts elsewhere on Wetherill's Mesa.[7]

Excavation did not commence at Long House until the launch of the Wetherill Mesa Project. Field work was led by George Cattanach with James 'Al' Lancaster acting as excavation supervisor. Complete excavation and stabilization of Long House was conducted from the fall of 1958 to the summer of 1962, beginning with the more exposed units in the western half of the site and those to the east most shielded by the cave. Stabilization occurred as an integral part of the archaeological work at Long House; repair and partial or

[7] Nordenskiöld, Gustav, *The Cliff Dwellers of the Mesa Verde,* Mesa Verde Museum Association, 1990 (Original printing, Stockholm: Royal Printing Office, 1893) 21-22.

absolute reconstruction of original masonry served to support existing structures or as retaining walls for fill.[8] It is estimated that nearly half of Long House has been stabilized.

Figure 2.4. Long House, general view west (Werner 1959).

Photographic documentation dating from May of 1988 records the strategic repointing and filling of areas of degradation under the direction of Park stabilization supervisor Kathy Fiero. Kiva benches/banquette shelves and areas exposed to weathering and water percolation through the alcove wall particularly in the western half of the site were subject to stabilization based on their elevated state of deterioration. Subsequent preservation efforts have focused primarily on surface finishes conservation, discussed

[8] Cattanach 6.

specifically in relation to Kiva E in Chapters 3 and 4. (Refer to Appendix A for historic excavation and stabilization photographs.)

3.0 LITERATURE REVIEW

3.1 Puebloan Architecture and Pottery Design

3.1.1 Kiva Construction

The term *kiva* comes from the Hopi word referring to special chambers constructed and used for civic or ceremonial purposes, and potentially as domiciliary spaces during colder seasons. Typically entered through an opening in the roof, kivas represent symbolic passages to the underworld, reinforced by the conventional inclusion of the sipapu, a small hole in the floor signifying the ingress for spirits.[9] Resonating with contemporary tribal practices, although varying by culture, decorative paintings on the walls of the chambers were often incorporated in ceremonies. Kiva construction differs throughout the Pueblo region, ranging in shape from circular or D-shaped to rectangular, often oriented on a directional axis and incorporating adjacent alcoves; structures "may be either wholly or partially subterranean or even completely above ground." [10] Kivas at Mesa Verde are consistently circular in plan and typically subterranean. Common internal features include pilasters to support the cribbed roofing vigas, banquettes or benches, fire pits, ventilator shafts and niches. In many cases, alterations to the space either through repairs or revisions

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[9] Brody, JJ., *Anasazi and Pueblo Painting*, 1st ed. (University of New Mexico Press, 1991) 54.
[10] Smith, Watson, "Kiva Mural Decorations at Awatovi and Kawaika-a," *Papers of the Peabody Museum of American Archaeological and Ethnolog,* Harvard University, 37 (Cambridge, MA: Peabody Museum, 1952) 5.
____ . *When is Kiva? And Other Questions About Southwestern Archaeology*, ed. Raymond H. Thompson (Tucson: The University of Arizona Press, 1990) 57.

in the kiva's layout are apparent; this is true of several of the kivas within Long House including Kiva E, as discussed in the subsequent chapter.

Wall Surfaces and Embellishments

Especially true of subterranean structures, kivas were entered through the roof and therefore walls were rarely interrupted, with the exception of niches. This enabled and encouraged elaborate applied design and repeating patterns along kiva walls.

Painted dados appear to be characteristic of the kivas from the Pueblo II and III periods at Mesa Verde. Commonly applied designs include simple geometric patterns, triangles, dots, handprints and pictorial elements of representational zoomorphs and anthropomorphs. The latter are reminiscent of the earlier pictographs and petroglyphs represented on cave walls and rock faces. Embellishments and patterns were not characteristic of every individual layer in an architectural space, nor did they consistently extend around the entire perimeter of the kiva.[11] Intricate wall designs at Mesa Verde are infrequent and less elaborate by comparison to the painted walls of sites to the south and west, which further attests to the rarity and significance of the embellishment found in Kiva E, discussed in later chapters.

[11] Smith "Kiva Mural Decorations at Awatovi and Kawaika-a" 21.

Plaster Renewal

Plaster renewal was common practice in ancestral Puebloan culture. Numerous layers found on walls across the region suggest the ubiquitous tradition of renewal occurring with relative frequency. Customary of modern Hopi practices, kivas are subject to periodic plaster renewal.[12] Repair of partial disintegration, plaster detachment or wall collapse may have called for the reapplication of surface finishes. Soot deposition or surface accretions such as soiling or salts may have prompted the refurbishment of the walls. Redecoration of the walls could also be attributed to ritual practices and the necessity to obscure images that had been used in a sacred rite after it had served its ceremonial purpose.[13]

3.1.2 Pottery Design, Rock Art, and Wall Paintings

Despite idiosyncratic approaches by the ancient Pueblo artists in the aesthetic treatment of different materials, relationships between pottery painting, rock art and mural painting are apparent, sharing stylistic and iconographic similarities.[14] Ancestral Puebloan aesthetic tradition is evident in each creative practice and art form, especially in the applied designs of pottery, rock art and murals, but also including basketry and textiles.

Pottery is considered to have been almost exclusively utilitarian, yet bowls and jars emerge with inventive linear patterns and angular designs even during early Pueblo periods. Ceramics of the San Juan Basin are largely characterized by the contrast of black painted

[12] Smith "Kiva Mural Decorations at Awatovi and Kawaika-a" 20.
[13] Smith "Kiva Mural Decorations at Awatovi and Kawaika-a" 20.
[14] Brody, *Anasazi and Pueblo Painting* 27, 59.

designs over a smooth slipped white or occasionally red ground. People of the southern and eastern regions place emphasis on fine attenuated lines applied in an iron-based reddish-black pigment; while those of the northern and western regions, including Mesa Verde, practice a tradition of strong positive/negative symmetrical patterns with dark masses in black or grey carbon-based pigment over a lighter ground.[15] Baskets served as the precedent for pottery, exhibiting design repetition and framed elements. Ancestral Puebloan design schemes illustrate a systematic manipulation and configuration of line, geometry and void space.[16]

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15 Brody, *Anasazi and Pueblo Painting* 29.
16 Brody, *Anasazi and Pueblo Painting* 41.

Figure 3.1. Mesa Verde black-on-white ceramic vessel (Breternitz, et al., 1974).

Rock art has a venerable and less understood history, and may have held ritual purposes similar to the traditions associated with plastered motifs. Not dictated by the physical constraints imposed by the margins of pottery and architecture, depictions on cliff faces and alcove walls meander across rock surfaces. Pictographs and petroglyphs frequently include painted and/or incised handprints and human or animal representations, creating evocative narratives, hunting scenes, mountain landscape portrayals and contextual figures.[17] Anthropomorphic silhouettes such as humpbacked flute players (Kokopelli), shield bearing humanoids and phallic figures interact with zoomorphic depictions of birds, serpents, and game animals resembling big horn sheep and deer. Etched, incised and eventually painted with the introduction of color into pictographs, analogous to the pigmentation found on architectural surfaces, similar embellishments are represented in wall paintings as well.[18]

Decorative Trends and Cultural Practices

Rich pictorial traditions of the later Puebloan periods occur in tandem with expanding populations, communal growth and resultant decorated architecture. The earliest wall paintings have been identified as Pueblo II (900-1100).[19] Two well-established Puebloan artistic traditions, the non-objective and structured design found on pottery in particular as well as the figurative and expressive approach of rock art, appear to have contributed to the iconography and development of early mural paintings. Mural paintings become progressively more intricate with increasing frequency in the later Puebloan periods as murals and architecture develop concurrently. Review of the literature implies a melding of cultural traditions in the American Southwest brings about the dissolution of sharp regional artistic distinctions.

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[17] Brody, *Anasazi and Pueblo Painting* 33-37.
[18] Brody, *Anasazi and Pueblo Painting* 38.
[19] Brody, *Anasazi and Pueblo Painting* 57.

Pottery designs are largely non-figurative, executed in structured and judicious uncomplicated geometric motifs in contrast to the often representational and less rigid arrangements of pictographs and petroglyphs; although isolated illustrations in rock art occasionally mimic the images framed on pottery with dots, bands, patterns or ticks that resemble textile stitching. Comparable design approaches are evident on architectural surfaces, especially between the decorative treatment of ceramic bowls and the circular structure of kivas, with patterns circumscribing their interiors.[20] Relationships between pottery painting and mural design are especially apparent in the uniformity and spatial organization of corresponding motifs of horizontal bands, diagonal lines, triangles and upright mounds, stepped forms, scrolls, frets, and other rhythmic arrangements, etc.[21] Beyond surface finishes, enclosed architectural spaces were widely viewed as vessels, with treatment and handling similar to that of pottery and basketry.[22] Civic buildings, such as kivas, were thought of as communal serving bowls with cribbed roofs that imitate the process and pattern of basket weaving.[23]

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[20] Brody, *Anasazi and Pueblo Painting* 62.
[21] Brody, *Anasazi and Pueblo Painting* 54, 59.
Cole, Sally J., "Imagery and Tradition: Murals of the Mesa Verde Region," *The Mesa Verde World, Explorations in Ancestral Puebloan Archaeology,* ed. David Grant Noble (Santa Fe: School of American Research Press, 2006) 92-99.
[22] Ortman, Scott, "Ancient Pottery of the Mesa Verde Country," *The Mesa Verde World, Explorations in Ancestral Puebloan Archaeology,* ed. David Grant Noble (Santa Fe: School of American Research Press, 2006) 100-109.
[23] Ortman 100-109.

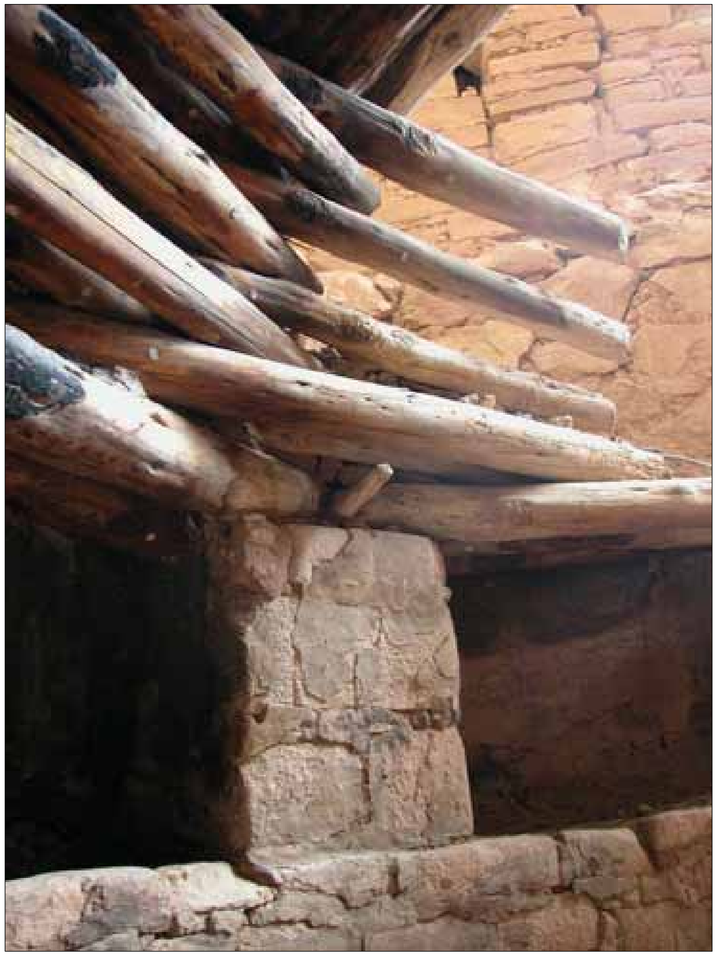

Figure 3.2. Kiva roof cribbing with vigas supported by the pilaster and resembling basketry in Cliff Palace (CASPAR 2003).

Based on historically recorded practices, researchers assume that the deliberate organization of pictures on vessels, ceramic or otherwise, were generally painted/applied by women whereas the larger scale figurative illustrations on rock faces and architecture were created by the ancestral Puebloan men.[24] Whether the task of mural painting and kiva decoration was reserved for members of a certain gender is unknown.

The comparability between pottery painting, rock art and the assiduous architectural construction that flourished between 900 and 1300 extends beyond that of applied decoration and converges with the emphasis of light and dark, between positive and negative design.[25] In architecture, the interaction of light and shadow visually articulates the structures of the south facing pueblos, creating chiaroscuro resultant of the relationship between the carefully assembled well-shaped masonry and the sunlight; much like the contrast between the white and black dynamic yet controlled designs of the Mesa Verde pottery.

Pottery painting, rock art and architectural surface finishes are all generally applied over a plaster ground and designs are painted by similar methods using brushes of yucca fiber, hands and fingers. The scale of the imagery is dictated by the medium or substrate on which it is applied. Discrete motifs coupled with large repetitive designs are characteristic of Mesa Verdean architectural surface finishes, exhibited in the wall scheme of Kiva E in Long House. Dots and triangles painted along the dado in Fire Temple at Mesa Verde constitute a pattern evocative of the designs found on much of the pottery of the Pueblo I (700-900) and

[24] Brody, *Anasazi and Pueblo Painting* 42.
[25] Brody, *Anasazi and Pueblo Painting* 53-54.

Pueblo II (900-1100) periods from various areas of the San Juan Basin.[26] The bird image painted on a kiva wall in Mug House, very similar to the bird found in Kiva J of Long House, is suggestive of birds depicted on numerous Puebloan ceramic vessels. Figurative elements in addition to birds include representational images of serpents and mountains as on the kiva walls in Ruin 12 of Wetherill Mesa, big horned sheep as in Kiva E at Long House, as well as the aforementioned flute players, also believed to have been present on the northeast wall of Kiva E, and often occur in monochromatic silhouettes. Both vertical and horizontal stripes often painted around the periphery of kiva banquettes, particularly at Mesa Verde, are a popular motif of Puebloan pottery as well.

[26] Smith, "Kiva Mural Decorations at Awatovi and Kawaika-a" 63.

Figure 3.3. Detail of sheep and set of antlers to the right on the banquette of Kiva E in Long House (Ferron 2006).

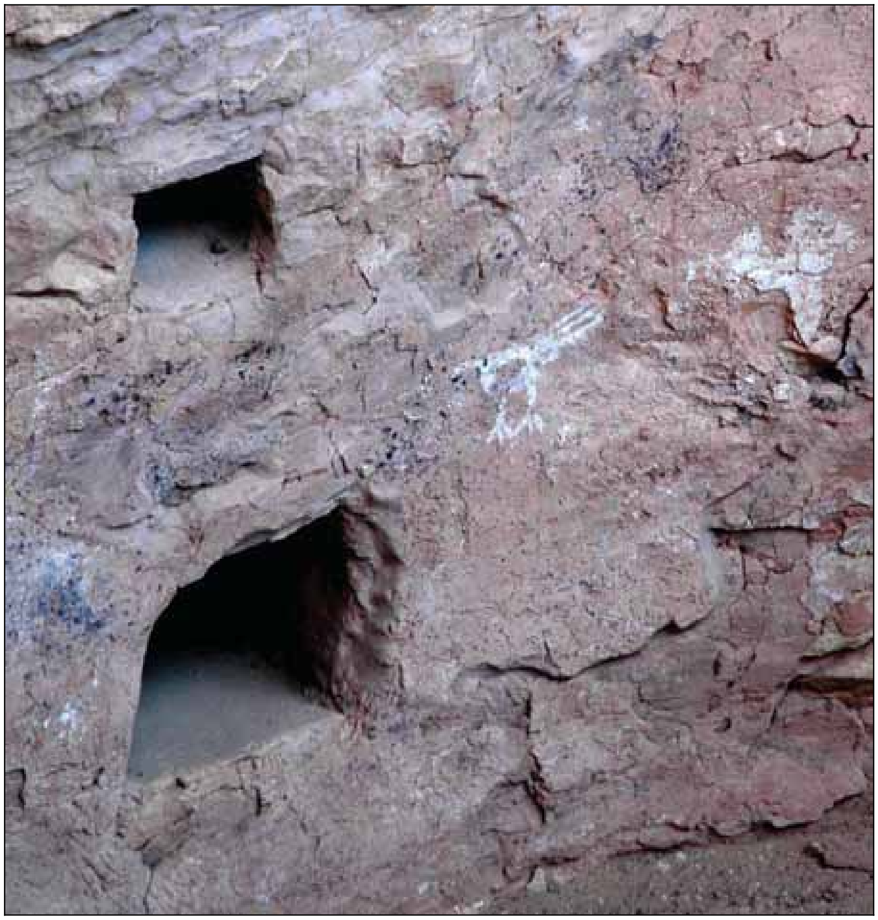

Figure 3.4. Image of a bird on the banquette of Kiva J in Long House (2006).

Pottery painting, mural painting and rock art were the three native precedents that served to influence and inspire the celebrated and collected Pueblo art of the late 19^{th} and early 20^{th} centuries.[27] As mentioned, Pueblo men were usually responsible for depictions on ritual objects for ceremonial use, while decorated domestic items are more frequently attributed to women, such as pottery; however, by the late 19^{th} century men became more

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[27] Brody, JJ., *Pueblo Indian Painting, Tradition and Modernism in New Mexico 1900-1930* (Santa Fe: School of American Research Press, 1997) 18.

associated with the painting of pottery. Availability of expanded media resulted in their use by Pueblo artists in to the 1900s, especially in watercolor painting. Historic motifs and iconography particularly characteristic of Mesa Verde pottery, including bird imagery, terraced mountain patterns, lighting, clouds and rainfall, and horned serpents, were translated to Pueblo costumes and ritual paraphernalia as well as their paintings on paper.[28]

Pottery Production and Distribution

Compositional analysis in conjunction with regional comparisons of architecture and pottery design, embellishment and pigmentation has the potential to reveal early ancestral Puebloan behaviors and reinforce the importance of a holistic investigative approach, considering theory, culture and scientific research. Coordination of field work and investigations of characterization and provenance of ceramics and other raw materials in the southwest has resulted in recent studies that focus on issues of production and distribution,[29] which support the mutual communication and interaction of ancient Puebloan civilizations. In spite of variations in fabrication, style and ornament, iconographic similarities, shared imagery and the use of alien pigments in sites across the region support the notion that autonomous groups borrowed and traded ideologies with each other. Considerable amounts of pottery and other raw materials are believed to have been transferred between contemporaneous settlements; delineation of pottery provenance in the Mesa Verde region

[28] Brody, *Pueblo Indian Painting, Tradition and Modernism in New Mexico* 20.
[29] Beaudry-Corbett, Marilyn, "A Social History of Archaeological Materials Characterization Studies," *Patterns and Process: A Festschrift in Honor of Dr. Edward V. Sayre*, ed., Lambertus van Zelst (Suitland, Md.: Smithsonian Center for Materials Research and Education, 2003) 22.

was based on differing design styles, production techniques and tooling, and composition compared to that of surrounding raw materials.[30]

As previously mentioned, cultural divisions between disparate regional groups waned during the late Pueblo II and Pueblo III periods, and closely related parallels in design motifs are frequently observed. In his research of the kivas at Awatovi and Kawaika-a, Watson Smith observed specimens of what appeared to have served as source material for pigment was often "found among the debris of the ruin, sometimes in ceramic bowls or caches as if they had been carefully stored;" [31] occasionally the raw pigment represented nonnative material that presumably had been acquired through trade with other pueblos.

3.2 Summary of Previous Research Completed at Mesa Verde

Apart from the numerous excavations, historical accounts and continued scientific research at Mesa Verde, this chapter seeks to chronicle the geological, pedological and plaster characterization studies that have contributed to the understanding of ancestral Puebloan architectural surface finishes.

3.2.1 Geologic Surveys

Included as part of the Wetherill Mesa Project, Orville Parsons of the Soil Conservation Service conducted a standard comprehensive soil survey of the Mesa,

[30] Varien, Mark D. and Richard H. Wilshusen, eds., *Seeking the Center Place, Archaeology and Ancient Communities in the Mesa Verde Region* (Salt Lake City: The University of Utah Press, 2002) 187.
[31] Smith, "Kiva Mural Decorations at Awatovi and Kawaika-a" 22.

published in a report for the U.S. Department of Agriculture in 1965. Douglas Osborne completed a geological study of the Park and compiled an anthology of anthropological essays and reports on the natural sciences in the mid-1960s for the Society for American Archaeology. Sponsored by the Mesa Verde Museum Association, Mary Griffitts' wrote *Guide to the Geology of Mesa Verde National Park* in 1990. To further understand the nature of the derivative materials employed at the ancient pueblos of Mesa Verde National Park, the following provides a synopsis of the aforementioned geologic studies.

Mancos Formation

Appearing as one great shaly mass of finely bedded planes formed by calm offshore marine conditions, the Mancos Formation is actually made up of numerous layers deposited over 10 million years and more than 600 meters (2000 feet) thick.[32] The earliest part of the formation, known as the Greneros Member, is comprised of marine fossils and large calcareous inclusions near its foundation with thin bentonite (mineralogical clay of weathered volcanic ash) inclusions that have oxidized to a rust color. Shells and oyster beds follow, covered with layers of dark shale. The succeeding Greenhorn Member is a 4-5 meter (15 feet) thick blue-gray limestone containing shales with concentrations of calcium carbonate and gypsum.[33] The seas regressed and mud becomes more abundant with the deposition of what is known as the Carlile Shales, largely free of fossils but containing

[32] Griffitts, Mary O, *Guide to the Geology at Mesa Verde National Park,* Mesa Verde Museum Association, Inc. (Lorraine Press, Utah, 1990) 42-43.
[33] Griffitts 44-45.

bentonite.[34] The shales becomes sandy with increasing evidence of clams and are capped by two dense bands of almost pure calcium carbonate known as the Juana Lopez Member of the Mancos Formation. This marks a period of aggressive wave activity. Thereafter, thin-bedded dark limy shales with later layers of undisturbed oyster beds suggest a calm period beneath the sea and subsequent regression. Finally, the upper stratigraphy is of sandy yellow-gray shales.

The Mesa Verde Group

The four most recent geologic formations exposed within Mesa Verde National Park include the abovementioned Mancos Formation and those of the Mesa Verde Group, all primarily composed of alluvial sediments of the Upper Cretaceous age.[35] The Mesa Verde Group, comprised of the Point Lookout Formation, the Menefee Formation and the Cliff House Formation, was initially described in 1875 and was formed by a rapid deposition over the course of 3 million years.

Point Lookout Formation

The transition between the underlying Mancos Formation and the Point Lookout Formation is visually difficult to discern, but is technically defined by the foundation of the first massive sandstone. Initial sediments are coarse and sandy with abundant biological evidence. Sandy layers are inter-bedded with shale and sheets of sandstone resulting from

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[34] Griffitts 45.
[35] Douglas, Charles L., James A. Erdman, and John W. Marr, *Wetherill Mesa Studies, Environment of Mesa Verde, Colorado* (Washington, D.C.: National Park Service, US Department of the Interior, 1969) 15.

marine deposition and ancient shoreline fluctuations. The lower portion of the formation is characterized by a layer of bentonite, indicating early volcanic activity. The Point Lookout Formation culminates with dense sheets of sandstone measuring 9-12 meters (30-40 feet) thick mainly deposited from a regressive shoreline.[36]

Menefee Formation

Streams and swamps resulted after the sea subsided facilitating the growth of lush vegetation and consequently many fossiliferous impressions of Cretaceous plants have been identified in the Menefee Formation. Thin coal beds developed amidst layers of dark shales, thus the boundary between the Point Lookout Formation and subsequent Menefee is easily distinguished.

Later irregular non-marine sediments amassed as broad layers of cross-bedded sandstones and shaly bands. Heavy volcanic activity or wind-deposited ash is evidenced by inclusions of bentonite layers within the middle of the Menefee sequence.[37] Additional layers of shale and coal make up the upper strata and are surmounted by soft sandstones, indicating the region was again covered by the sea.

Cliff House Formation

A shifting shoreline reminiscent of earlier transgressive marine activity created an ambiguous margin between the Menefee and Cliff House Formations. The horizon is

[36] Griffitts, table 5.
[37] Griffitts 56.

distinguished just after the final coal deposition of the Menefee Formation.[38] The Cliff House Formation consists of two large shear buff-colored sandstone beds divided by thin shale and sandy shale bands. Weathered by variable marine activity, the sandstone appears comprised of homogenous grains. Fossilized sea creatures and ripple marks are evident in this formation. Later geologic formations once on top of the Cliff House sandstone have since eroded away replaced by the eoilan loess.

3.2.2 Soils

While the periphery of Wetherill Mesa is primarily defined by barren rock escarpments, the over 31 square kilometers (12 square miles) of the mesa top are covered with residual soils.[39] Through identifying the dominate factors in soil development as well as their physical and chemical properties, Orville Parsons classified nineteen types of soils on Wetherill Mesa in his pedological survey of the early 1960s. A majority of soils on the mesa developed from a variety of parent materials, primarily including weathered rock or eolian or alluvial deposits. Soils of the southern portion of the mesa are typically calcareous, friable loam to clay loam with a moderate sand fraction and loess influence and a fine granular structure.[40] These soils are closely related to the non-calcareous series found immediately north on Wetherill Mesa.

[38] Griffitts 59.
[39] Parsons, Orville A. Soil Survey of the Wetherill Mesa, Mesa Verde National Park. United States Department of Agriculture. 1965.
[40] Parsons, n.p..

The Mesa Verde Loess

The unconsolidated sediment of the mesa tops are believed to be eolian deposits by strong southwesterly winds with continued accumulation most significant during the dust storms that occur between late February and early July. Distinct differences in the physical characteristics and constituents of the bedrock and the overlying soils confirm the above theory rather than the possibility of their resulting from the weathering of the sandstone in situ. Predominately silt to very fine sand, the loess is reddish-brown in color ranging from 2.5 YR to 7.5 YR on the Munsell Color Charts.[41] The distribution of the silts across the terrain varies from thin over topographic peaks and deeper in the depressions. According to Douglas Osborne's interpretation, soil profiles from Chapin Mesa suggest an upper and lower loess separated by a zone of calcium carbonate resulting from the leaching and weathering of the soils.[42] Soil profiles investigated by Osborne, Parsons and others reveal the lower loess is marked by a layer of basal caliche, with a 54% concentration of calcium carbonate resting on the Cliff House sandstone.[43]

Physical Properties of Mineralogical Clays

Several principal forms of mineralogical clays are present to some degree at each of the sites reviewed in the literature; occurrence and concentration of mineralogical clays are

[41] Parsons 17.
[42]Arrehenius, Gustaf and Enrico Bonatti, "The Mesa Verde Loess, Contributions of the Wetherill Mesa Archeological Project," *American Antiquity*, ed. Douglas Osborne, 31.2, Part 2 (The Society for American Archaeology, October 1965).
[43] Arrehenius.

discussed according to specific site in the following section. Clays are comprised of pseudo-hexagonal particles made up of alternate sheets of alumina and silica. Despite varying degrees of water sensitivity, all clays are hydrophilic and plastic when wet as water effects the intralamellar bonds and allows the thin crystals to slide over each other.[44] The ability to replastisize surface finishes has facilitated the success of treatment in recent years, both from an adherence and aesthetic point of view.

[44] Torraca, Giorgio, *Porous Building Materials: Materials Science for Architectural Conservation*, 2nd ed. (Rome: ICCROM, 1982) 96.

Kaolinites are the most common form of mineralogical clay and are the least reactive with molecular moisture. Comprised of a two layer structure of oxygen tetrahedrons with a silicon center and a layer of oxygen octahedrons with an aluminum center, kaolinites exhibit a strong bond between the layers of silicon and aluminum, thus generally stable when exposed to water.[45] Kaolinites have a fixed intralamellar distance which is responsible for their resistance to swell, but are less resilient as building materials as their stiff structure may promote friability and breakage.

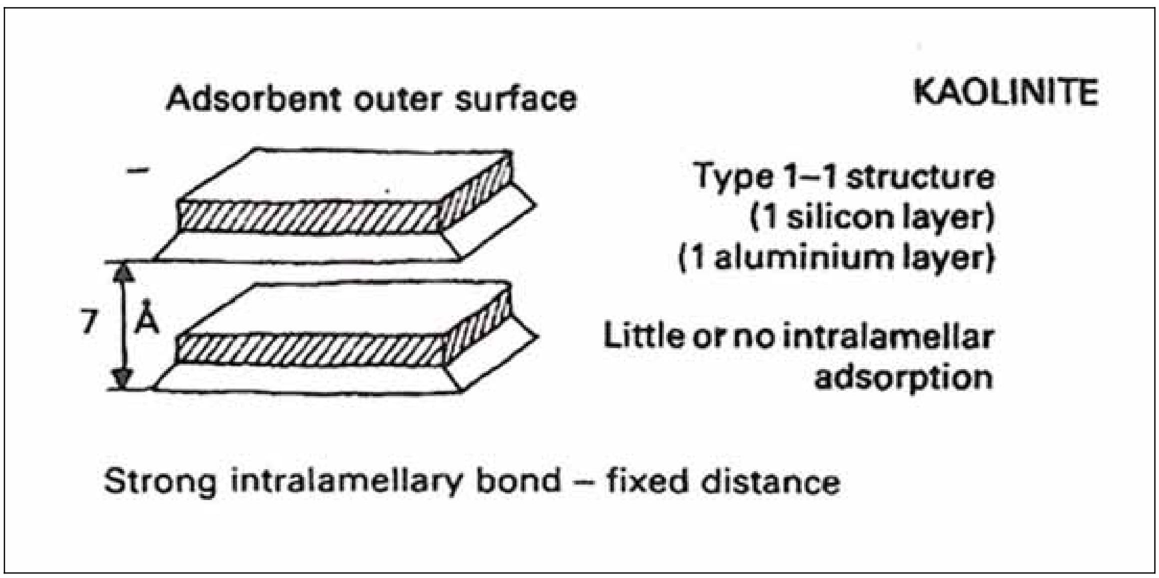

Figure 3.5. Diagram of kaolinite (Houben 1994).

[45] Houben, Hugo and Hubert Guillaud. *Earth Construction* (London: Intermediate Technology Publications, 1994) 27.

Illites have a three layer structure, one alumina layer between two silica layers, with a moderately strong intralamellar bond. Magnesium or iron may substitute for the aluminum ions, while aluminum ions can partly replace the silicon. Positively charged potassium ions bond with the negatively charged sheets to balance the charges. Illites are moderately unstable when in contact with moisture and have the tendency to swell.[46]

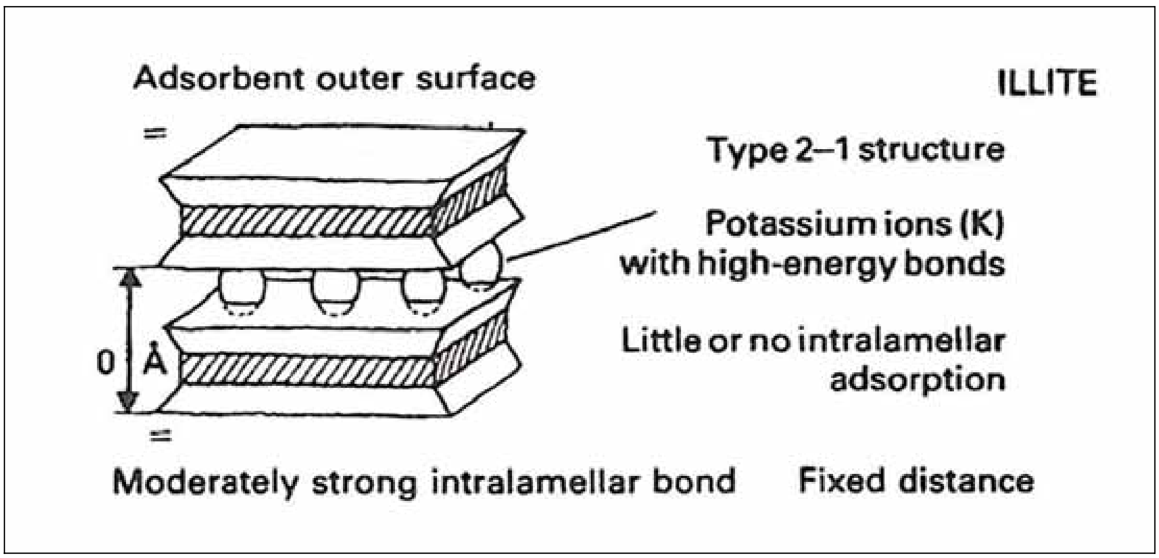

Figure 3.6. Diagram of illite (Houben 1994).

[46] Houben 27.

Montmorillonites' layers are neutrally charged and similar to the tri-layered structure exhibited with illites. The aluminum ions may be replaced by a number of other metallic ions while exchangeable cations and water molecules can linger between sheets of alumina and silica.[47] With adsorbent intralamellar surfaces and weak or variable bonds, montmorillonites are responsive, workable and flexible. Smectites, a form of montmorillonite and often found as a component of Mesa Verde plasters, are extremely expansive when exposed to water and severely swell, yet their tendency for micro-expansion contribute to properties of cohesion, plasticity, and durability when present in construction materials.[48]

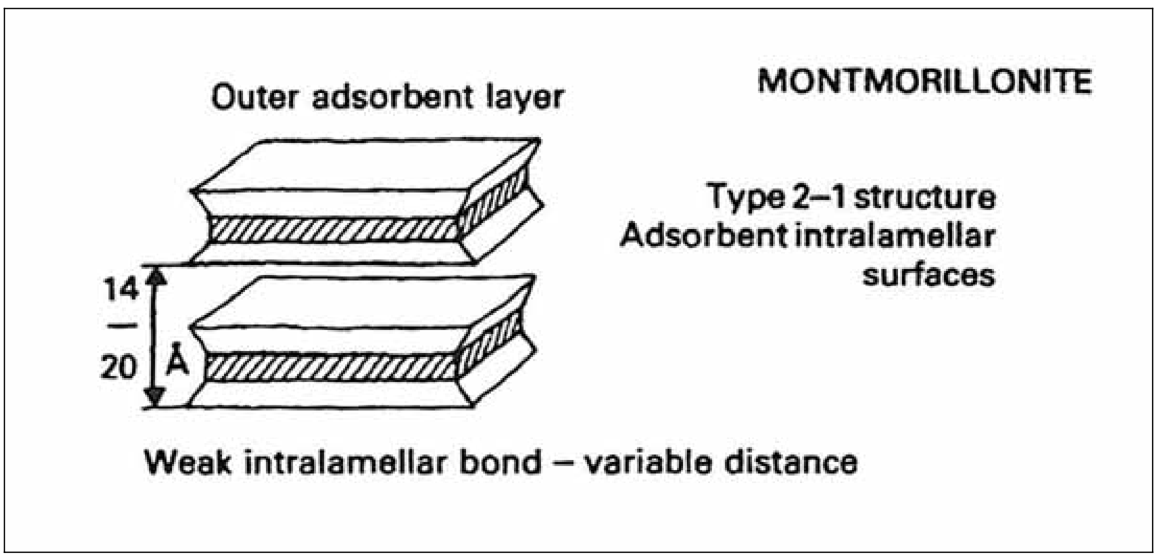

Figure 3.7. Diagram of montmorillonite (Houben 1994).

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[47] Houben 27.
[48] Houben 27.

3.2.3 Architectural Surface Finishes

The testing methodology for this thesis is based on a review of the literature from former studies, compiling information from previous analyses and findings on the characterization of surface finishes at Mesa Verde, particularly from sites in the Park such as Mug House on Wetherill Mesa and Cliff Palace on Chapin Mesa.

Watson Smith: Component Materials and Physical Properties

Although additional scientific studies have been completed at Mesa Verde and elsewhere in the Four Corners region, Watson Smith's initiative at Awatovi and Kawaika-a remains the seminal reference for researchers. Smith distinguished the difference between applied plaster and bedding mortar in their form, function and physical composition.[49] The mortar at Awatovi is composed of "clay or adobe with varying admixtures of sand," yielding good cohesion and a coarse texture.[50] The "brown coat" or preparatory layer of plaster was finer and exhibited a resistance to shrinkage. Recounted from an earlier study, [mineralogical] clays/calcareous material acted as the binding agent of the preparatory coat and made up an estimated 10% while the remaining 90% of the material was made-up of quartzitic sand.[51] Smith recognized the ability of earthen plaster to replasticize, a property that has been fundamental to the treatments and continued conservation efforts of the surface finishes at Mesa Verde.

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[49] Silver, Constance, "Architectural Finishes of the Prehistoric Southwest: A Study of the Cultural Resource and Prospects for its Conservation," Master's thesis, Columbia University, 1987, 55.
[50] Smith 14.
[51] Smith 18.

Using microscopical, microchemical and spectroscopic techniques to characterize the ancestral Puebloan palette, Smith reportedly analyzed over 100 mineral-derived pigments with the help of researchers Rutherford J. Gettens, Harry Berman, and Rockwell Kent, III at Harvard University and Harriet H. Greene at the Massachusetts Institute of Technology.[52] One of the most universal pigments found in surface finish embellishments are various shades of red, including pinks, salmons and a particularly vibrant hue all derived from iron oxide hematite (Fe_2O_3). Principally identified as hydrous iron oxides goethite ($H\ Fe\ O_2$) or limonite ($Fe_2O_3 \cdot n(H_20)$), yellows occurred in range of shades and intensities. In Smith's description he notes two distinct blue pigments, one from the mineral azurite $2CuCo_3{\cdot}Cu(OH_2)$, and a more prevalent cool gray which analysis revealed to have often been a mixture of charred wood particles and white clay. Green pigments were utilized on occasion and appeared to have derived from malachite $CuCO_3{\cdot}Cu(OH_2)$, a mineral closely related to azurite. Black pigments came from a variety of sources, primarily burned organic matter and pure carbon, but minerals such as iron and manganese were present in several samples. Whites similarly came from multiple sources primarily including siliceous material or kaolin, gypsum, and calcium carbonate.

Research at Mesa Verde

As mentioned above, the first conservation efforts of Pueblo mural paintings of the American southwest occurred in 1935 under Watson Smith at Awatovi and Kawaika-a in

[52] Smith 22.

Arizona. Critical analysis of architectural surface finishes specifically at Mesa Verde National Park and elsewhere in the Four Corners region began with Constance Silver's research in the late 1970's and early 1980s. Advocated by ICCROM, the aims of her 1978-79 regional survey and condition assessment were to ascertain the present extent of Pueblo mural paintings in the southwest, analyze the general rate and cause of deterioration, and subsequently make recommendations for their preservation and maintenance.[53] Silver was one of the first to concentrate on the conservation of the architectural surface finishes of the ancestral Puebloans, acknowledging the inherent vulnerabilities of the plasters, from exposure to the elements, sensitivity to moisture, subjection to surface accretions as well as anthropogenic threats from destruction during excavation/stabilization, inappropriate conservation techniques and vandalism. Often considered beyond the realm of conventional archaeological materials, Silver recognized that care and consideration of earthen plasters and paintings required a different methodological approach involving pilot testing of treatments, remediation and maintenance.[54]

Acting as Project Director, Silver produced a report in 1981 in which plaster stratigraphy is described based on onsite observations. Typically, an initial coat of plaster is spread over the masonry support to create a uniform surface, followed by a thinner layer and finished with a smooth coat on which painting and embellishments are applied. Silver likens

[53] Silver, Constance, "Summary of the Results of the 1985 Project Survey of Prehistoric Plaster and Rock Art at Mesa Verde National Park," Internal Report, Mesa Verde, Colorado, ICCROM, 1985, 3.
[54] Silver, "Summary of the Results of the 1985 Project Survey," 3.

the physical properties exhibited by earthen plasters to that of adobe. In adobe, when used as a construction material and described in National Bureau of Standards publications, clay and silt fractions act as the binding agent, forming a matrix in which the sand particles are embedded, the sand content reduces dimensional changes where clays have the inherent tendency to shrink and swell with varying moisture levels.[55]

In 1985, Silver headed the first comprehensive investigation of architectural surface finishes and rock art at Mesa Verde National Park producing a series of seven internal reports which include archival research, documentation and providing recommendations for the conservation of architectural plasters at the Park. Although still somewhat subjective, this study established the foundation for a standardized nomenclature for the description of architectural surface finishes at Mesa Verde. Six site surveys were completed for Balcony House (MV616), Cliff Palace (MV625), Spruce Tree House (MV640), Long House (MV1200), Mug House (MV1229), and Step House (MV1285), recording the architectural spaces, finished wall segments and general overall conditions, relying predominantly on visual investigation. Through the examination it was determined that a majority of the decorative finishes in the Park dated to the Pueblo III period of occupation, the height of Pueblo culture in the southwest manifest in the development of complex communities and cliff dwellings.[56] Site surveys documented plaster applications and decorative elements such

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[55] Clifton, J.R., P.W. Brown and C.R. Robbins. "Methods for Characterizing Adobe Building Materials," *NBS Technical Note 977* (Washington, D.C.: National Bureau of Standards, 1978).
[56] Silver, "Architectural Surface Finishes of the Prehistoric Southwest" 5-7.

as unmodified plain plaster, de facto plaster or extruded smooth mortar/plaster (where mortar extends beyond the joints and is spread over the masonry surface), slip-like colored washes that covered large areas of architectural surfaces both interior and exterior, bichrome designs and dados, auras around door openings and niches, floor bands which were often extensions of the plaster that finished the floors, painted designs, incised designs, and combinations of incised, etched and painted designs occurring as independent elements depicting zoomorphic, geometric, or abstract embellishments, handprints, dots/daubs, and occasionally anthropomorphic figures.[57]

Silver's research and experience culminated in her 1987 master's thesis at Columbia University and encouraged further studies at Mesa Verde. Under contract with the National Park Service, "The 1987 Mesa Verde Plaster Recordation Project," conducted by Jerry Fetterman and Linda Honeycutt of Woods Canyon Archaeological Consultants, Inc., documented the extent and condition of architectural finishes in twelve cliff dwellings at the Park using a two-part hierarchical survey form, recording architectural spaces containing decorative surface finishes as well as written and photographic details of each wall. Coinciding with the 1990 publication for her geologic investigation of the Park, Mary Griffitts studied the plasters and mortars at Wetherill Mesa sites, Step House and Mug House. Like Silver's earlier investigations, her analysis using x-ray diffraction also revealed quartz to be the primary component of both materials, although to a lesser degree, with a

[57] Silver, "Architectural Surface Finishes of the Prehistoric Southwest" 44-46.

significant amount of calcite and accessory minerals of feldspar, kaolinite, gypsum, and mica. The results obtained in her study suggested that some plasters were a combination of loess soils and the basal caliche directly beneath.[58] As Rocky Mountain Regional Curator, Allen S. Bohnert conducted a literature survey in 1990, published in the *Adobe 90 Preprints*, synopsizing the work of predecessors Silver, Fetterman and Honeycutt, and Griffitts, reiterating the importance of collecting inventory data on earthen surface finishes and their potential capabilities for the identification of developmental phases within sites across the region. His recommendations included active stabilization and control of deterioration mechanisms where possible; scheduled monitoring based upon a predetermined criteria; evaluation for conservation treatments and determining the effectiveness of pilot treatments; training Park staff to integrate plaster documentation and preservation into interpretation and stabilization programs; continued field surveys ensuring the compatibility of new and existing data; and expanding research to incorporate the analysis of plaster constituents, source material, fabrication, application and appropriate treatments.[59] In 1994 the Graduate Program in Historic Preservation at the University of Pennsylvania in conjunction with the Architectural Conservation Laboratory initiated a program to survey, document, analyze, interpret, stabilize and monitor the masonry and architectural surface finishes at several cliff dwellings at Mesa Verde.

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[58] Griffitts, Mary, letter to Allen Bohnert (1990) in Bohnert, "The Preservation of Prehistoric Mud Plasters at Mesa Verde National Park."

[59] Bohnert, Allen S., "The Preservation of Prehistoric Mud Plasters at Mesa Verde National Park," *6th International Conference on the Conservation of Earthen Architecture, Adobe 90 Preprints*, (Los Angeles: Getty Conservation Institute, 1990) 263.

University of Pennsylvania students Linnea Dix and Mary Slater characterized earthen plasters by laboratory methods using light microscopy and geo-physical analysis for their 1996 and 1999 theses on spaces at Mug House and Cliff Palace respectively. Thin and cross sections of Mug House mortar and plaster demonstrated a homogenous matrix of fine particles of clay and silt with a uniform distribution of heterogeneous black, red, yellow and translucent grains. Plasters were typically more compact than the mortars with an average ratio of 60:40 coarse to fine fraction, while the washes appeared relatively smooth with few inclusions and an estimated 10:90 ratio of course to fine particles.[60] Microstructure and chemical composition of plasters from Cliff Palace were further analyzed in thin section for a report prepared by Frank Matero, Claudia Cancino and Rynta Fourie in 2002. Since gravimetric analysis was not possible on the small samples, grain size distribution profiles of each layer were determined by digital visual analysis using a proprietary software called Bioquant Nova® for Windows, 98 BQ Nova Version 5.00.8 MR (R&M Biometrics, Inc.), revealing a well-graded quartz coarse fraction in a homogenous clay and silt matrix, while confirming the difference between plasters and washes, as the washes displayed a higher matrix to aggregate ratio.[61] Slater notes that the quartz grains appeared to have been intentionally crushed as an added aggregate based on their unweathered faces and the nature of particle fracture. Large calcareous inclusions of calcite or dolomite and fossils as well as

[60] Dix 54.
[61] Matero, Cancino, Fourie, "Conservation of Architectural Surfaces Program for Archaeological Resources Report," prepared for the National Park Service, Mesa Verde National Park, Colorado, 2002.

ferromagnesium minerals such as hematite, biotite and muscovite were commonly observed.[62]

Chemical spot testing for soluble salts confirmed the presence of naturally occurring carbonates and sulfates in the plaster from Kiva C and nitrates in Room 28 at Mug House; chlorides and nitrates were present in a plaster sample from the lower portion of the banquette of Kiva Q in Cliff Palace, as well as carbonates in the water-insoluble solids.

A high percentage of kaolinite was detected by x-ray diffraction (XRD) on the mortar and plaster sampled from Mug House. Illite and smectite as well as a mixed-layer of illite and smectite were present in significantly lower amounts. Quartz and gypsum were also present, although quantitative results were not produced in Dix's research. Indicative of the non-calcareous soils on the northern part of Wetherill Mesa described in Parsons' survey, no calcite was detected in the mortar sample tested. X-ray diffraction performed on gross samples from both Kiva Q and Kiva K at Cliff Palace in 1999 and 2002 revealed an abundance of quartz. Analysis of the bulk mineralogy also revealed plagioclase and feldspars as accessory minerals and trace amounts of kaolinite and mixed illite/smectite in the mortar sample from Kiva Q. The clay-size fraction was separated from each of the gross samples; XRD identified relatively small amounts of mixed illite/smectite, kaolinite, illite, smectite and

62 Slater, Mary, "Characterization of Earthen Architectural Surface Finishes From Kiva Q, Mesa Verde National Park, Colorado," Master's Thesis, University of Pennsylvania, 1999, 40; Matero, Cancio, Fourie, 38-59.

calcite in the plaster and no mineralogical clay in the fine-fraction of the mortar.[63] Similarly, spectral results from Fourier Transform Infrared Spectroscopy (FTIR) corresponded with that of the montmorillonite (specifically smectite) database spectrum and less so with that of kaolinite and gypsum.

Scanning electron microscopy (SEM) with electron dispersive spectroscopy (EDS) provided the elemental profile for samples from Kiva C and Room 28 in Dix's Mug House study. Both mortar and plaster samples contained aluminum, silicon and oxygen as well as trace amounts of iron and carbon, and minimal quantities of potassium, magnesium, sodium and chlorine.[64] The white pigment contained a high content of calcium carbonate used to impart the chalky white color. SEM-EDS elemental analysis identified aluminum, calcium, copper, iron, potassium, magnesium, silicon, sulfur and titanium in order of concentration for the plasters in Kiva Q at Cliff Palace. Pigments, tested by various methods and reminiscent of Smith's early investigations, occurred in quantifiable concentrations and include gypsum and kaolin to produce white, iron oxide for red and organic carbon compounds created black.[65]

[63] Slater 48-49.
[64] Dix 86.
[65] Slater 56.

3.3 Stabilization and Treatment History of Kiva E

According to historic photographs and onsite observation, nearly half of Kiva E was reconstructed along its northwest side and heavily stabilized in other areas. Robert Nichols of Cattanach's team uncovered the embellishment along the southeast wall by removing later layers of plaster revealing the design beneath. Photographic documentation dating from May - June of 1988 records the strategic repointing and filling of areas of degradation under the direction of former Park stabilization supervisor Kathy Fiero. Areas exposed to weathering and water percolation through the alcove wall, particularly in the western half of the site, were subject to stabilization based on their elevated state of deterioration. Masonry repointing was carried out on portions of the southern recess in Kiva E, while soil compaction and fill of the banquette shelf or "bench" was implemented at intersections of upper walls and pilaster returns, along the partial wall of the eastern banquette and the space above the western banquette abutting the alcove wall. These interventions were repeated in 1989 using amended mortars of indigenous soils and Rhoplex (an aqueous acrylic emulsion) diluted in water. Subsequent preservation efforts have focused primarily on surface finishes conservation.

Fiero's vigilant graphic monitoring and documentation of the unique embellishment on the northeastern banquette of Kiva E maintained a photographic record of the condition of the plaster. Images from 1990-1994 present a sequence of photographs that enable pictorial examination and notation of changes in the plaster's condition over time as well as treatments applied to this delicate area.

According to her records, in September of 1994 Frank Matero of the University of Pennsylvania and Angelyn Bass of Mesa Verde National Park performed vital conservation work on the plaster on Pilaster 4 and the embellishment below. Treatment involved hydrating the friable plasters with water and isopropyl alcohol to readhere the layers and applying Japanese facing paper for support with diluted solutions of Polyvinyl Alcohol (PVOH), a water soluble synthetic polymer.[66] The facing loosened and was reattached by Bass in the winters of 1994 and 1995 and again by Matero in October of 1996 as temporary stabilization. A hydraulic lime grout was used in 1997 to fill voids within the walls and reattach loose fragments, but the localized flaking and delamination of the surface finishes proved a persistent problem.[67] Paper facing was again applied in the spring of 1998 after notable detachment of the plasters.

[66] Rivera, Angelyn Bass, "Conservation of Architectural Finishes Program, Mesa Verde National Park, Project Report," 1999. 15.
[67] Rivera 15.

Figure 3.8. Frank Matero and Angelyn Bass Rivera treating the plasters in Kiva E (Fiero 1994).

Included in a brief synopsis on the treatment history of the plasters in Kiva E in the 1999 Project Report on the Conservation of Architectural Finishes at Mesa Verde National Park, the finishes had required temporary in situ stabilization at least five times between 1994 and 1998. The report, compiled by then Park employee Angelyn Bass Rivera, provides a record of the treatments executed under her discretion specifically on plasters in the northeast quadrant of the banquette. The Japanese tissue, reapplied with PVOH and water in April of 1998, was removed in July of that year to administer 5% gelatin solution by injection to reattach flaking and delaminated plaster.[68] Loose fragments and exposed edges were filled and capped with an earthen mortar.

Apart from monitoring and survey, no other treatments were conducted in Kiva E until the University of Pennsylvania's involvement at Long House in the summer of 2006. Careful examination of this embellished area by project director, Frank Matero, verified that previous treatments by injection proved mostly beneficial. Largely, areas of profound loss since earlier treatment campaigns occurred where the stone substrate had severely deteriorated. Treatments during the 2006 season included plaster reattachment by gelatin injection of 5 and 10% concentrations, grouting of Inter pilaster space 5 with four parts hydraulic lime to two parts aggregate (1:1 of natural sand and microspheres) to four parts water, and edging with soil-based putty amended with 5% Rhoplex diluted in water. Monitoring and additional treatments will commence in May of 2007.

[68] Rivera 16.

4.0 KIVA E

Figure 4.1. View of Kiva E from above the southern recess (August 2006).

4.1 Architectural Description

Kiva E, located in the western half of Long House, is on a near north-south axis and abuts the alcove wall to the west. Rooms 11, 37 and 38, built between Kivas D, E, and F are situated along the north wall of Kiva E and are believed to postdate the kiva. Measuring approximately 4.25 meters (14 feet) in diameter, Kiva E is a circular ceremonial structure of considerable size including a fire pit and stone deflector with a niche on its north face directly below the southern recess, equipped with a ventilator tunnel and vertical shaft, the mouth of which opens to the east of Pilaster 1. The masonry walls are one wythe thick and coursed. All elements of original construction display remnants of applied finishes.

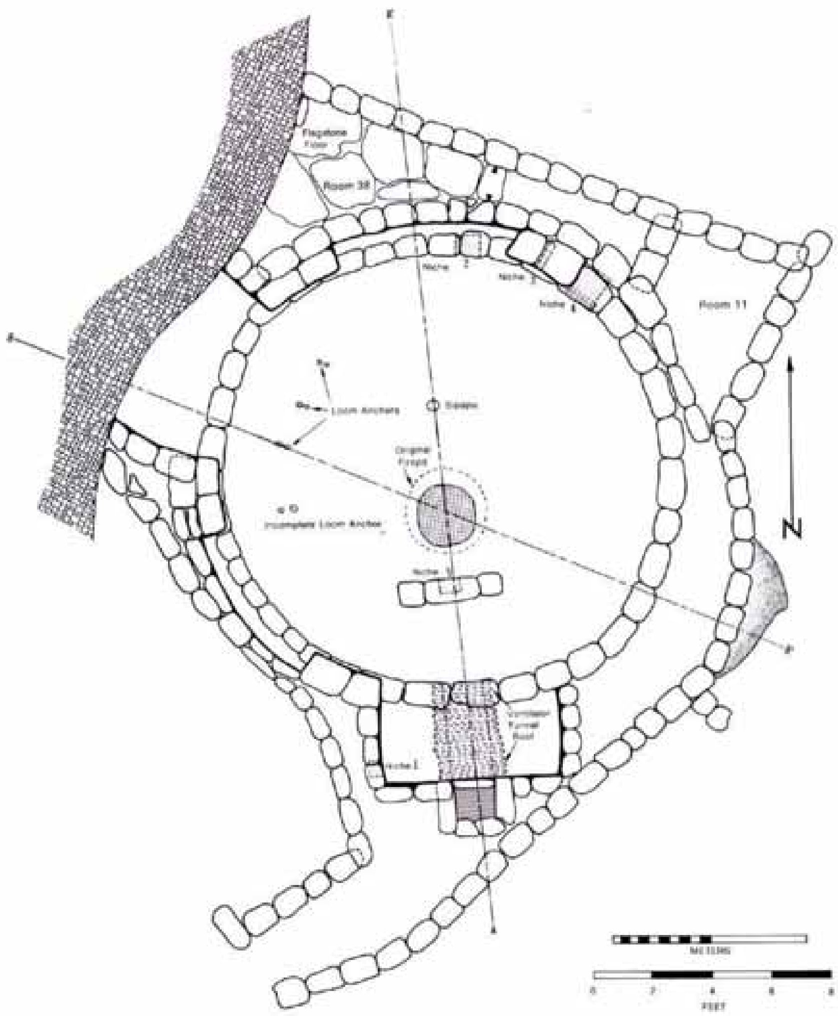

Figure 4.2. Plan of Kiva E (Cattanach 1980).

A portion of the floor is of exposed pecked bedrock which is deeply cut along the western half where it forms the base of the wall up to 15 cm (6 inches) in height. A later floor has been applied in an adobe plaster, roughly 7.5 cm (3 inches) thick, which now covers a majority of the floor. The 1959-1961 Wetherill Project excavation/interpretation has exposed part if the original bedrock floor. Three sets of loop holes have been pecked into the bedrock floor along the northwestern wall of the banquette. George Cattanach's excavation report records a fourth incomplete set directly to the southwest of the other three. In keeping with both Hopi and Zuni practices, it has been suggested that theses loop holes served for an upright loom.

Figure 4.3. Detail of loom holes in the bedrock floor of Kiva E (Nichols 1959).

The banquette is of modest yet deliberate construction. The lower six to seven courses are comprised of small carefully shaped tabular stones rising 30-35 cm (12-14 inches) high with larger rectangular stones coursed above and completing the full height of the banquette at approximately 1 meter (42 inches). This method of construction allowed the Puebloan builders to determine the shape of their kivas by using smaller units to define the contour and circumference of the plan during its initial construction. The banquette shelves are laid in large rectangular blocks and broad flat slabs with a red earthen mortar filling the voids. The pilasters are well defined, constructed of rectangular shaped and peck-finished stones creating smooth flat surfaces and clean edges. The upper inter pilaster walls are of irregularly shaped, semi-coursed masonry, all of which have been stabilized or entirely reconstructed with the exception of the southern recess and alcove wall. The rock wall of the alcove between Pilasters 2 and 3 is heavily sooted and severely delaminating.

The original masonry was laid in a finely textured, reddish-brown colored earthen mortar which appears, in some places, to have been spread beyond the mortar joints, serving as the base coat for plaster or smooth extruded mortar/plaster. Along the base of the northwestern banquette wall between Pilasters 3 and 4, a grey shaley mortar has been used presumably as an early repair of the lower courses above the bedrock and as an infill to an original niche (now concealed) before or at the time of the later plaster floor. Excavation of the niche in August of 2006 revealed sand and bits of coal within the wall, confirming the report in Cattanach's field notes from 1959. As the mortar and stone masonry are friable and discrete nodules of salt are present, this area appears to have been subject to degradation from recurrent moisture penetration, seemingly from the time of construction and resulting in prehistoric repair.

Figure 4.4. Excavated niche of the lower portion of the northern banquette wall (Jensen 2006).

4.1.1 Repairs

Almost half of the kiva has been reconstructed between Pilasters 1 and 4, predominately during Cattanach's excavation and stabilization from 1959 to 1961. According to Cattanach's field notes, Arthur Rohn and Walter Stein covered the floor of Kiva E with a trowel-smoothed shallow fill prior to stabilization, which was cleared before reconstruction. Stabilization of Kiva E began with the east exterior wall on June 26, 1959 and commenced until July 9, 1959, when reconstruction of the kiva's west wall started. After repointing areas along the eastern portion of the banquette below Pilaster 4, stabilizing portions of the banquette, exterior walls and Inter pilaster space 4, and reconstructing the west wall of the banquette, Pilasters 2 and 3, as well as Inter pilaster spaces 1 through 3, the crew proceeded with "mudding" the rebuilt walls. In August of 1959, when the backfill in Kiva E was removed and the floor was cleaned, the bedrock floor was discovered along with the sipapu and hearth.

4.2 Onsite Investigations

4.2.1 Extant Surface Finishes and Embellishments

Kiva E General

Original masonry surfaces are all finished with an initial application of pale red-brown or pinkish-tan plaster of variable thickness depending on the finish of the stone (3mm – 1cm thick). This appears to have been an initial finish judging from depositions of soot on subsequent layers. A second monochromatic red plaster, although thinner, has been applied, followed by a complex scheme of intricate designs including a red dado over a white ground. This campaign presumably incorporates the partial polychromatic geometric and zoomorphic embellishment to the east of Pilaster 4 on the upper banquette. A final scheme of monochromatic reddish-brown wash appears to be the last scheme before abandonment. Microscopal analysis of both thin and cross sections confirm or negate the following onsite observations.

Banquette

Perhaps one of the most elaborate and complex surviving wall designs found park wide, the remnants of the embellishment located below Inter pilaster space 4 along the east wall of the kiva provide insight to the intricacy, care and craft given to the design and adornment of these ceremonial chambers. Intact to the right of Niche 4, a geometric banded design with opposing triangular shapes with irregular borders and separated by three lines of uniform width is painted in red on a white ground with greenish blue accent lines. The blue paint appears to have been applied rather thickly by comparison with evident brush marks, seemingly from brushes made from yucca fibers. Small remnants of what is believed to be the continuation of the band design with the same red markings on a white ground is located farther east of the bulk of the design just below where the upper wall of the banquette has collapsed.

Figure 4.5. Detail of banded embellishment below Pilaster 4 with remnants of blue pigment around Niche 4 (Ferron 2006).

To the right or eastern side of Niche 4 and just below the geometric banded design runs a yellow stripe applied over the white ground with traces of blue-green design elements around the niche. The pattern or motif of these blue-pigmented fragments is indeterminate, but may indicate a once present aura around Niche 4. Just above the niche, a red sheep is observed in its entirety while a partial sheep is indicated by a second set of horns/antlers painted directly to the east also on the white ground. The zoomorphic and possibly anthropomorphic figures are largely obscured by waxy brown staining from the deposition of pack rat excrement. The white ground on which these embellishments have been painted is predominantly sooted and displays long smooth striations from hand or animal hide application, which are especially evident along the upper banquette below Pilaster 4.

A red dado is painted over a creamy white ground, possibly corresponding to the campaign of the geometric/zoomorphic design, and is discernable in several areas along the base of the banquette. A large portion of the red dado is extant on the southwest lower wall below Pilaster 4 and Niche 3. The dado line of red wash over white ground is evident to the right/east of Niche 4 and includes traces of blue-green plaster as part of the embellishment above. The intersection of the red dado and the white field above is most apparent in an area below Pilaster 1.

Near the base of the banquette on the northwestern portion of the wall there is evidence of a previous design scheme of a geometric pattern also in red over a white ground, yet appearing to predate the large embellished scheme near Pilaster 4. This embellishment occurs on a re-laid stone and therefore its original location or provenance cannot be determined.

Pilaster 1

The face of Pilaster 1 has fragments of vibrant red plaster. Based on design trends at other alcove cites, these remnants may have originally been handprints. This is the only area within the kiva where this bright red pigment is currently present. On the upper left quadrant of the pilaster face a partial design element survives with a red (although less intense in hue) line painted diagonally across the cream colored ground. Remnants of cream colored paint on the face of Pilaster 1 are assumed the same scheme as the red embellishments. In the center of the pilaster face are small fragments of yellow ochre, as part of a scheme that appears earlier than that of the vibrant red embellishments. Also part of an earlier scheme, is the evidence of bright white paint heavily sooted and covered by a subsequent campaign.

Figure 4.6. Detail of fragmentary bright red paint on the mid-face of Pilaster 1 (Ferron 2006).

4.2.2 Schematic Observations

Banquette

Below Pilaster 1 on a portion of the banquette, a coat of pale red plaster is applied over the masonry wall and serves as the base coat of plaster for subsequent layers. An additional layer of red plaster is on top, similar in color and consistency but not as thick. These two layers may represent the same campaign in efforts to create an even wall surface or overlapping layers from the initial application. A third layer of reddish-brown plaster is applied on top of the previous two and displays light deposits of soot. This layer is directly beneath the bright red wash of the dado. The apparent line of the dado measures 52 cm (20.5 inches) above the bedrock floor along the lower southwest portion of the banquette wall and overlaps the white plaster field above. A brown-red wash appears as the final finish.

On the upper wall of the banquette, above the dado line and below Pilaster 1, the pale red-brown plaster is directly applied to the masonry. The creamy white wash is the subsequent layer, corresponding to the red dado. Succeeding layers include a red plaster topped by a brown-red wash like that below.

These schemes are more or less repeated on the opposite wall of the banquette beneath Pilaster 4. On the lower wall to the west of Niche 3 and immediately adjacent to the closed niche discussed above, observation of the plasters revealed a base layer of pale red-brown plaster with an additional layer of pale red plaster on top, covered with the bright red wash of the dado revealed by the detaching layer of brown-red, representing the latest extant layer of surface finish. There is no evidence of carbon deposition on any of the observed finishes on this portion of the wall.

On the upper portion of the northeastern wall directly below Pilaster 4, pinkish red plaster serves as the foundation layer followed by a thin coat of sooted red plaster. White plaster is applied over the sooted layer of red and displays evidence of sooting as well. This layer contains the elaborate embellishment exposed from beneath the outermost finish of brown-red plaster, removed in this location by Robert Nichols of George Cattanach's team in 1961. The banquette shelf is of a thick reddish brown plaster, resembling the color and texture of the original bedding mortar.

Pilasters

Only Pilasters 1 and 4 are original to the structure. As previously described, Pilaster 1 is entirely covered in a base coat of pinkish-tan or pale red-brown plaster topped with a layer of heavily sooted bright white paint. This layer is followed by a sooted creamy white ground with vibrant red fragmentary embellishments and appears earlier than the design schemes along the banquette. A layer of white with soot deposition is covered with a final coating of pale brown-red wash.

Pilaster 4, apparently more weathered than Pilaster 1, has the pale red plaster base coat, similar to the bedding mortar, and is topped with a layer of sooted red plaster, followed by remnants of bright white paint and finished with the brown-red wash.

Upper Walls

Inter pilaster spaces 1 and 3 have been entirely reconstructed and appear to contain no original surface finishes. Inter pilaster space 4 has been stabilized but seemingly retains the masonry units original to its construction apart from three heavily sooted stones inserted during the 1959 stabilization; one of which has been pecked, another contains three layers of red plaster with carbon deposits and the third is unfinished. The in situ blocks directly adjacent to the return of Pilaster 4 have a single layer of heavily sooted thick reddish plaster, possibly extruded smooth mortar. The rear wall of the southern recess is coated with a red layer of finish, heavily sooted, followed by a sooted layer of white and topped by a layer of red with relatively thin deposits of soot. The opposing alcove wall of Inter pilaster space 2 appears to have a single layer of heavily sooted red plaster.

4.3 Sampling

Samples of surface finishes and mortar were taken for further study of constituents and material properties, layering of surface finishes, decorative scheme interpretation, repair mortar campaigns, and salts present. Analysis of these samples facilitate a better understanding of the aesthetic intent of Kiva E providing information for potential interpretive opportunities, as well as establish an understanding of the physical properties exhibited by these materials, critical for the application of future treatments of earthen surface finishes.

Small samples, approximately 5-15mm in diameter, were taken from locations after a thorough study of visible finish layers and determination of areas where cross-sectional analysis would be most useful. Samples were obtained where material had been compromised and their removal was least destructive to the existing finishes and schemes.

Repair mortar samples were taken after a review of historic documentation, archival photographic comparison and detailed examination of the repair campaigns present had yielded a comprehensive understanding of the phases of repair and significant characteristics of each. Samples were taken of each phase to aid in the identification of repair campaigns throughout Long House.

Samples for salt analysis were obtained after conditions surveys had been completed, yielding a thorough understanding of the probable locations of salts and several hypotheses as to the mechanisms of their transport. To be discussed in Chapters 5 and 6, samples S01, S03, S05 and S06 were qualitatively and semi-quantitatively analyzed through chemical spot tests and ion test strips to help determine their type, origin and possible effect on the decay of finishes.

Unique numbers have been applied to all samples and their locations noted on a representative image of Kivas E. Upon removal, sample materials were packed in individual plastic sample boxes with cotton, labeled with site number and name and a description of the sample taken as well as its specific location (see Appendix B for sample schedule). The samples were stored and transported in sealable plastic bags for laboratory investigation.

5.0 TESTING METHODOLOGY

Instrumental and chemical analyses can provide information regarding the microstructure and elemental, chemical and mineralogical composition of a material. Such analyses can also address evidence of morphological changes over time and suggest physical properties based on constituents. With an emphasis on traditional laboratory testing methods, this chapter seeks to formulate and understand a methodology for the characterization and investigation of earthen surface finishes, how various testing methods can assist in their study, and what information each method yields. Based on conclusions drawn from previous investigations, techniques determined conducive to the analysis of earthen materials and surface finishes are explored and utilized for the purposes of this thesis.

Types of instrumental testing addressed include optical light microscopy, Fourier Transform Infrared Spectroscopy (FTIR), and scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS). Chemical analyses discussed in this chapter are micro-chemical spot-testing and semi-quantitative analysis of soluble-salts.

As many of the material constituents have been identified in past studies, the primary method of analysis performed on the surface finishes of Kiva E has relied on visual observation of the samples. Color, stratigraphy, application and presumed renewal methods and identification of schemes were determined by observing cross sections under reflected light microscopy, as described in Chapter 6. Thin section petrography as well as high-magnification images provided by SEM allowed for the determination of physical properties of the mortars and plasters including particle size distribution, course fraction, microstructure and morphology through visual examination. Pigments were viewed under plane and polarized light and the elemental composition of pigments was confirmed with the use of micro-chemical spot-testing. Information such as this along with visual examination of materials, historic documentation and in situ stratigraphic examination enable the second component of research, the interpretation and conjectural illustration of Kiva E, illustrated in the following chapter.

Due to the nature of the samples as well as the nature of these methods, analysis involves an extremely small amount of material and can sometimes be problematic and misrepresentative if the specimen was extracted from a large surface area. The potential misinterpretation of a material is a possibility and is taken into consideration.

5.1 Instrumental Analysis

5.1.1 Light Microscopy

Microscopal investigation allows the study of stratigraphy and microstructure, calculable assessments of constituent ratios, fabrication methods, and application as well as the evidence of alterations. Polarized light microscopy offers qualitative aspects of analysis as well as characterization by morphological analysis and identification of specific features.

Characterization, evaluation, analysis, and, where pertinent, diagnosis can, in many cases, be effectively ascertained with the use of a microscope.[69]

A Leica MZ16 stereomicroscope was used for preliminary gross sample examination, noting physical characteristics such as color, plaster and wash texture, and general layer stratum of embedded cross sections. Cross sections were viewed with a Nikon Optiphot 2-POL compound polarizing microscope and a Nikon Alphaphot-2 YS2 compound microscope. A compound microscope employs a two lens system, both objective and ocular, to create total magnification enabling higher magnification (up to 1000x) and high resolution, producing clear quality photomicrographs. Specimens can be viewed under reflected or transmitted light, prepared as thin sections or powder dispersions, or provided the compound scope has been retrofitted to enable dark field capabilities, specimens are illuminated on a dark background with tangential light or under transmitted light with a block filter to provide a black background which is optimal for visualization.[70]

Observation of cross-sections offers information from a small amount of material including the sequence of finish layers, the thickness of each layer, color, texture, particle size and shape, opacity/transparency, and often crystallinity. SEM analysis and chemical-reagent testing may also be executed on cross-sectioned samples away from the sample source. Comparative analysis of cross-sections, in specific reference to Mesa Verde, has revealed

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[69] Myers, Cassie, lecture on microscopy, University of Pennsylvania, 14 Nov. 2006.
[70] Myers.

consistencies in application and technique and confirmed the ritual of renewal as discussed in earlier chapters. Although dependent on the nature of the support material, it is desirable to include the substrate in the cross-section to ensure that all layers are present. Pigment identification revealed by crystalline structure is determined by the use of polarized light microscopy. Pigments are often identifiable with microscopical and chemical examinations alone. Cross-sectional analysis does present limitations in that minute samples may not be representative of the whole.

Polarized Light Microscopy

In Polarized Light Microscopy (PLM), the doubly refractive or anisotropic specimen splits the light beam into two which then travels at varying speeds, thus exhibiting different optical paths. These wave components are in perpendicular planes and collected by the analyzer (the second polarizer) which is placed in the optical pathway. The polarized light microscope is the only instrument the can provide a complete characterization and identification of a diverse set of organic, inorganic, biological, crystalline and non-crystalline materials including, but not limited to the following: metals, minerals, corrosion products, ceramics, vegetable and wood fibers, textile fibers, animal hair by species, pigments, media, supports/substrates, dyes, inks, etc.[71] Techniques used in identifying materials include, size and shape characteristics/morphology, color, surface topography, refractive indices,

[71] McCrone, Walter, "Polarized Light Microscopy in Conservation, a Personal Perspective," *Journal of the American Institute for Conservation* 33.2 (1994): 102.

birefringence, melting point, edge contrast, orientation of refractive indices relative to "crystallographic" directions in a particle or fiber, etc.[72]

Cross Sections

Representative samples were embedded in Bio-Plastic™, a proprietary polyester/methacrylate resin polymerized with a methyl ethyl keytone peroxide catalyst, sectioned on a Buehler Isomet™ micro-diamond blade low speed saw, and mounted to glass slides with Cargille Meltmount™. Several samples were polished on a Buehler felt polishing cloth using Stoddard solvent on account of the material's water sensitivity; however, due to material loss the majority of samples were not polished.

Cross sections were viewed under normal quartz halogen reflected light using a compound microscope. Stratigraphies were recorded on data sheets (see Appendix B), various layers were identified and described based on seriation (stratigraphy) and morphology. Plasters, defined by a thickness greater than one millimeter, consistently appear to have coarse grains and large inclusions, while washes are thinner and finer and generally make up areas of applied design and embellishment. Surface finishes were often applied when previous layers were still wet, particularly in the case of leveling plasters, thus yielding an ambiguous horizon between layers.[73] The presence of soot or soiling on the

72 McCrone 102.
73 Dix, Linnea, "Characterization and Analysis of Prehistoric Earthen Plasters, Mortars and Paints from Mug House, Mesa Verde National Park, Colorado," Master's thesis, University of Pennsylvania, 1996, 53.

surface of a layer indicates that it was exposed as a final finish. Determination of the sequential application of layers revealed the design schemes exhibited on the kiva walls over time and are discussed in the following chapter. (See Appendix B for stratigraphy data forms including scheme identification, layer description and photomicrographs.)

Thin Sections[74]

Petrographic thin sections of mortars and plasters were prepared by National Petrographic Service, Inc. in Houston, Texas. Samples were vacuum-impregnated with blue dyed epoxy, cut and polished in oil to approximately 30-40 microns thick.

Slides were viewed with the Nikon Optiphot 2-POL compound microscope under transmitted light. Petrographic thin sections enable the identification of features relating to soil structure and fabric, such as pore geometry and occurrence, grain shape, color, proportion and granulometry. Specimens from Kiva E range from a loamy sand to a sandy silt loam. Mineral components appear as opaque or prominently white/translucent. With regard to the fabric, each sample demonstrates an assemblage of heterogeneous grains with a moderately graded particle size distribution, ranging from rounded to sub-angular. Grain boundaries appear clear, particularly in the case of the white/translucent particles, or diffuse. Large white glassy grains present in each thin section exhibit low birefringence and extinction, indicating the inclusion of anisotropic quartz.

[74] Descriptive terminology has largely been adopted from the *Handbook for Soil Thin Section Description* (Bullock, et al., 1985) and *Soil Microscopy and Micromorphology* (FitzPatrick, 1993).

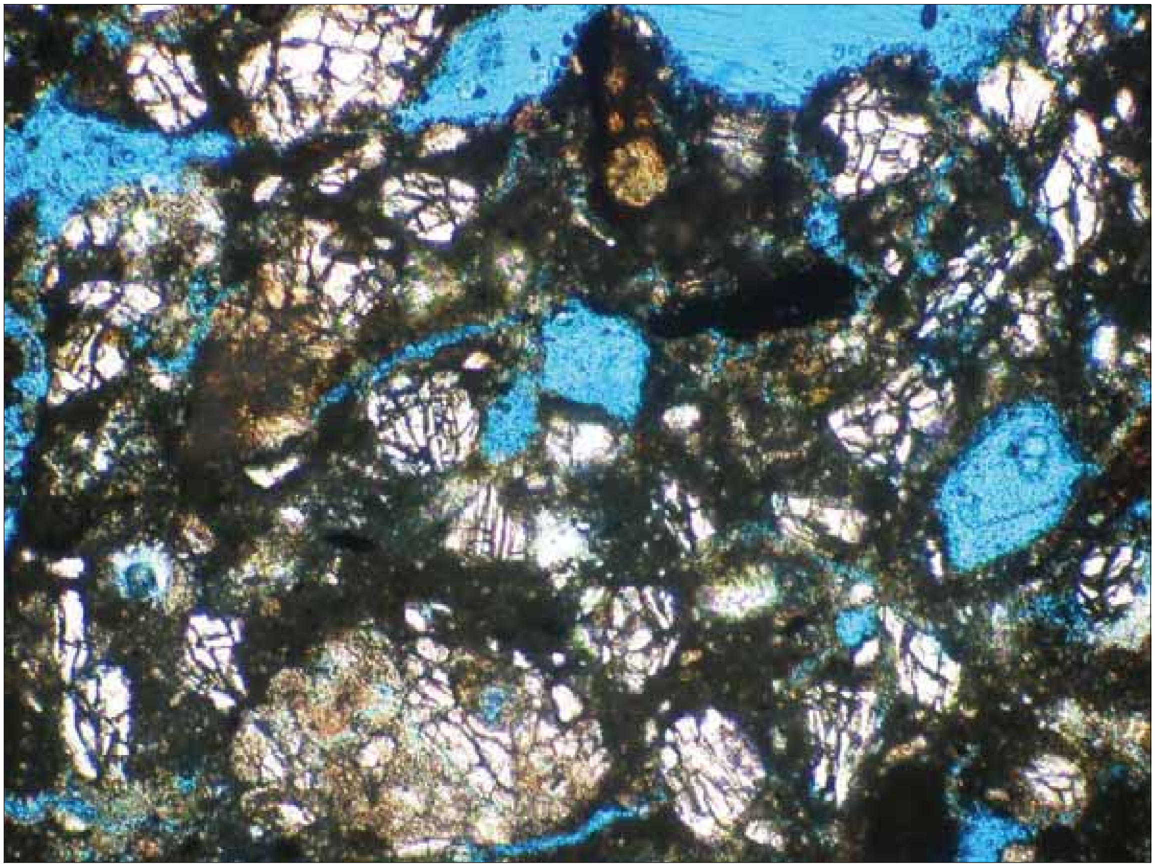

Figure 5.1. Thin section, sample M01, gray mortar from enclosed niche. Blue areas are voids and micro-cracks. Note predominance of weathered subrounded grains of sand (100x mag, plane polarized light).

Sample M01, (Figure 5.1) gray mortar from an enclosed niche along the northern portion of the lower banquette, is original to the kiva and was later sealed by a prehistoric infill. The mortar is coarse in texture and displays an irregular and inconsistent pore system of large voids and micro-cracks. The weathered grains are white or translucent in color and mostly sub-rounded to sub-angular in shape, possibly a quartzitic sand. Also present are angular dark to reddish-brown inclusions, possibly charcoal, that are incorporated into a dark relatively continuous phase or matrix of clay/silt.

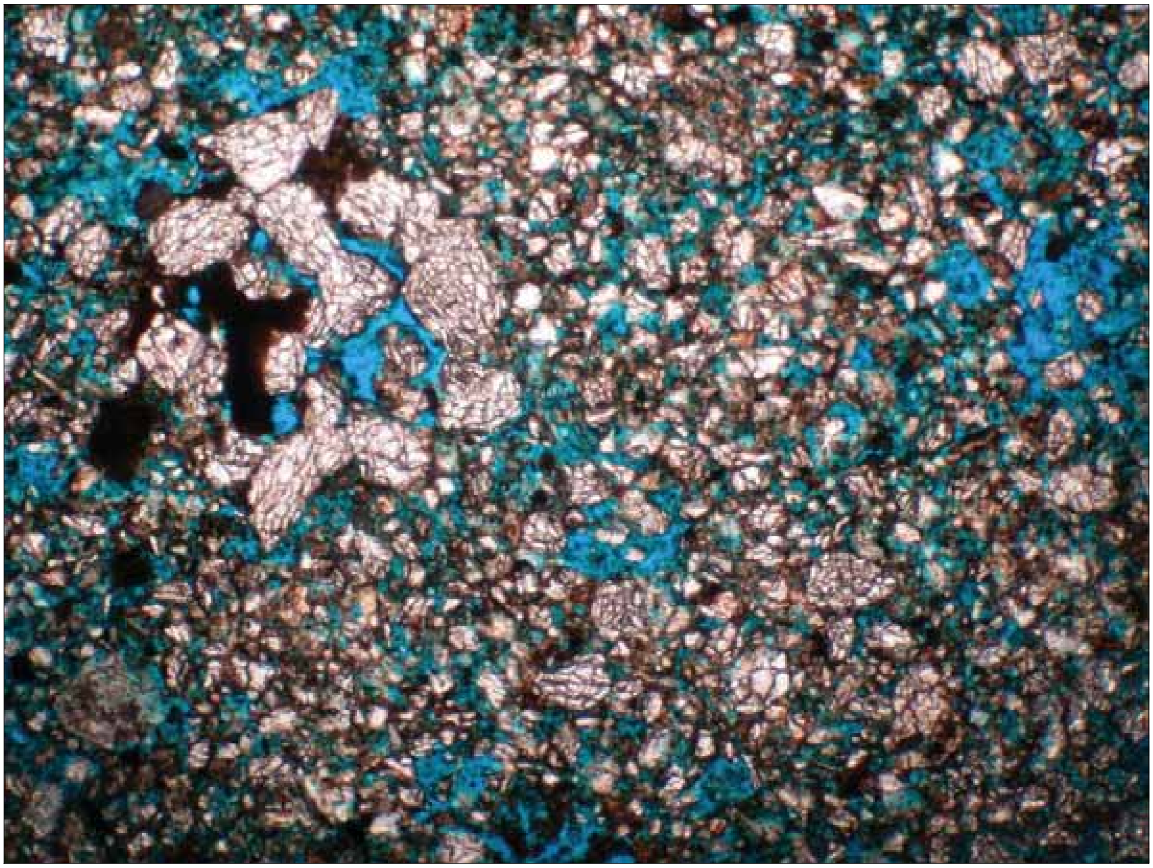

Figure 5.2. Thin section, sample M02, reddish bedding mortar (100x mag, plane polarized light).

Sample M02, (Figure 5.2) an original reddish bedding mortar from the center of Inter-pilaster space 3, is fine textured and displays a fabric of largely conchoidally fractured white, brown, red and yellowish sub-rounded to angular platy grains creating a blotched or mottled appearance. The sample's well-sorted aggregate creates a fairly consistent relationship between grains with frequent clusters of larger particles surrounded by void space occurring evenly throughout the sample.

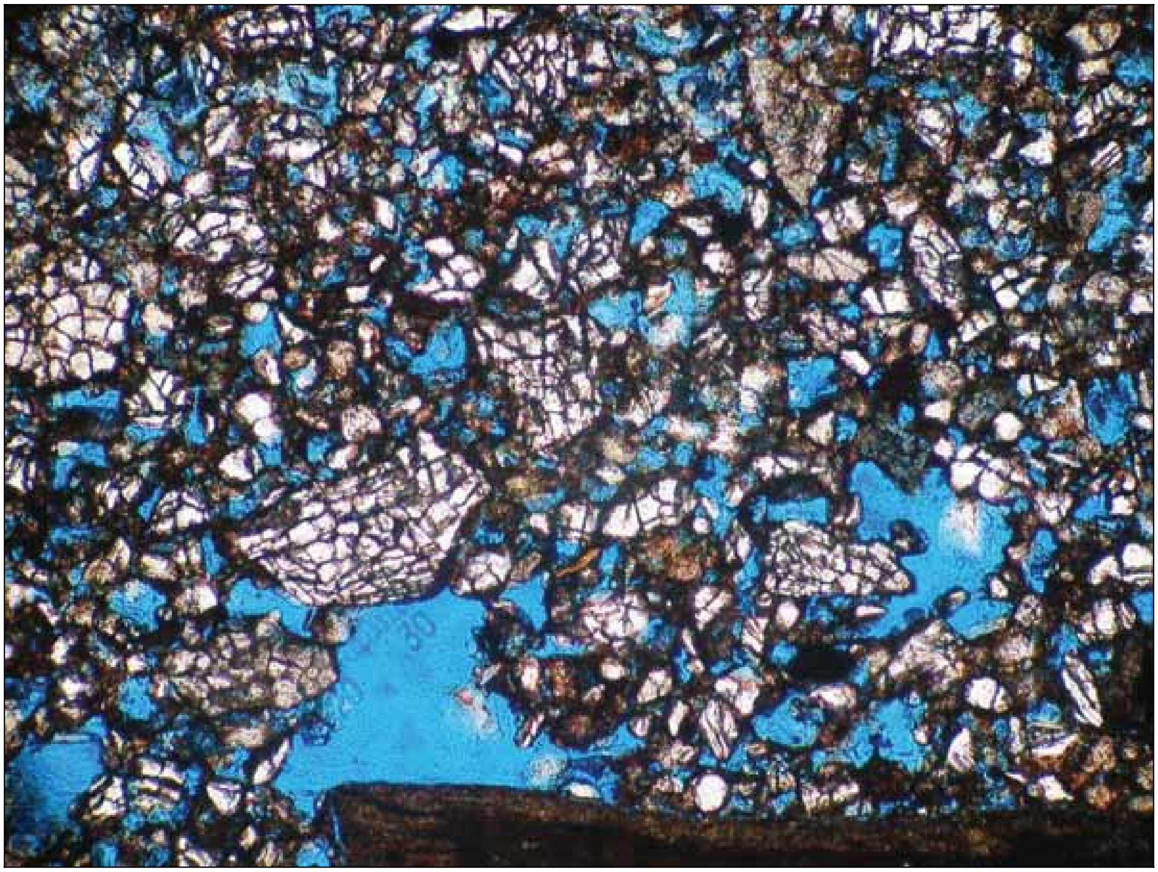

Figure 5.3. Thin section, sample M03, banquette shelf plaster (100x mag, plane polarized light).

Sample M03, (Figure 5.3) original banquette shelf plaster from between Pilasters 1 and 2, exhibits a similar fabric as Sample M02 but with larger voids.

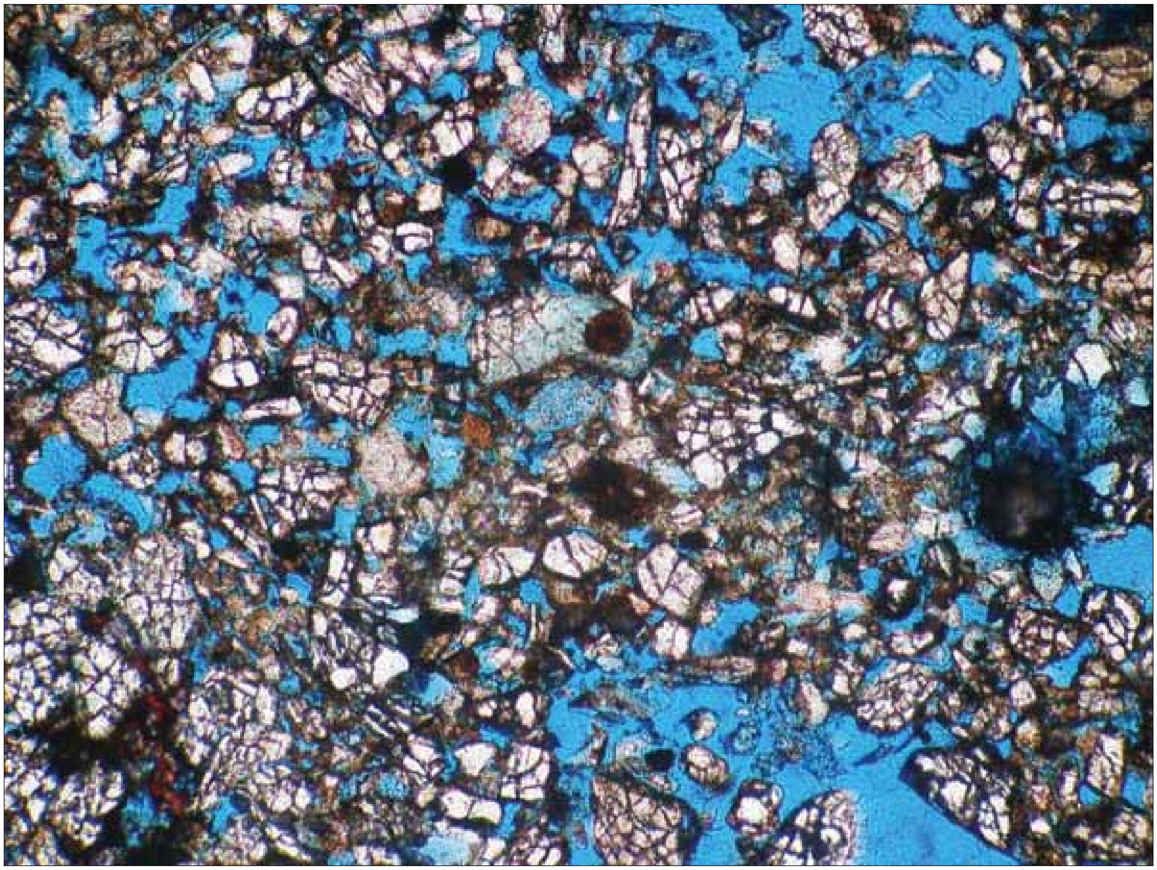

Figure 5.4. Thin section, sample M09 preparatory plaster (100x mag, plane polarized light).

Sample M09, preparatory plaster from the mid-face of the banquette field below Pilaster 1, is a fine textured, well graded and moderately sorted mixture of angular to sub-rounded grains, yet this initial layer of leveling plaster contains a high percentage of voids and random relationships between the conchoidally fractured particles. Large concretions or clusters of brown and yellow finely divided material are present and probably represent agglomerates of clay/silt.

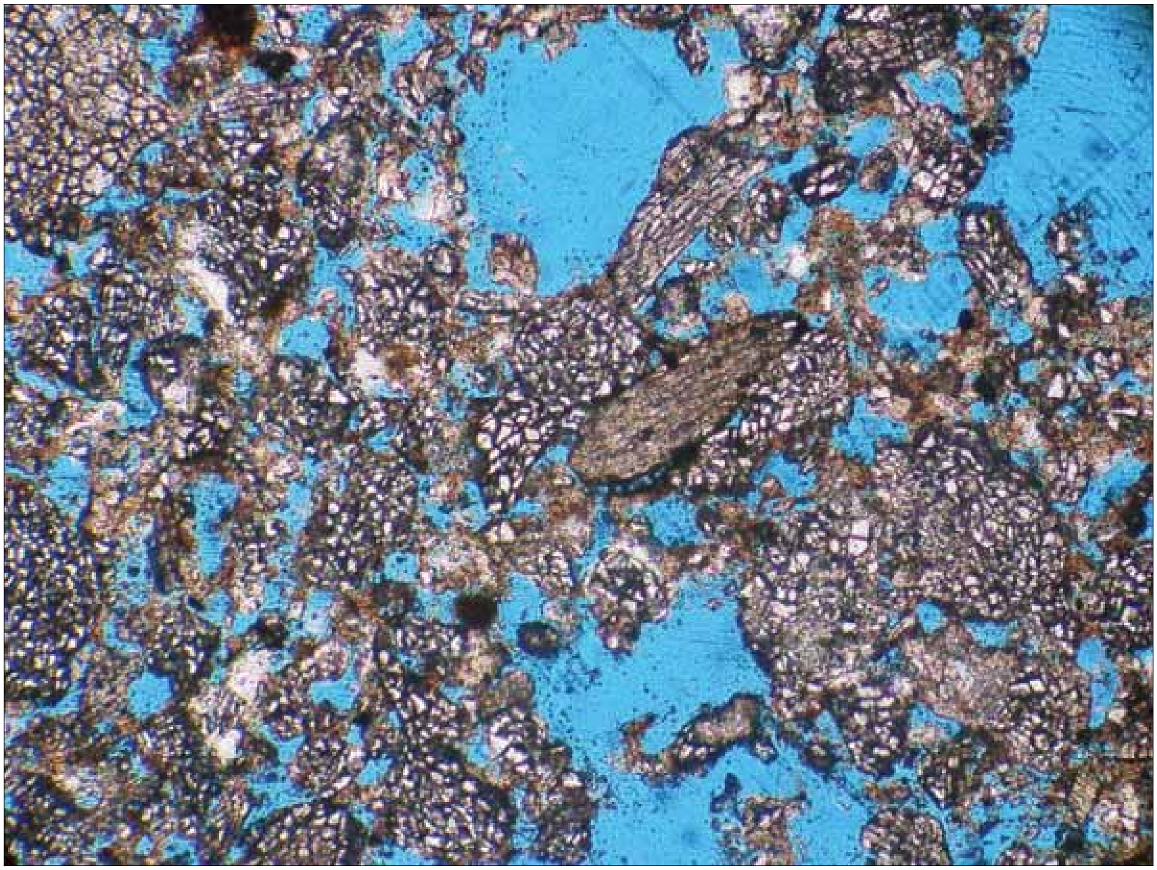

Figure 5.5. Thin section, sample M16, floor plaster (100x mag, plane polarized light). Very weathered with a high porosity.

Sample M16, a floor sample taken along the northwest wall of Kiva E, exhibits a very fine, presumably weathered texture , with a large percentage of etched white and brown sub-rounded grains and a small percentage of large lenticular platy grains, possibly crushed shale. This sample presents an extremely irregular pore structure and high ratio of void space with little matrix filling the interstitial spaces.

CHAPTER 5

Pigment Dispersions

The red and blue-green pigments from the geometric embellishment on the east wall of Kiva E were gently ground and dispersed in Cargille Meltmount under a cover slip and viewed under reflected, transmitted and cross-polarized light. Their color, morphology, birefringence, and refractive indices were compared to known pigment dispersions from the McCrone reference library in the Architectural Conservation Laboratory.

The red pigment was compared to red lead, hematite and red ochre. Red lead [Pb_3O_4], also known as *minium* in its pure mineral form, is typically fine grained.[75] Often appearing orange, particles may be crystalline, rod-like or amorphous depending on the pigment's origin and fabrication.[76] Hematite is a naturally occurring anhydrous ferric oxide [Fe_2O_3] coarsely crystallized, strongly colored and generally stable with exposure to light and air, characterized by angular grains and conchoidal fractures. Aluminum may occur or substitute into hematite.[77] Red ochre [Fe_2O_3], one of the most widely used natural pigments, is an iron oxide hematite in very fine globular and sub-rounded particles. Red ochre is generally mixed with clay and some silica resulting from weathered and oxidized iron-rich

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[75] Eastaugh, N., et al, *Pigment Compendium, A Dictionary of Historical Pigments* (Oxford: Elsevier Butterworth-Heinemann, 2004) 320.
[76] Gettens, R. and G. Stout, *Painting Materials, A Short Encyclopaedia* (New York: Dover Publications, Inc., 1966) 152.
[77] Eastaugh 183.

minerals, particularly from the direct breakdown of hematite and therefore shares the same chemical composition.[78]

The red pigment particles from Kiva E appeared anisotropic in cross polarized light and demonstrated a refractive index much higher than that of the medium, indicating that the unknown red pigment was potentially one of the following: red lead, red ochre, hematite, or vermillion.[79] Based on microscopical evaluation, the color and morphology of the red pigment most closely resembled that of the red ochre, with rounded and sub-rounded particles occurring as bright red inclusions dispersed among transparent globular grains.

The blue-green pigment was compared to malachite and terre verte (green earth). Malachite ($Cu_2CO_3(OH)_2$), also mis-referred to as chrysocolla which is a hydrous copper silicate, is a green copper carbonate mineral and commonly occurs in clustered masses with a striated, fibrous or granular texture.[80] Terre verte or green earth, typically containing iron, magnesium, aluminum and potassium is mainly glauconite, an iron, potassium, magnesium hydrous silicate; conversely, celadonite, a related light-fast and unreactive yellow-green hydrosilicate mineral, may be present often with inclusions of quartz, chlorite, feldspar, iron oxides and mineralogical clays such as kaolinite, illite and montmorillonite.[81]

[78] Eastaugh 320.
[79] Meltmount, the medium for pigment dispersions, has a refractive index of 1.66.
[80] Eastaugh 248.
[81] Eastaugh 174-175.

Occurring among numerous translucent globular grains and some tiny sub-angular red inclusions, the distinct blue-green pigment particles appeared few and faint as tiny sub-rounded to sub-angular granules. The refractive index of the unknown blue-green particles was determined to be lower than that of the dispersing medium, therefore posing terre verte or verdigris as possible matches. Although verdigris dates to antiquity, its origins and use prevail in Europe and Mediterranean regions, not necessarily in southwestern regions of the continental United States.[82] The blue-green pigment from Kiva E resembled the amorphous particles of the terre verte, which presents an appropriate match as terre verte largely originates from marine environments and may be found in alluvial sediments. Confirmed by alternative methods of analysis described in subsequent sections of this chapter, the pigment used to produce the blue-green hue is not a copper derivative.

5.1.2 FTIR

Fourier Transform Infrared Spectroscopy (FTIR) is considered one of the most practical spectroscopic techniques because a minimal amount of sample material is required for analysis. This method of analysis is based on the interaction of infrared radiation (IR) with a material. Infrared energy is directed at a sample; portions of infrared wavelengths that are absorbed by the sample match the vibrations or oscillations of the material's specific types of atoms and bonds, or molecules, while the remainder that pass through the sample

[82] According to the *Pigment Compendium*, the application of verdigris is cited by Vitruvius and Theophrastus with its earliest known use in 13th century BC Egyptian papyri. Eastaugh 385.

are measured by a detector and recorded as a spectrum.[83] The shape and intensity of the bands of the spectrum are correlated with reference data of comparative spectra to determine the functional groups in the sample, serving to identify compounds within the material.

In some cases the sample is put into a vial with a ball and potassium bromide. The sample is pulverized and placed in a vacuum and pressed into a pellet for the IR beam to pass through. Other times, samples are isolated, extracted and placed directly on a [diamond] square cell sample window. Specimens are flattened and put on a metal objective to avoid the absorption of infrared, and placed under magnification.

FTIR, primarily a qualitative technique, is especially helpful in identifying organic compounds and some crystalline structures as well as the presence of some salts.[84] In instances where samples do not conform to a mineralogical composition, using FTIR may confirm fractions of organic matter, either used as a binding agent or as colorant or pigment. Some organic compounds may be more specifically defined with the assistance of a trained technician and comparison with a catalog of relevant spectra.

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83 Price, Dr. Elizabeth, lecture at the Philadelphia Museum of Art, 24 Oct. 2006.

84 Bitossi, G., et al., "Spectropic Techniques in Cultural Heritage Conservation: a survey," *Applied Spectroscopy Reviews*, 40.3 (Taylor and Francis, 2005) 204-205.

CHAPTER 5

Sample Preparation

The blue-green pigment present in the geometric design on the eastern side of the banquette in Kiva E is atypical of the wall paintings at Mesa Verde, especially in comparison to the extensive use of various earthen hues of red and brown. In order to determine the pigment used in producing the unique hue, FTIR was performed at the Philadelphia Museum of Art on a portion of the blue-green paint extracted from a larger sample and placed directly on a diamond square cell sample window rather than compressed in a vacuum. The specimen was flattened and put on a metal objective, to avoid the absorption of infrared, under magnification.

Analysis and Observations

Two hundred complete spectra were collected in transmittance mode and translated into absorption mode upon completion of the test. Comparison of the spectra revealed the sample to be predominately silica based with some quartz. For data/spectra comparison it is important to refer to the shape and wave number range rather than the intensity when analyzing a compound material. In addition to mineralogical clays, namely illite, trace montmorillonite, and smectite (a form of montmorillonite), collected data suggested the presence of the mineral chrysocolla, ($CuSiO_3 \cdot nH_2O$)), represented in the generated spectra shown below. Ultramarine is indicated as a match to the spectrum produced by the blue pigment, but based on its provenance, this is an unlikely component of the sample material.

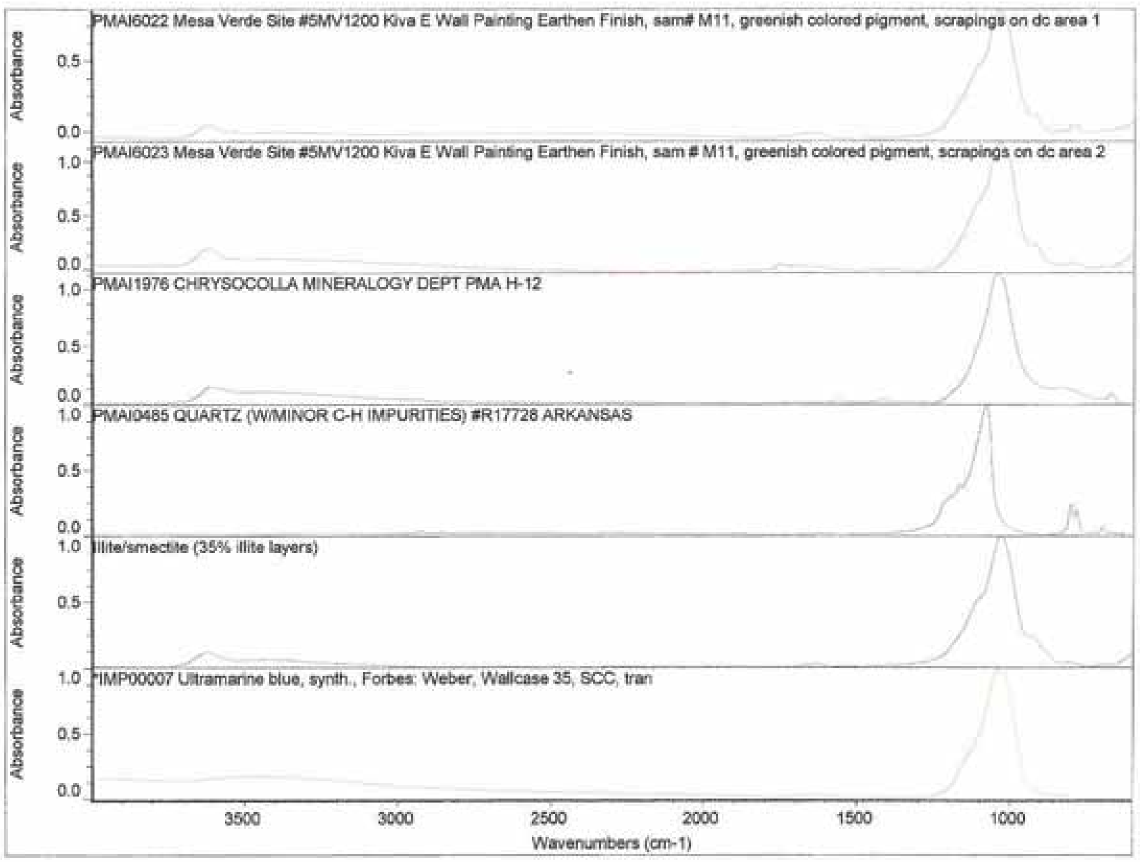

Figure 5.6. FTIR analysis on sample M11, blue-green pigment from the east wall of Kiva E, 2006.

Although two samples of the blue pigment were tested, the results were inconclusive and disputable with regard to the presence of chrysocolla. SEM-EDS was suggested as the next preferred method of instrumental analysis. The subsequent results of the electron dispersive spectroscopy on the bluish pigment, performed at the Philadelphia Museum of Art as well as the University of Pennsylvania Laboratory for Research on the Structure of Matter, are discussed below.

5.1.3 SEM-EDS

A scanning electron microscope exposes a sample to an electron beam in a vacuum system and can produce an image up to 100,000 times magnification facilitating the observation of minute surface features based on the interaction of electrons with the textured surface of a material. Three components which provide the greatest amount of information in SEM are the production of secondary electrons, backscattered primary electrons, and the emission of x-ray radiation.[85] As a result of the bombardment with the electron beam (primary electrons), secondary electrons from an atom's inner shells are ejected from the sample and create a pattern which produces a visible image, revealing the morphology of the sample. Simultaneously, the frequency and wavelength of generated characteristic x-rays can be measured by wavelength-dispersive or energy-dispersive spectroscopy (EDS) and serve to identify the elemental composition of the material by producing peaks or bands on a digital spectrum.

This testing method is advantageous in the analysis of surface finishes in that a highly magnified image is produced allowing for the visual examination of a material's physical characteristics and microstructure, including surface topography and porosity, and further contributes to establishing a material's physical and elemental composition. Distinguishing particle size and morphology in cases where substantial sample materials are not available for the performance of geo-physical testing can present a challenge; SEM/EDS enable the close

[85] Charola, Dr. A. E., *Scanning Electron Microscopy*, HSPV 656, Advanced Architectural Conservation Lecture Notes, University of Pennsylvania.

visual inspection of surface features and particle arrangement thus offering a means of examination and explanation for certain physical properties, and therefore constitute an important part of the analytical testing performed for this thesis.

Sample Preparation

Embedded, cut and mounted cross sections of representative samples M06, M09, M10, and M11 were removed from glass slides by reheating the Cargille Meltmount and were placed on circular aluminum stages adhered with black carbon tape. A chip of yellow wash was removed from the bulk sample M11 to be analyzed independently for the determination of elements present in the yellow pigment. Carbon paint was applied around the base of each sample to create a conductive seal between the specimen and the stage. Samples were then coated with palladium and gold to assure conductivity and stimulation from the electron beam.

Analysis and Observation

Analysis was performed at the University of Pennsylvania Regional Nanotechnology Facility at the Laboratory for Research on the Structure of Matter, Edison Building. A JEOL 6400 scanning electron microscope coupled with electron dispersive spectroscopy was operated by Bruce Hilman at 20 kV. Images produced by SEM clearly revealed greater detachment in the layers of plaster than in the washes. Washes have a finer texture and exhibit greater adhesion (Figure 5.7), except in samples from areas of apparent degradation and exposure to weathering in situ (Figure 5.8). Sooted layers are smooth with almost no apparent aggregation.

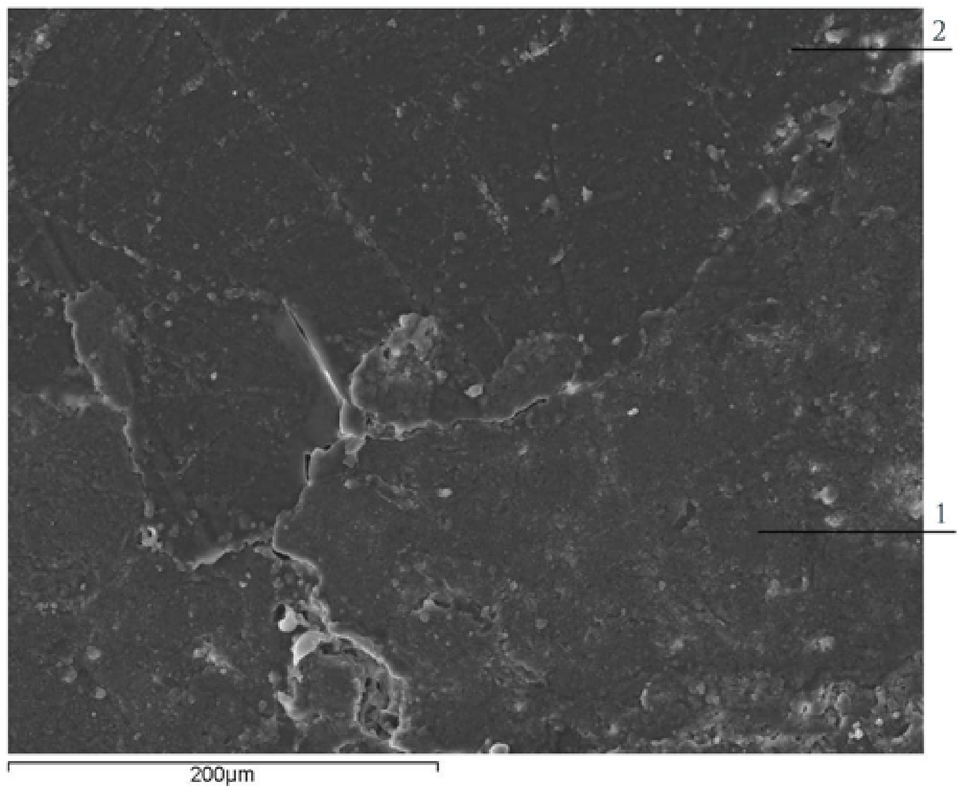

Figure 5.7. Sample M11 - boundary between the white (1) and red (2) washes of the embellishment along the NE wall of Kiva E. Washes are smooth in texture with few coarse grains (270x mag).

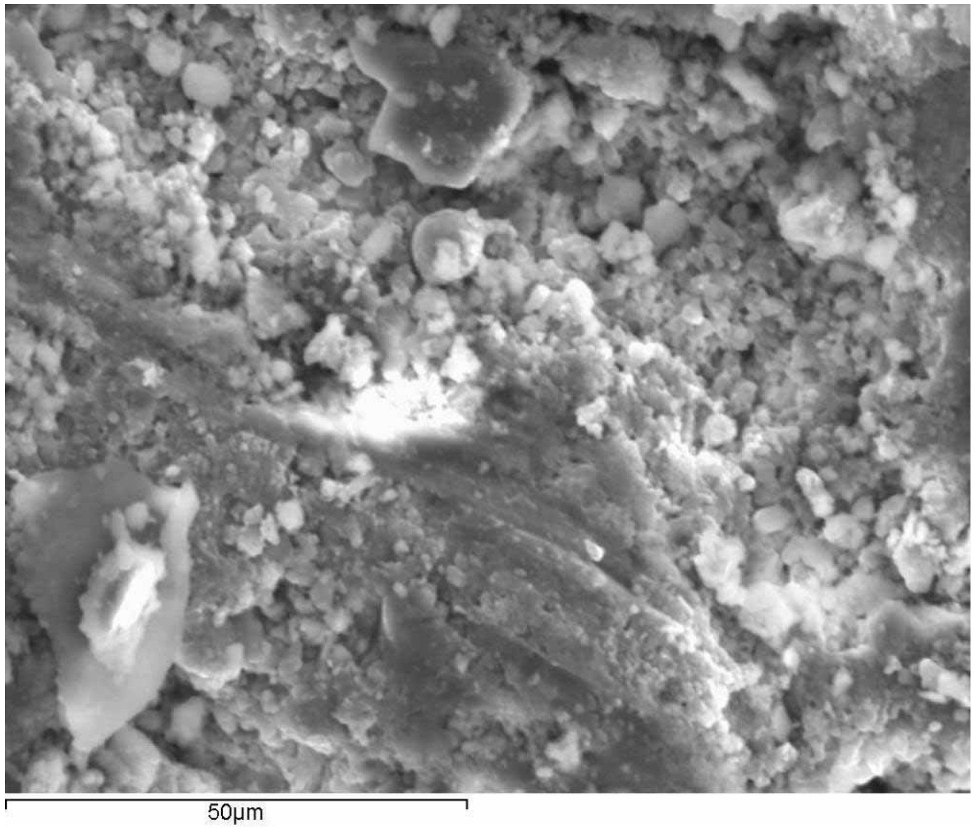

Figure 5.8. Sample M11 of yellow pigment along NE wall of Kiva E, part of the embellishment scheme and badly deteriorating (SEM at 1100x mag).

EDS mapping at 22x magnification at 20kV revealed elemental profiles by layer (see Appendix C for electron dot maps and spectra graphs). Silicon and aluminum were mostly detected, as well as indications of potassium and magnesium in modest concentrations throughout. The silicon appears as discrete nodes typically coupled with oxygen, while the aluminum appears in areas adjacent to but largely apart from the silicon. Concentrations of calcium consistently occur within white layers, while carbon, generally dispersed throughout, comprises the soot and thick black layers almost exclusively.

Previous studies suggest the pervasive presence of iron oxide minerals in the plasters and washes of the Mesa Verde region, imparting the reddish color that characterizes the walls of rooms and kivas. Detection of iron in each sample tested with EDS was minimal, particularly for the bright red washes of the applied designs on the banquette. Iron appears in peaks of the spectrum, but is not prominently displayed in the electron dot maps of the layer strata. Iron is more conspicuous in plaster layers than in the intensely red washes. Mercury, lead and chromium do not appear to be major constituents of the red paint.

EDS performed at the University of Pennsylvania as well as at the Philadelphia Museum of Art on the blue-green pigment failed to distinguish a noticeable incidence of copper, a mineral present in the compounds malachite and chrysocolla, apart from a light uniform dispersal throughout the entire sample.

5.2 Chemical Analysis

Organic and inorganic constituents can be determined by chemical spot-testing, especially for the identification of salts, pigments and proteins. Spot-testing methods are particularly useful in the field or as a substitute for costly instrumental analyses. Reactions between samples and reagents will yield changes (dramatic in some instances) in color or effervescence. Achieving accurate and consistent results with spot-test techniques may be challenging with impure or extremely small samples, such as the case with the salt samples tested for Kiva E.[86]

5.2.1 Chemical Spot-Testing for the Determination of Pigments

Identification of constituents in the red and blue-green pigments was largely unresolved with EDS analysis. Based on observations under polarized light, potential pigments were determined for the red and blue-green washes found along the east wall of Kiva E based on comparative investigations of the anisotropy and refractive index of known pigments, including red ochre and terre verte respectively. Chemical spot tests were conducted to determine the presence of iron, an element present in each of the known control pigments, and copper, which may indicate that the blue-green pigment is malachite or chrysocolla, however unlikely. Control pigments were sampled from the University of Pennsylvania Architectural Conservation Laboratory Pigment Library. All reactions were observed under 115x magnification with a Leica MZ16 stereomicroscope.

Sample Preparation

Several particles of each pigment were removed from the bulk sample with a tungsten needle onto a well slide and treated with one drop of 1:1 nitric acid (HNO_3) diluted in deionized water to ionize the metallic components present. The slides were warmed on a hot plate to evaporate the acid.

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[86] Odegaard, Nancy, Scott Carroll, Werner S. Zimmt, David Spurgeon, Stacey K. Lane, *Material Characterization Tests for Objects of Art and Archaeology,* 2nd ed. (London: Archetype Publications, 2005).

CHAPTER 5

Analysis and Observation

To test for iron in both the red as well as the blue-green samples, one drop of potassium ferrocyanide ($K_4[Fe(CN)_6]$) reagent (0.05 M solution) was added to the acid-treated residue on each slide. The reactions were compared to those of red ochre, natural hematite and terre verte serving as known controls for the test. Both the known red ochre and natural hematite exhibited a faint bluish precipitate around the periphery of the test area and the development of a cloudy precipitate within the solution. Conversely, the terre verte control reacted immediately, producing an intense Prussian blue precipitate. Both unknown red and blue-green pigments from Kiva E yielded similar results as the test on the control pigments of red ochre and hematite with the slight formation of a hazy blue halo around the potassium ferrocyanide solution.

A second sample of the blue-green pigment was subjected to testing for copper. One drop of deionized water was added to the residual dissolved and dried pigment in the nitric acid solution, followed by a drop of potassium ferrocyanide reagent. Results were compared to treated controls of copper resinate and verdigris—for the purposes of comparative observation. The known copper resinate had a mild reaction, its particles exhibiting gold and brownish edges. An instant formation of a reddish-brown precipitate occurred with the testing of the verdigris control. There were no similar visible reactions indicating the presence of copper in the unknown blue-green pigment from Kiva E.

5.2.2 Chemical Spot-Testing for the Presence of Salts

Salt samples were collected from around the periphery of Kiva E where discrete white nodules were present in the stone or mortar. Determination of salts is achieved initially by chemical spot testing for anions and cations and compared to known premixed diluted salt solutions and deionized water as a control, and confirmed by approximate quantitative analysis with the use of salt test strips.

Preparation, Analysis and Observation

All lab equipment was swabbed in acetone prior to testing to prevent contamination. Known compounds such as Calcium Carbonate ($CaCO_3$), Sodium Chloride (NaCl), Calcium Nitrate ($Ca(NO_3)_2$), Sodium Nitrite ($NaNO_2$), Sodium Phosphate (Na_2HPO_4), and Sodium Sulfate (Na_2SO_4) were diluted in deionized water to five percent concentrations weight by volume (5% w/v aq); salt solutions served as the control for chemical spot testing and were placed in the well next to that of the raw sample on ceramic test plates. Deionized water also served as a control on the test plates.

Semi-qualitative analysis was conducted with the use of test strips to obtain the relative concentrations of salts present, particularly chlorides, nitrates, nitrites, phosphates, and sulfates, indicating the approximate amount of salt in each sample suspended in deionized water in a test tube. Ionic test strips provide qualitative as well as semi-quantitative analyses for the type and amount of salts detected.[87]

Sample S01 extracted directly from the sandstone alcove wall of Inter-pilaster space 2 indicated a strong presence of chlorides, as well as nitrites, nitrates, and sulfates, although to a much lesser degree. Nitrites and especially nitrates and sulfates were present in sample S03 from the banquette bedding mortar below the southern recess to the east of the ventilator shaft. Traces of chlorides, nitrites, nitrates and sulfates were present in samples S05 and S06 from the banquette stone directly below Pilaster 1 and at the base of the wall beneath Inter-pilaster space 2 respectively. Phosphates exhibited a presence in sample S05 as well as in trace amounts in sample S06. The presence of sulfates in all samples was indicated by the ionic test strips only, as chemical reagent testing did not produce a reaction.

[87] Because the data is provided within a certain numerical range of milligrams per liter and is therefore not precise, the results are considered semi-qualitative.

Table 5.1. Chemical Spot-Testing for Salts

Reagent Lab Testing for the Presence of Salts						
Sample No.	**Carbonates**	**Chlorides**	**Nitrites**	**Nitrates**	**Phosphates**	**Sulfates**
S01	Strong	Present	Present	Weak reaction	None	None
S03	None	Trace	Present	Very weak	None	None
S05	None	Trace	Present	Very weak	Present	None
S06	None	Trace	Present	Very weak	Trace	None

Table 5.2. Salt Test Strips

Quantitative Lab Analysis of Soluble Salts with Ionic Test Strips						
Sample No.	**Carbonates**	**Chlorides**	**Nitrites**	**Nitrates**	**Phosphates**	**Sulfates**
S01	Not tested	b/t 2000-3000 mg/L	2-5 mg/L	b/t 50-100 mg/L	Not tested	>1600 mg/L
S03	Not tested	>0 mg/L	<10 mg/L	500 + mg/L	Not tested	>1600 mg/L
S05	Not tested	None	~5 mg/L	~50 mg/L	Not tested	>400 mg/L
S06	Not tested	>0 mg/L	~2 mg/L	~100 mg/L	Not tested	b/t 200-400 mg/L

6.0 INTERPRETATION AND CONCLUSIONS

6.1 Interpretation of Schemes

The sequential applications of plain and embellished plasters and washes to the interior of Kiva E are referred to as schemes. Synchronic relationships between the finish applications on the banquette, pilasters and inter-pilaster spaces were determined through field examination and stratigraphic analysis and interpreted as schemes. Microscopical observations largely comply with those made onsite with the identification of additional layers and therefore possible additional schemes. Due the limited amount of original extant finishes found in Kiva E, particularly in the half of the kiva that has been reconstructed, and the minimal number of samples collected for further analysis, design schemes are based on speculation. The banquette appears to have had eight to ten finish layers and the pilasters, based on the analysis of the finishes on Pilaster 1, may have had approximately eight. Finish layers present on the southern recess are probably indicative of the finish sequence on the inter-pilaster spaces, but the finishes on the southern recess are not expressly clear in their association to the finishes on other architectural elements in Kiva E and are therefore surmised based on observation and comparison of previously determined schemes for the purposes of this study.

Scheme 1

Original masonry surfaces are finished with an initial application of pale reddish-brown or pinkish-tan plaster with a rather homogenous granular red matrix and large translucent, yellow and black sub-angular inclusions, of variable thickness depending on the finish of the stone (3mm – 1cm thick) and serving as the substrate applied directly to the stone walls. A second thinner red plaster with a similar soil structure has been applied, barely detectable in cross-section from the thicker plaster below; these two layers may represent the same campaign, applied wet-into-wet, in efforts to create a uniform smooth wall surface This monochrome reddish-brown plaster finish appears to have been the first scheme exposed for a short time judging from a light deposition of soot.

Schemes 2 and 3

A third and possibly fourth layer of thin reddish plaster are applied on top of the previous layers, visible by a detachment between the layers and light deposits of soot which are scarcely discernable in cross sections but detected by the indication of carbon in the EDS mapping. These successive layers may represent periods of plaster renewal for the purposes of resurfacing after wear or loss and potentially correspond to a thin red wash in the southern recess applied over a relatively thin layer of soot. This red layer is directly followed by a thin and luminous white wash on the southern recess, although the horizon between the two is somewhat irregular, which may relate to the thick smooth black layer of soot exhibited on Pilaster 1. This combination may present a possible second design scheme of a reddish-brown banquette with white inter-pilaster walls and black pilasters (Scheme 2). The southern recess then appears to have accumulated a dense accretion of soot while the pilasters may have retained the black, creating a bichrome design representative of Scheme 3.

Scheme 4

Scheme 4 appears to be followed by the application of white plaster to the pilasters and the banquette as well as the southern recess. Samples M09, M10 (Figure 6.2) and M21, all approximately sampled from the middle of the banquette, each display a smooth layer of creamy white plaster of uniform thickness with large bright white and translucent particles in a creamy-yellowish matrix and covered by an associated corresponding layer of light reddish-brown, very similar in color and morphology to the preceding layers of red plaster. These layers of plaster presumably represent the same campaign based on the even transition and absence of soot or weathering between the two; the result being a red plaster dado with a white field above. Sample M08, from the top course of the banquette directly below Pilaster 1, exhibits finishes pertaining to the campaigns of the pilasters, providing information on the relationships between the banquette and pilasters above. Pilasters are believed to have been white or creamy-tan like the field above the dado with applied embellishments in red, such as linear designs, handprints, depictions of animal paws, dots, daubs, etc. This is suggested by the presence of fragmentary bright red (Figure 6.1) and areas of white or light brown. In contrast, the southern recess exhibits an even layer of reddish plaster over an inconspicuous thin white wash, indeterminate as a finish layer and suggesting the inter-pilaster spaces paralleled the red of the dado in Scheme 4.

Figure 6.1. Photomicrograph of sample M07 exhibiting a fragment of bright red wash from the mid-face of Pilaster 1. Viewed in reflected light at 50x magnification.

A second thick and possible intentional incorporation of black into the design scheme, reminiscent of that described for Schemes 2 and 3 with few visible grains and striated texture, is present on Pilaster 1 as well as the southern recess. This layer is coated with a film of grayish soiling or soot indicating that it was exposed, but does not appear as a consistently uniform layer, and therefore may not have extended up the entirety of the pilasters or was concentrated in areas to compose embellishments. This discontinuous layer is not represented in the illustrated conjectural schemes.

Scheme 5

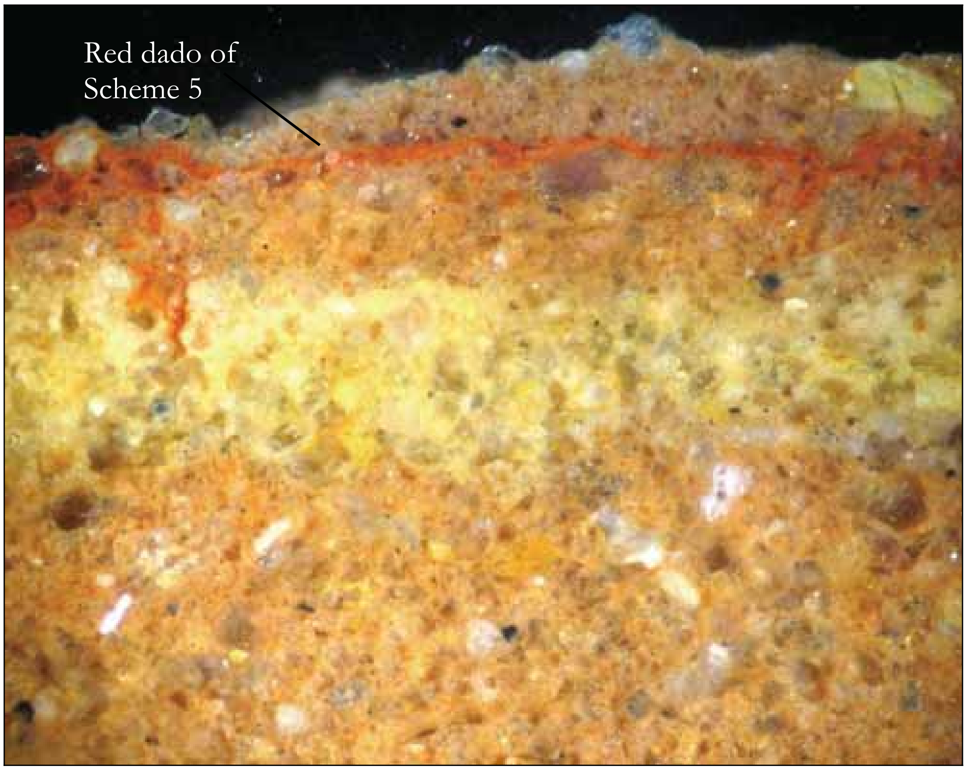


Figure 6.2. Photomicrograph of sample M10 in cross section from the mid-face of the banquette. Viewed in reflected light at 50x magnification.

The analogous layers of white and pale reddish-brown are followed by a complex scheme of intricate designs including a red dado (Figure 6.2) around the lower periphery of the banquette painted beneath a creamy white field. This campaign, Scheme 5, presumably incorporates the partial polychromatic geometric and zoomorphic embellishment to the east of Pilaster 4 on the upper banquette. Appearing thick and striated in situ, the blue and red paint of the design embellishment exemplify a substantial and even application when viewed in cross section (Figure 6.3), presumably subject to surface weathering and partial loss since its exposure in late 1950s, substantiated by the increasingly prominent grains closer to the surface and the irregularity of the outmost contour. Onsite investigations reveal a yellow

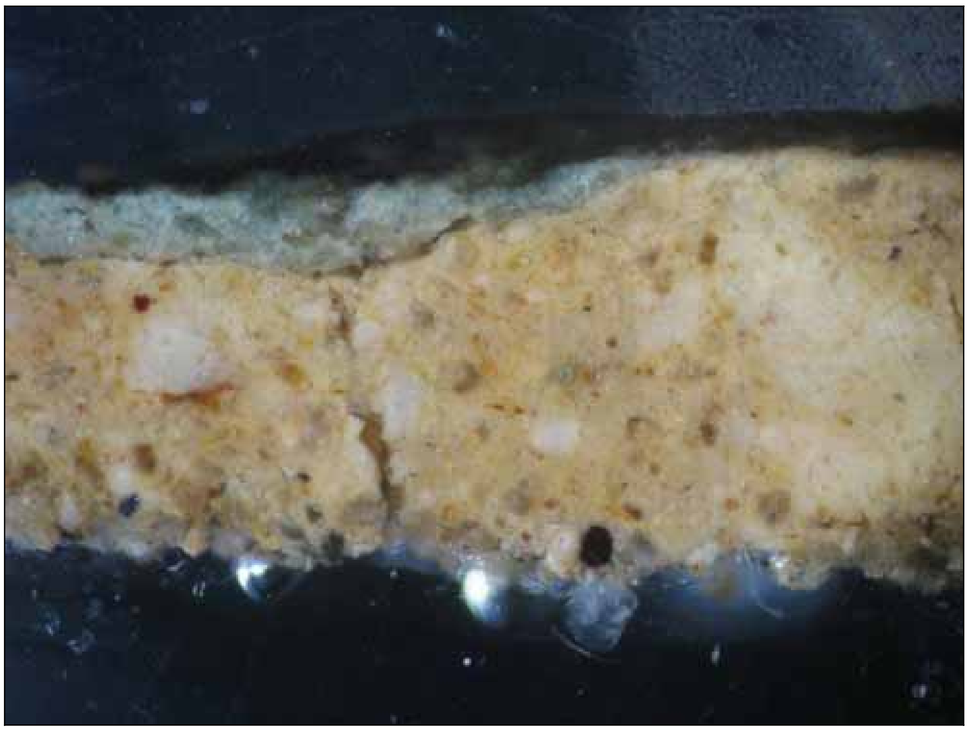


Figure 6.3. Sample M11 viewed in cross section under reflected light at 100x magnification. The lightly sooted blue-green pigment is applied over a white ground, representative of Scheme 5.

band beneath that of the geometric pattern and a possible blue-green/turquoise aura around Niche 4. Presumably of the same campaign, a fine grained bright red dado slightly overlaps the corresponding white plaster field above, which appears somewhat yellow in cross-section (seen above in sample M11). Pilaster 1 and the southern recess demonstrate an even layer of light brown/tan with a high ratio of translucent crystalline particles, presumably associated with Scheme 5 based on sequence, with possible bright white embellishments.

Scheme 6

Thin traces of soot as well as remnants of the subsequent reddish-brown wash, occurring as the final monochromatic scheme before abandonment (Scheme 6), are evident in cross section on areas of both layers of red and blue-green washes, white ground and dado, as well as heavier accretions of soot on samples from Pilaster 1 and the southern recess. This final layer appears to have protected the highly embellished Scheme 5 until Cattanach's team removed it to reveal the designs below.

Conjectural visualizations of identified Schemes 2-5 may be found on the following pages.

Conjectural Scheme Two
Kiva E, Long House, Mesa Verde National Park, Colorado

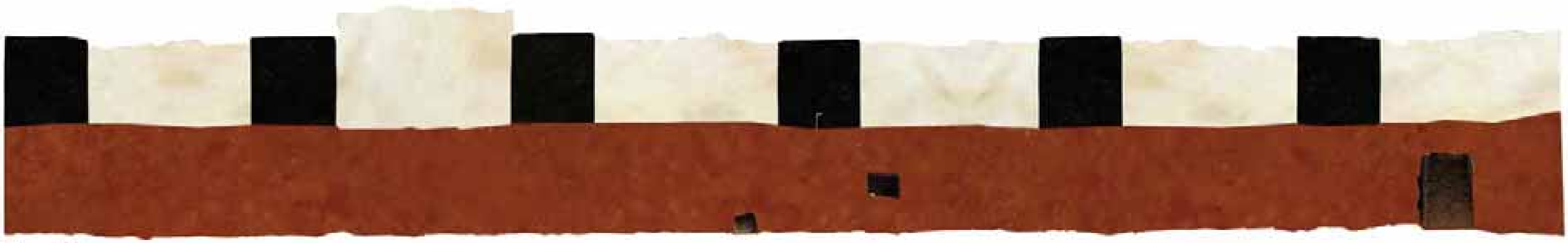


Figure 6.4

Conjectural Scheme Three
Kiva E, Long House, Mesa Verde National Park, Colorado

Figure 6.5

Conjectural Scheme Four
Kiva E, Long House, Mesa Verde National Park, Colorado

Figure 6.6

NOTES:
1. Pilasters contained tan/white and bright red embellishments such as handprints or patterns, evidenced by fragments of colored washes.

Conjectural Scheme Five
Kiva E, Long House, Mesa Verde National Park, Colorado

Figure 6.7

NOTES:
1. Pilasters 1 and 4 contain remnants of white wash indicating the presence of embellishments.
2. Trace amounts of blue/green wash around Niche 4 suggest it may have been surrounded by an aura, depicted here.
3. Evidence of additional embellishments on the banquette include both representational and linear design elements in red and blue washes, such as big horn sheep and zig-zag patterns.

6.2 Interpretation of Data

6.2.1 SEM-EDS

As explained in Chapter 5, samples containing a full sequence of finishes and/or fragmentary pigmented washes from the banquette and Pilaster 1 were analyzed using SEM-EDS and are interpreted here. Generally, washes and thick layers of soot incorporated

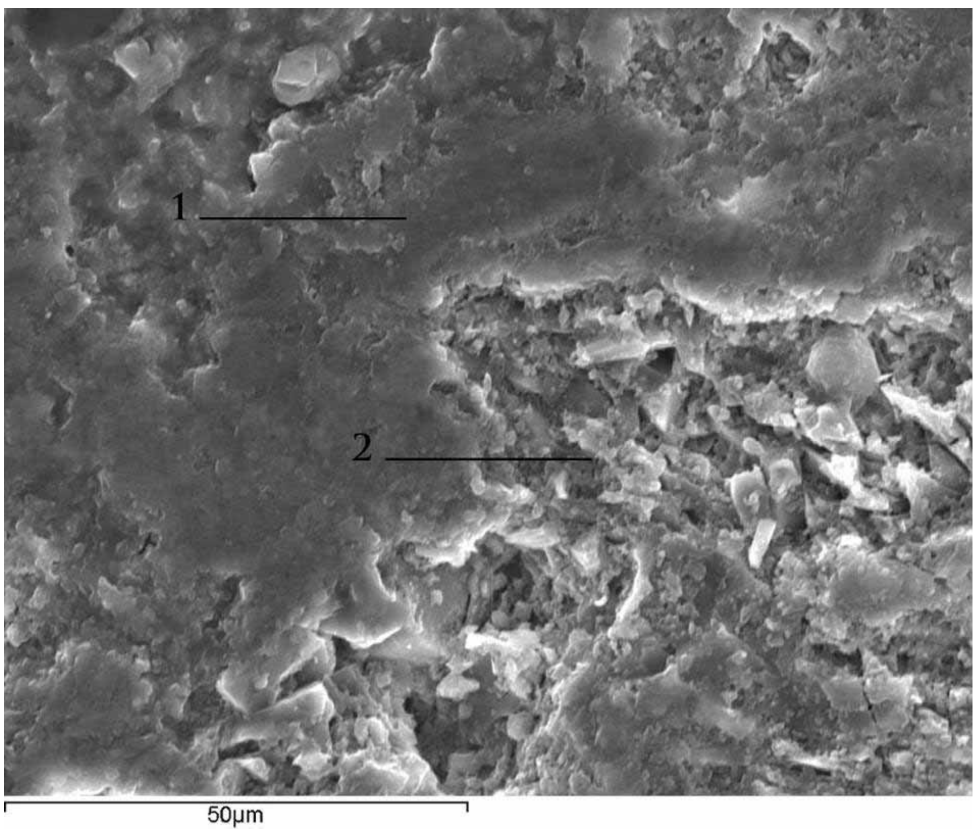


Figure 6.8. SEM image of sample M06 at 1100x magnification. Layer 1 represents a sooted layer while the second layer (2) is the discontinuous granular texture of the plaster below.

into design schemes display much finer grains, greater cohesion with a dense inter-granular structure and less void space with a powdery texture where subject to weathering or surface erosion. Several small fissures and loose particles are evident. Conversely, plasters exhibit sharper grain boundaries with a textured binder, some particulates appear clumped together while others are isolated flakes.

EDS mapping of each sample displays the presence of silicon as discrete nodes generally occurring in the company of oxygen, representing the high quartzitic sand fraction in both the plaster layers as well as the washes. Quartz is resistant to weathering and will concentrate in eroded surfaces, suggesting a higher ratio of sand and silt to clay than may have been present originally.[88] This is also observed in the morphology of the petrographic thin sections prepared for the mortars and plasters in Kiva E, where delineated glassy crystals occur throughout. Aluminum appears independent of the sand grains, largely constituting the matrix. Trace iron is demonstrated throughout, but in some cases, lead and chromium indicate stronger quantities than iron in the reddish-brown plaster layers. Nodules of potassium occur with relative frequency in several of the layers, possibly representing the presence of feldspar, or biotite/mica, or illite particularly with the dispersal of magnesium. Carbon strongly follows the sooted bands revealed in the EDS mapping. Consistent with Mary Slater's research on Cliff Palace from 2002, trace amounts of titanium were dispersed in the red-brown plasters. Spectra graphs from finishes comprising the banded embellishment on the east wall demonstrate peaks of bromine. Bromine, often found in bromide compounds and similar to chlorides, may result from the once marine

[88] FitzPatrick, E. A., *Soil Microscopy and Micromorphology* (New York: John Wiley & Sons, 1993) 87.

environment or possibly have been in a component in earlier conservation treatment solutions.[89] As earthen materials, specimens were expected to demonstrate a broad range of constituents, but some elements suggested by EDS spectra, such as niobium, were considered erroneous.

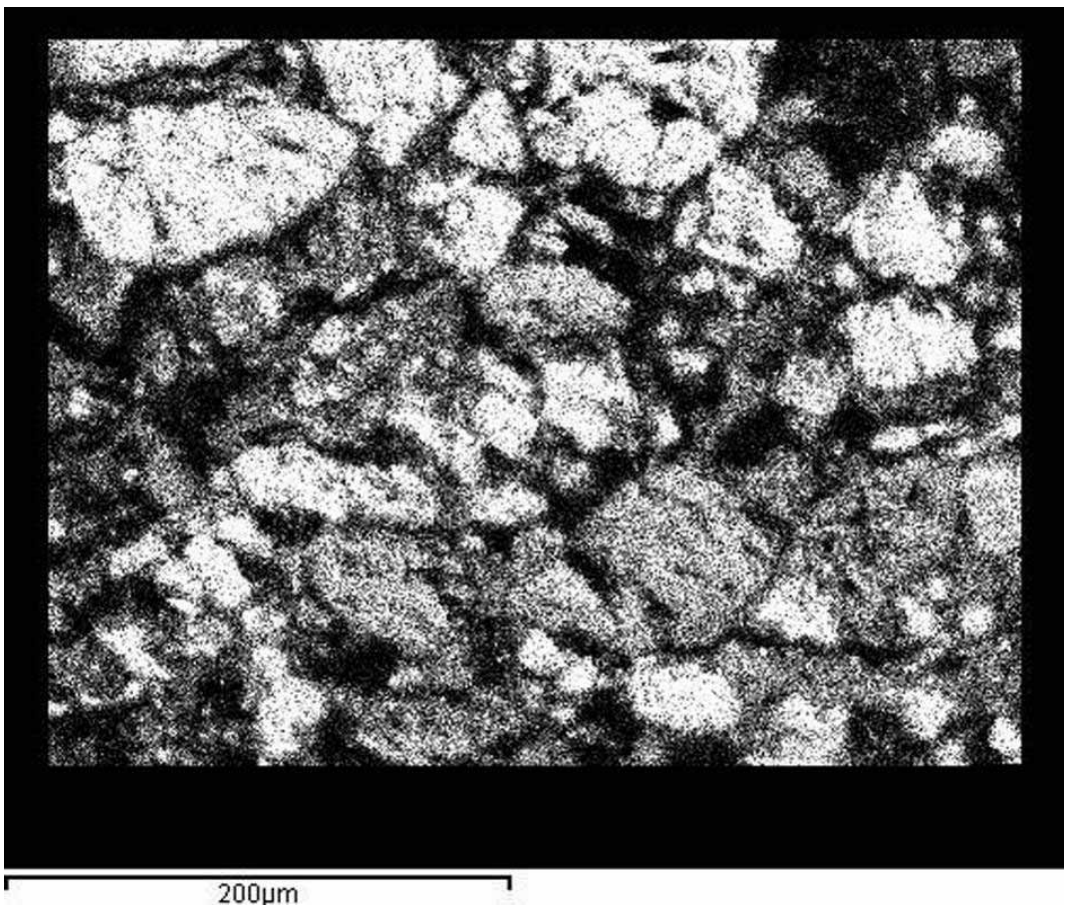


Figure 6.9. Elemental dot map of silicon, representative of sand and silt grains, found in sample M09 at 270x magnification.

[89] As suggested by Dr. A. Elena Charola, April 2007.

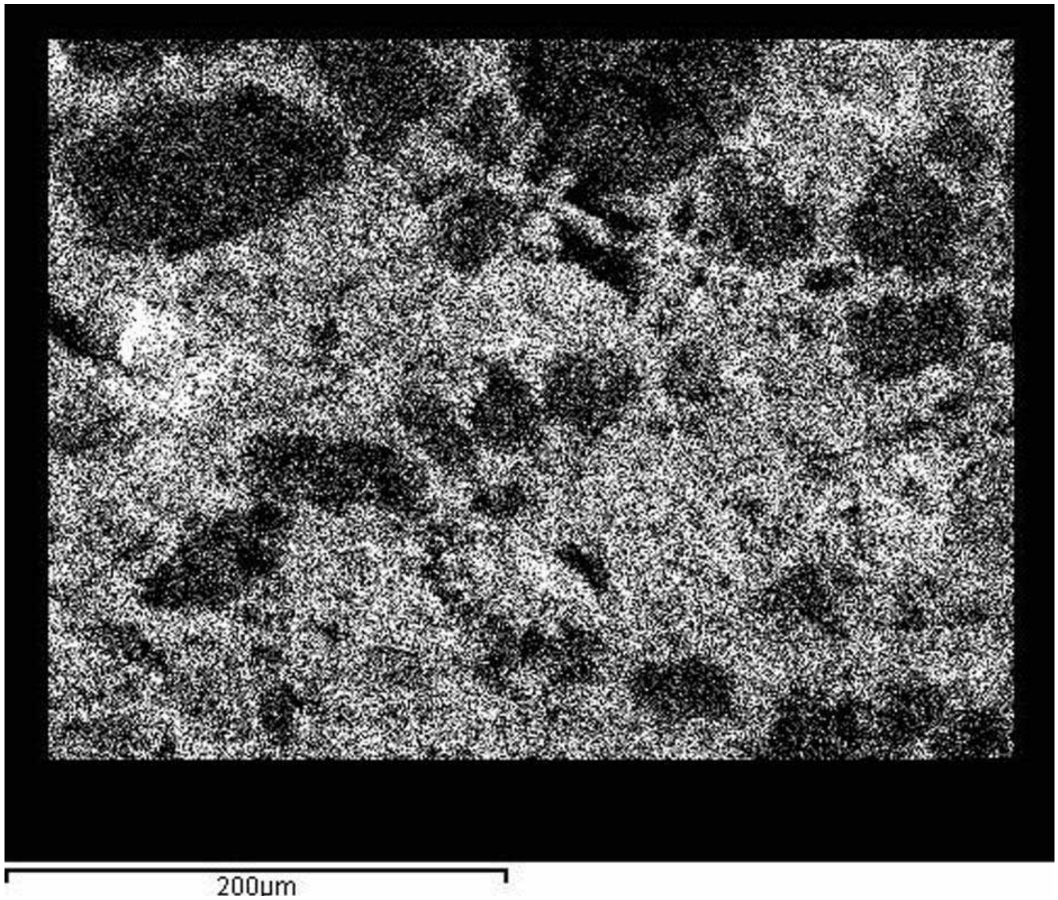


Figure 6.10. Elemental dot map of aluminum in sample M09 at 270x, found in concentrations largely independent from silicon, but occurring mutually in the clay matrix.

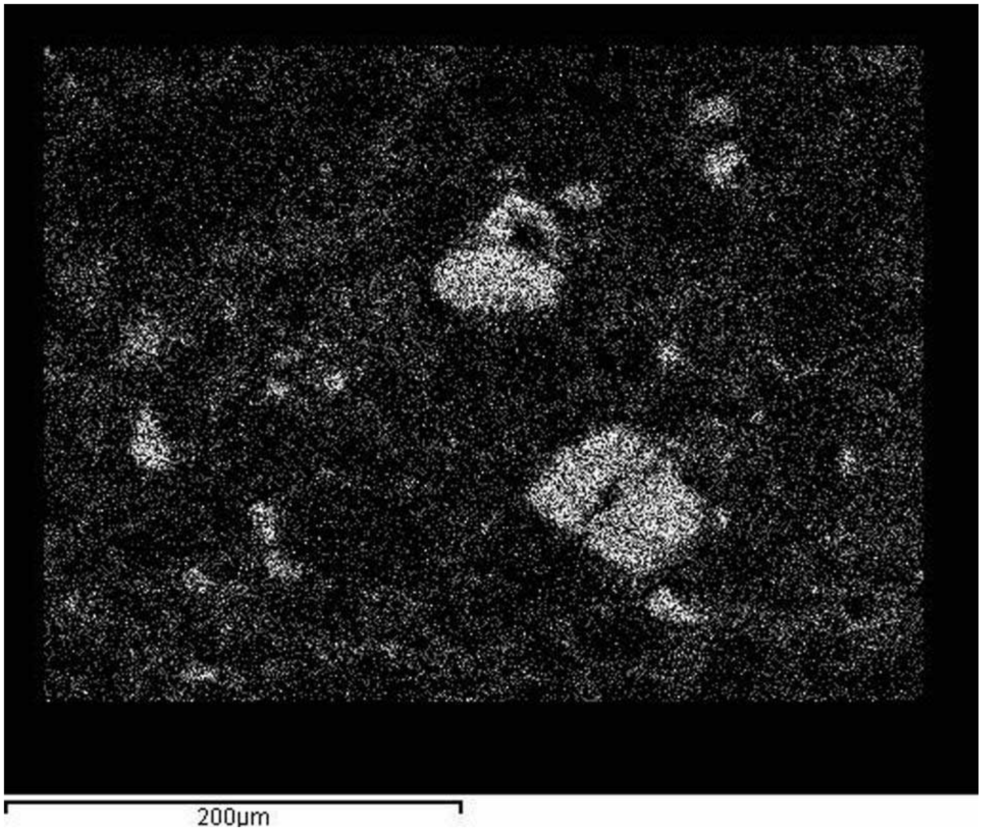


Figure 6.11. Elemental dot map of potassium nodes in the base layer of red plaster from sample M09, 270x magnification.

The raw sample of yellow pigment displays a prominent presence of iron, and as corroborated with former microscopic and micro-chemical analyses, has been identified as a hydrous iron oxide. As other samples and plaster/wash layers are believed to contain iron as well, divergent results within the samples tested may merit further investigation. Even a small amount of iron present in a material can produce intense color, and only nominal amounts were detected in the red finishes with EDS. The readings are correlative with lower concentrations of iron found with EDS in previous analyses. Aluminum can occur or substitute into hematite[90], which may account for the notable aluminum content of the red plaster layers in addition to the mineralogical clay fraction dispersed throughout the matrix. As expected, concentrations of calcium are present in nodes or clusters in lighter or white layers. The lack of copper in the blue-green pigment, as determined by EDS and confirmed by spot testing, refutes the possibility of malachite or chrysocholla pigment base; rather, discrete concentrations of iron were detected (represented in Figure 6.12), further substantiating the blue-green pigment as terre verte (green earth) or glauconite.

[90] Eastaugh 183.

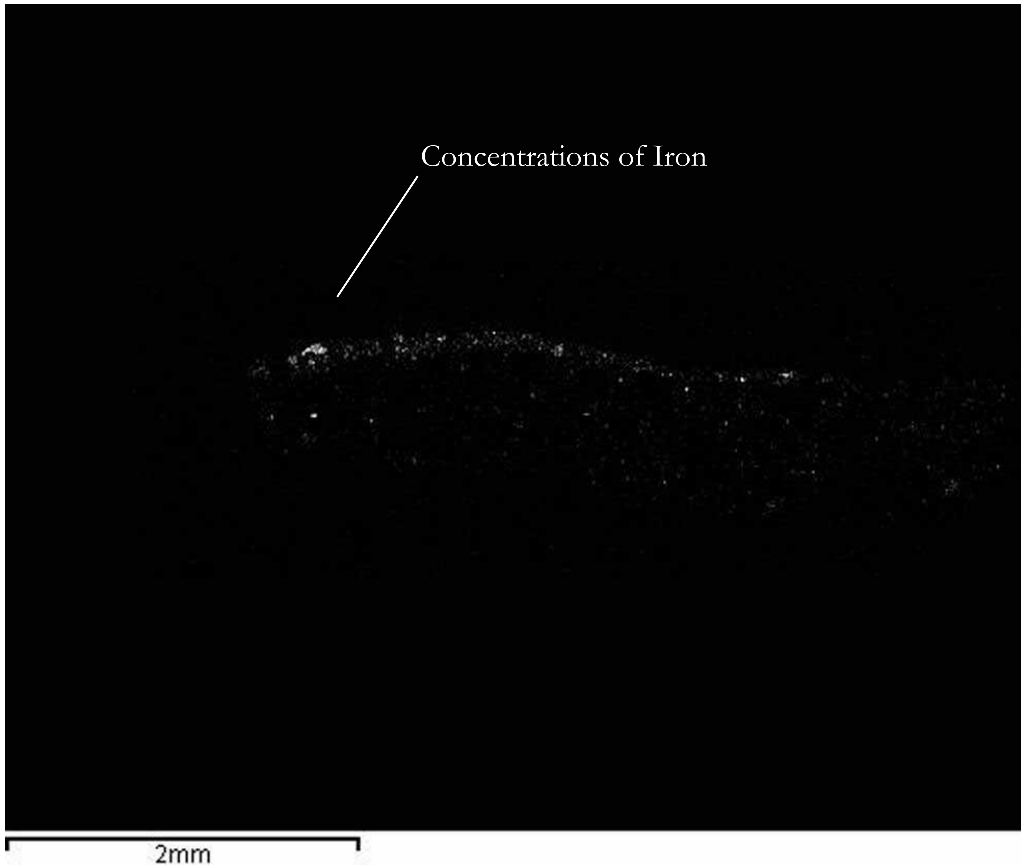


Figure 6.12. Elemental dot map of sample M11 at 20x magnification. A small concentration of iron was detected in the blue-green wash layer at the top of the sample.

6.2.2 Salts [91]

Calcium carbonate, an intrinsic constituent of the sandstone at Mesa Verde, occurs as a virtually insoluble compound from the carbonation of lime. Chlorides often derive from deposition of sea water or as resultant residual impurities in a material, particularly sand, most likely occurring at Long House from the marine alluvial sediment of the

[91] Information on the derivation of salts is synopsized from the *Laboratory Manual for Architectural Conservators*, Teutonico 58-62.

sandstone alcove. Nitrites, which oxidize into nitrates, generally originate from the decomposition of organic material, such as fecal matter or burial grounds in the case of archaeological sites. Phosphate salts, of phosphoric acid, are generally insoluble when in contact with water and are particularly indicative of areas of former occupation when present in soils at archaeological sites.[92] Origins of sulfates, most commonly manifest as hydrated calcium sulfate (or gypsum $CaSO_4 \cdot 2H_2O$) or magnesium sulfate ($MgSO_4$), may include infiltration from incidence in agricultural soils, occurrence from the presence of marine environments, metabolized sulfur by microorganisms, and most often by atmospheric pollution. Anhydrite, a typically colorless mineral of calcium sulfate ($CaSO_4$) is present at Mesa Verde and has been found in the finishes at other analyzed sites.

Results between reagent testing and ion test strip analysis differed, particularly in the case of nitrates and sulfates, and were not conducted concurrently. Controls for nitrites and nitrates failed to react with reagents in multiple tests. Repeat testing may produce confirmatory results and analysis with chemical reagents and ionic test strips should be conducted simultaneously.

6.3 Conclusions

The architectural surface finishes in Kiva E at Long House represent a unique and significant cultural resource, a pivotal example of and testament to the height of design

[92] Odegaard 188.

development of Classic Puebloan mural painting. Evaluation and comparative analysis of the plasters and schemes have provided further insight into the iconography and practices of the ancestral Puebloan peoples as well as verified the significance of the applied designs in Kiva E. Chronicling the evolution of this important and representative kiva was an opportunity to document, study and add to the growing database of architectural surface finishes at Mesa Verde and the region in general. Compiling a record of Kiva E and its series of surface finishes, subject to treatment for over thirteen years prior, this thesis sought to build upon previous studies and contribute to the knowledge on the use and constituents of earthen architectural surface finishes, providing additional information from which future collaborative research and interpretation may continue while encouraging the management of this and other important spaces at Mesa Verde National Park.

APPENDIX A:

Excavation and Stabilization Photographs

Figure A.1. Early photograph of Long House (attributed to Wetherill and Nordenskiold 1891).

Figure A.2. General view of Long House looking west (Neg No. 0719, no date).

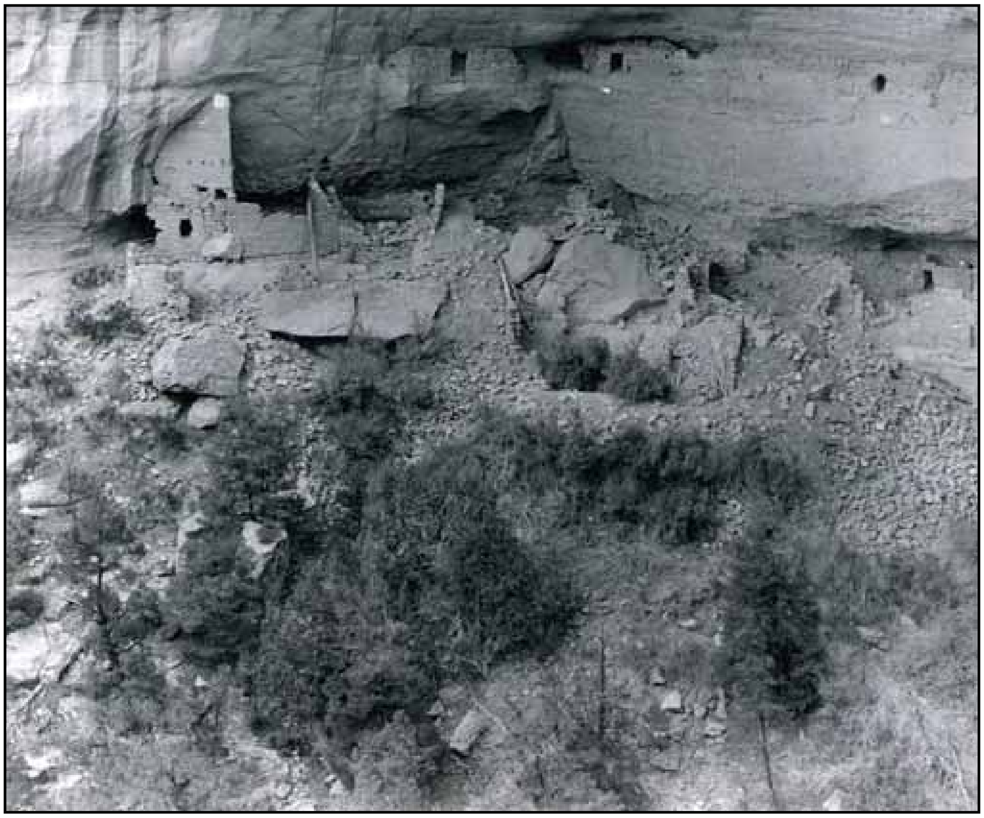


Figure A.3. Image of Long House from across the canyon before excavation during the Wetherill Mesa Project (Cattanach 11/06/1958).

Figure A.4. View of the central and west portions of Long House before excavation (Nichols 09/10/1959).

Figure A.5. General view of Long House looking west (Werner 07/02/1959).

Figure A.6. Northeast wall and Pilaster 4 before excavation/stabilization (date unknown).

Figure A.7. Northeast wall and Pilaster 4 after stabilization (1959).

Figure A.8. Kiva E south and west walls before excavation (presumably 1959).

Figure A.9. View of Kiva E from above after stabilization and reconstruction (Wood 06/13/1960).

Figure A.10. Wall reconstruction between Kivas E and F (Werner 7/23/1959).

Figure A.11. Kiva E south exterior wall before excavation/stabilization (Werner 6/12/1959).

Figure A.12. Kiva E south exterior wall after stabilization/reconstruction) Hannah 08/11/1961).

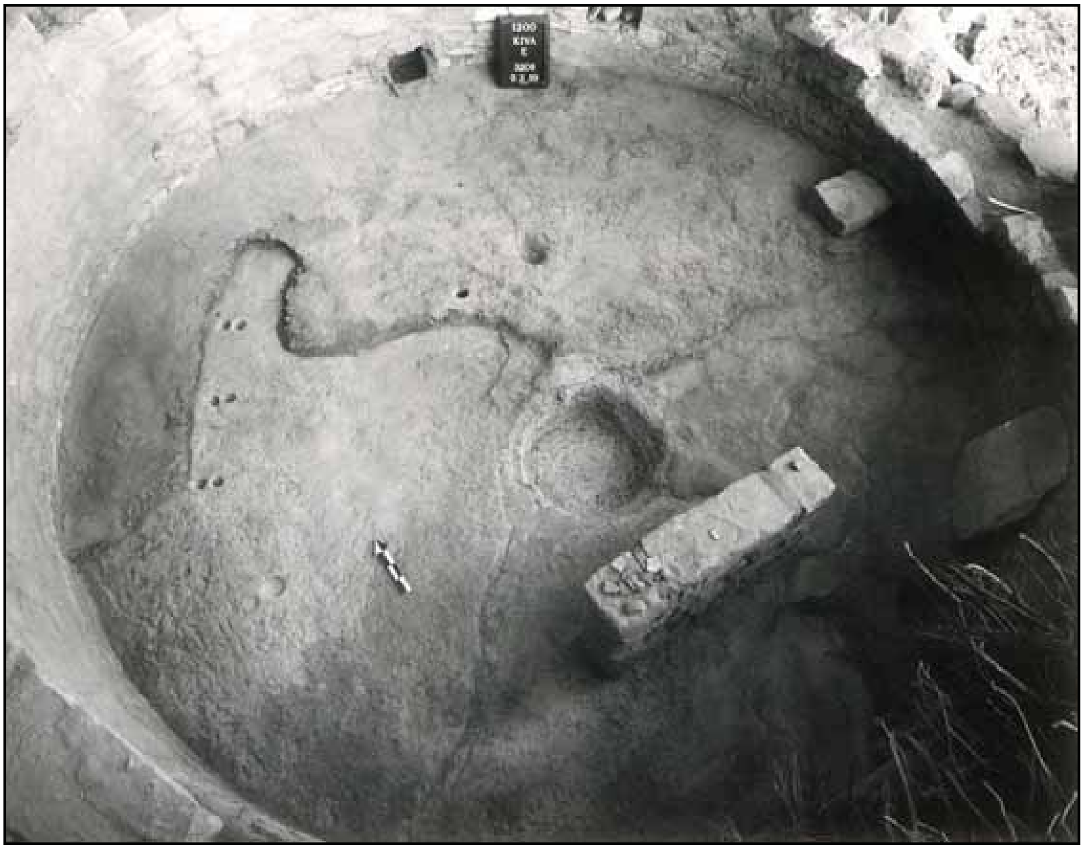


Figure A.13. Kiva E floor after excavation/stabilization (Nichols 09/03/1959).

Figure A.14. Loom holes in the bedrock floor along the northwest wall of Kiva E (Nichols 09/03/1959).

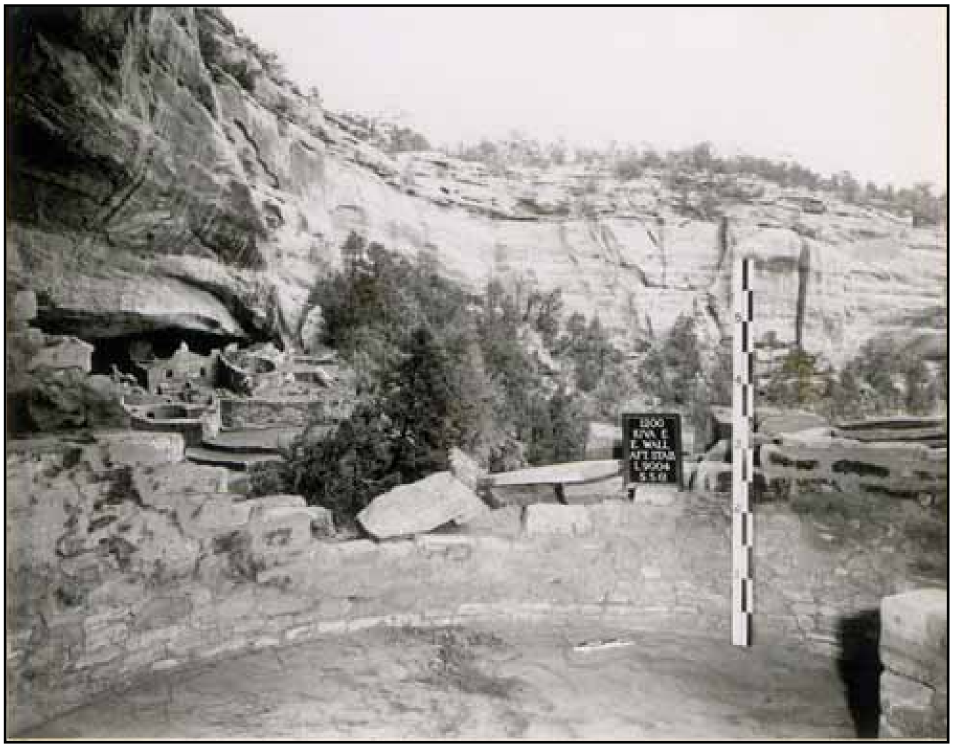


Figure A.15. Southeast wall after stabilization (Hannah 05/05/1961).

Figure A.16. Kiva E south interior wall after stabilization (Wolfman 05/04/1961).

Figure A.17. West wall, abutting the alcove, after reconstruction (Wolfman 5/04/1961).

Figure A.18. North wall after recontruction (Hannah 05/05/1961).

Figure A.19. Exposed embellishment after removal of subsequent surface finishes (Hannah 07/11/1961).

Figure A.20. Condition of the embellishment along the east wall of the banquette (Begay 05/24/1988).

Figure A.21. Detail of a fragment of the red dado over white ground with suggestions of blue-green linear designs, these plaster elements are no longer present (Fiero 7/14/1999).

Figure A.22. Japanese facing paper in place as an emergency plaster conservation treatment (Fiero 11/04/1994).

Figure A.23. Reattachment by injection, Angelyn Bass Rivera (Fiero 7/17/1999).

APPENDIX B:

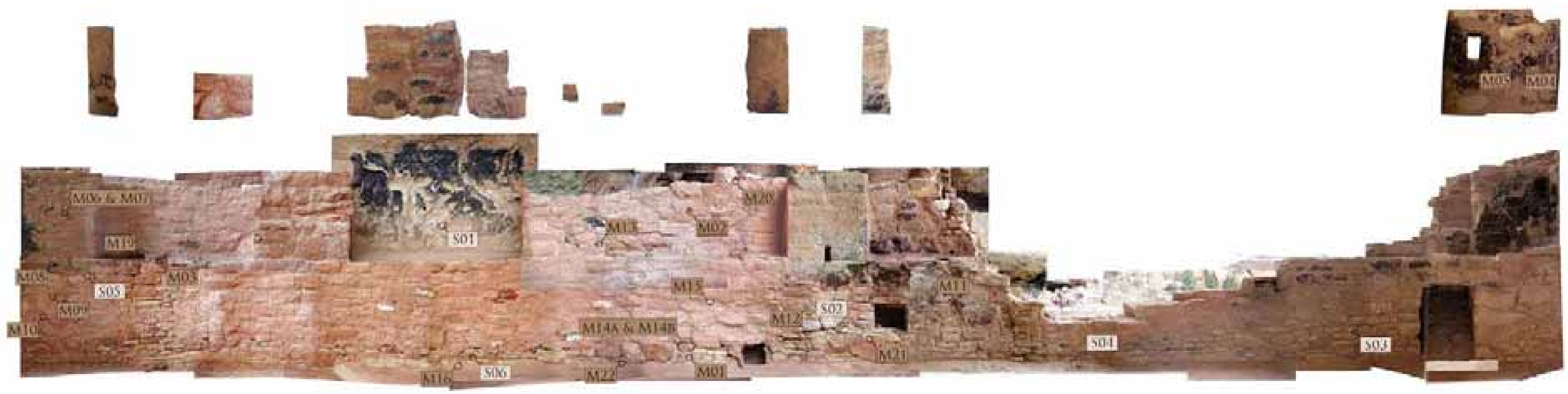
Sample Schedule, Sample Map, Table of Conjectural Schemes and Slide Stratigraphy Forms

Kiva E: Master Sample Schedule Long House, 5MV1200 Mesa Verde National Park, Colorado August 2006				
Mortars, Plasters and Finishes				
Sample	**Description**	**Testing**	**Analytical Techniques**	**Consolidant**
M01	Lower Banquette niche mortar (Condition Sheet 11)	yes	Thin Section	10% B67 w/v in toluene
M02	Original bedding mortar, Inter pilaster space III	yes	Thin Section	10% B67 w/v in toluene
M03	Banquette shelf between pilasters I and II, original shelf plaster	yes	Thin Section	10% B67 w/v in toluene
M04	South Recess, west face of recess/pilaster I, original plaster (fallen)			
M05	Southern recess, west wall, center, full finish and plaster	yes	Cross Section	preconsolidated with methyl ethyl keytone catalyst prior to embedding
M06	Pilaster I, mid-face, white wash over sooted plaster	yes	Cross Section and SEM/EDS	preconsolidated with methyl ethyl keytone catalyst prior to embedding
M07	Pilaster I, mid-face, red embellishment and general background	yes	Cross Section	sample of general background preconsolidated with methyl ethyl keytone catalyst prior to embedding
M08	Banquette face immediately below Pilaster I, top course, full scheme	yes	Cross Section	10% B67 w/v in toluene
M09	Banquette face, mid, below Pilaster I, field	yes	Thin Section, Cross Section and SEM/EDS	preconsolidated with methyl ethyl keytone catalyst prior to embedding due to material loss in early sample prep
M10	Banquette face, lower, below Pilaster I, red dado	yes	Cross Section and SEM/EDS	
M11	Design to the right of Pilaster IV, on upper banquette, all colors	yes	Cross Section, SEM/EDS, FTIR on blue-green pigment, pigment dispersions and chemical spot-testing	

M12 (a)	Repair, 1935, Lancaster (in bag)			
M12 (b)	Repair, 1935, Lancaster (in box)			
M13	Cattanach repair, 1959-61, soil cement(?), deep pointing over grey Portland cement bedding mortar			
M14 (a)	(Sheet 11), repair and original mortar over original infilled niche, lower banquette between Pilasters III and IV			
M14 (b)	(Sheet 11), niche infill, NW, coal and sand			
M15	Mid banquette, NW, 1951 Lancaster repair, clay joint pointing over grey cement bedding mortar of re-laid stones			
M16	Floor sample along NW wall, original plaster	yes	Thin Section	10% B67 w/v in toluene
M17	Deflector, north face lintel, original plaster			
M18	Deflector, back right corner of niche, original plaster			
M19	Shelf plaster between Pilasters I and II			
M20	Upper wall, between Pilasters III and IV, mortar			
M21	Lower wall under niche, red dado layer (sheet 14)	yes	Cross Section and pigment dispersion	
M22	Lower banquette base, fallen			

Salts			
Sample	**Description**	**Testing**	**Analytical Techniques**
S01	Salts in stone, IPS II, lower middle	yes	Reagent testing and semi-qualitative analysis
S02	Salts in stone, under Pilaster IV, middle		
S03	Salts in mortar, lower south banquette	yes	Reagent testing and semi-qualitative analysis
S04	Salts in stone, lower south banquette		
S05	Salts in stone, southwest banquette, below Pilaster I	yes	Reagent testing and semi-qualitative analysis
S06	Salts in stone, banquette, below IPS II	yes	Reagent testing and semi-qualitative analysis

Map of Sample Locations
Kiva E, Long House, Mesa Verde National Park, Colorado

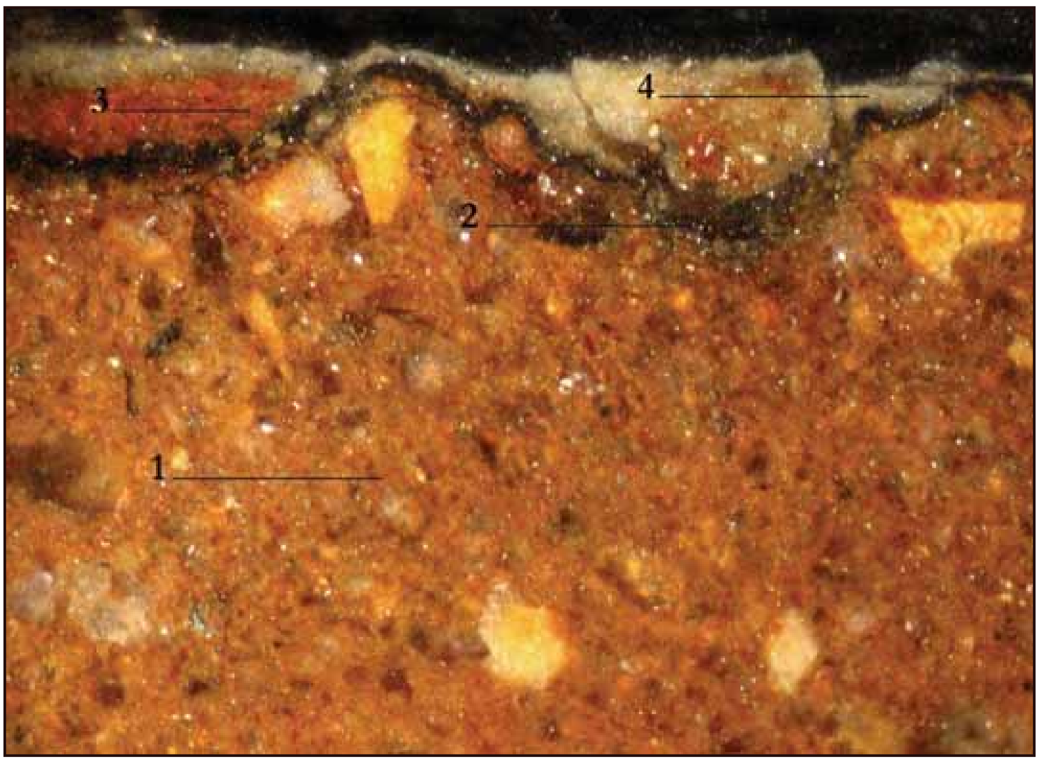


M05-Southern Recess	M06 (a)-Pilaster 1	M06 (b)-Pilaster 1	M07-Pilaster 1	M08 (a)-Banquette
red-brown prep layer		red-brown prep layer	red-brown prep layer	
med/light soot		light soot	light soot	
red	red-brown	red-brown	red-brown	red-brown (a)
white-very thin	**soot**	**soot-**sooted	**soot-**sooted	**soot**-finish coat (a/b)
soot				
white	white/brown (a)	white (with some brown inclusions)	white w/ frag red	
reddish				
thick soot	**soot**-heavy	**soot-**lighter	trace soot	
light brown	light brown	white		
thick uneven soot				
thin brown-red wash				

M08 (b)-Banquette	M09-Banquette	M10-Banquette	M11-Banquette	M21-Banquette
	red-brown prep layer	red-brown prep layer		
	light soot			
	reddish	reddish		
soot-finish coat (a/b)	soot	light soot (EDS)		
white/brown (b)	white	white		white
	red--dado	red--dado		red--dado
soot-finish coat (b)				trace soot
light brown (b)			red and blue over white (embellishment)	
bright white (b)		red dado		red dado
		thin brown-red wash	trace brown-red wash	

SCHEMES
Scheme 1
Scheme 2
Scheme 3
Scheme 4
Scheme 5
Scheme 6

Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M05 (a)	
Sample Location: Southern Recess, west wall	
Date Sampled: August 2006	
Date of Analysis: April 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 40x	
Type of Illumination: Reflected	
Mircoscope: Nikon Alphaphot-2 YS2	
Photomicrograph: Cannon PowerShot S400 Digital Elph	



Support: Stone and Mortar				
Layer	Color	Thickness		Scheme
1	pink-tan	+++	plaster/substrate	Scheme 1
2	pink-tan	++//	plaster	Scheme 1
3	red-brown	- - ^	wash	possible leveling coat or embellishment?
4	white	- - - ^	wash	Scheme 2

KEY: + thick layer - thin layer / soot or soiling ^ fracture

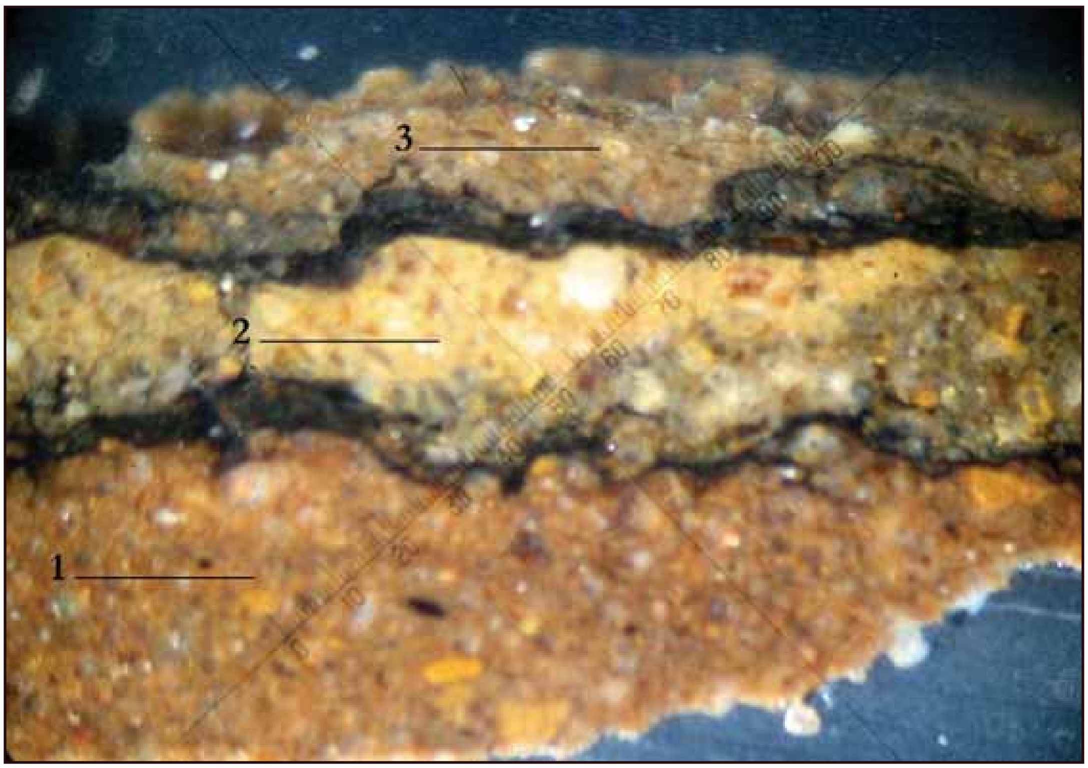
Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M05 (b)	
Sample Location: Southern Recess, west wall	
Date Sampled: August 2006	
Date of Analysis: April 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 100x	
Type of Illumination: Reflected	
Mircoscope: Leica MZ16	
Photomicrograph: Cannon PowerShot S400 Digital Elph	

No Image Available

Support: Stone and Mortar				
Layer	Color	Thickness		Scheme
1	red-brown	+++ //	plaster/substrate	Scheme 1
2	red	- - ^ ^	indeterminate	indeterminate; possible leveling coat or embellishment
3	white	- - - ^	wash	Scheme 2
4	black	++++	soot	Scheme 3
5	white	- - - -	indeterminate	indeterminate; very thin, may not actually be a layer
6	red-brown	+	plaster	Scheme 4
7	black	++	soot	Scheme 4
8	brown	+ ///	plaster	Scheme 5
9	light brown	- - - ^	wash	Scheme 6

KEY: + thick layer - thin layer / soot or soiling ^ fracture

Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M06 (a)	
Sample Location: Pilaster 1 mid-face, ground	
Date Sampled: August 2006	
Date of Analysis: March 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 50x	
Type of Illumination: Reflected	
Mircoscope: Nikon Optiphot 2-POL	
Photomicrograph: Cannon PowerShot S400 Digital Elph	



Support: Stone and Mortar				
Layer	Color	Thickness		Scheme
1	pink-tan	++ ^	plaster/substrate	Scheme 1
2	black	-	soot	Scheme 2-3
3	creamy-white	+///	plaster	Scheme 4
4	black	- /	soot	Scheme 4
5	light brown	+ ^	plaster	Scheme 5

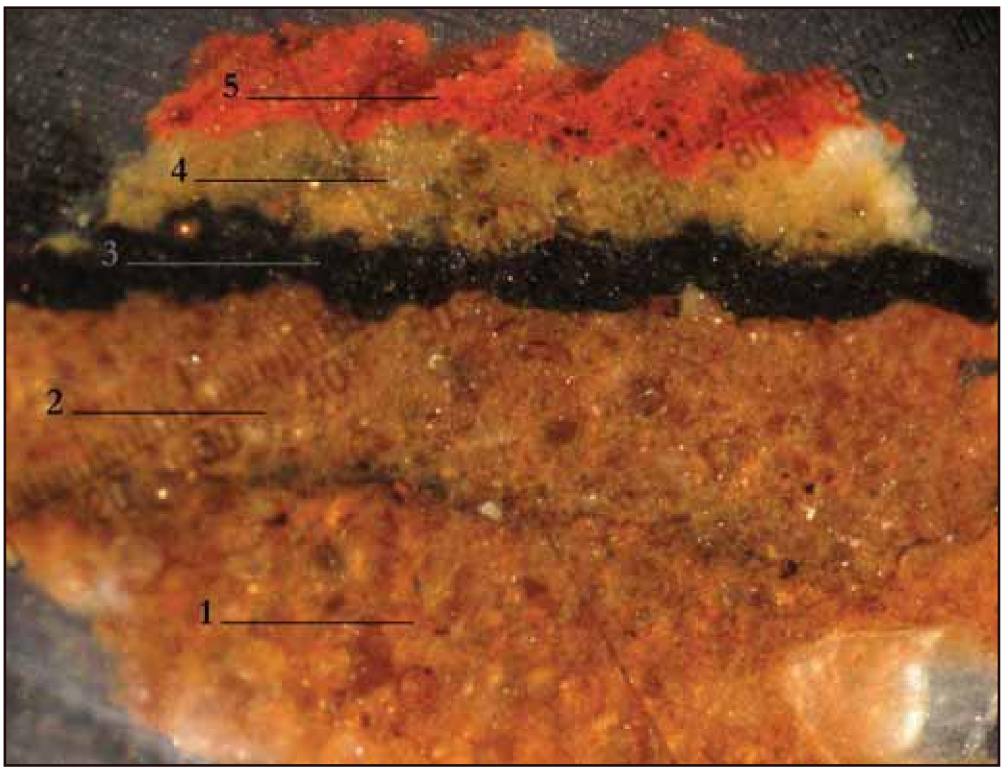
KEY: + thick layer - thin layer / soot or soiling ^ fracture

Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M06 (b)	
Sample Location: Pilaster 1 mid-face, fragmentary white	
Date Sampled: August 2006	
Date of Analysis: March 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 40x	
Type of Illumination: Reflected	
Mircoscope: Nikon Alphaphot-2 YS2	
Photomicrograph: Cannon PowerShot S400 Digital Elph	

Support: Stone and Mortar				
Layer	Color	Thickness		Scheme
1	pink-tan	++ /	plaster substrate	Scheme 1
2	pink-tan	++	plaster	Scheme 1
3	black	-	soot	Scheme 2/3
4	creamy-white	+ /	wash	Scheme 4
5	creamy-white	-	wash	Scheme 5

KEY: + thick layer - thin layer / soot or soiling ^ fracture

Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M07	
Sample Location: Pilaster 1 mid-face, red embellishment	
Date Sampled: August 2006	
Date of Analysis: March 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 50x	
Type of Illumination: Reflected	
Mircoscope: Nikon Optiphot 2-POL	
Photomicrograph: Cannon PowerShot S400 Digital Elph	



Support: Stone and Mortar				
Layer	Color	Thickness		Scheme
1	pink-tan	++ / ^	plaster/substrate	Scheme 1
2	pink-tan	++	plaster	Scheme 1
3	black	+	soot	Scheme 2/3
4	white	+	wash	Scheme 4
5	red	+	wash	Scheme 4

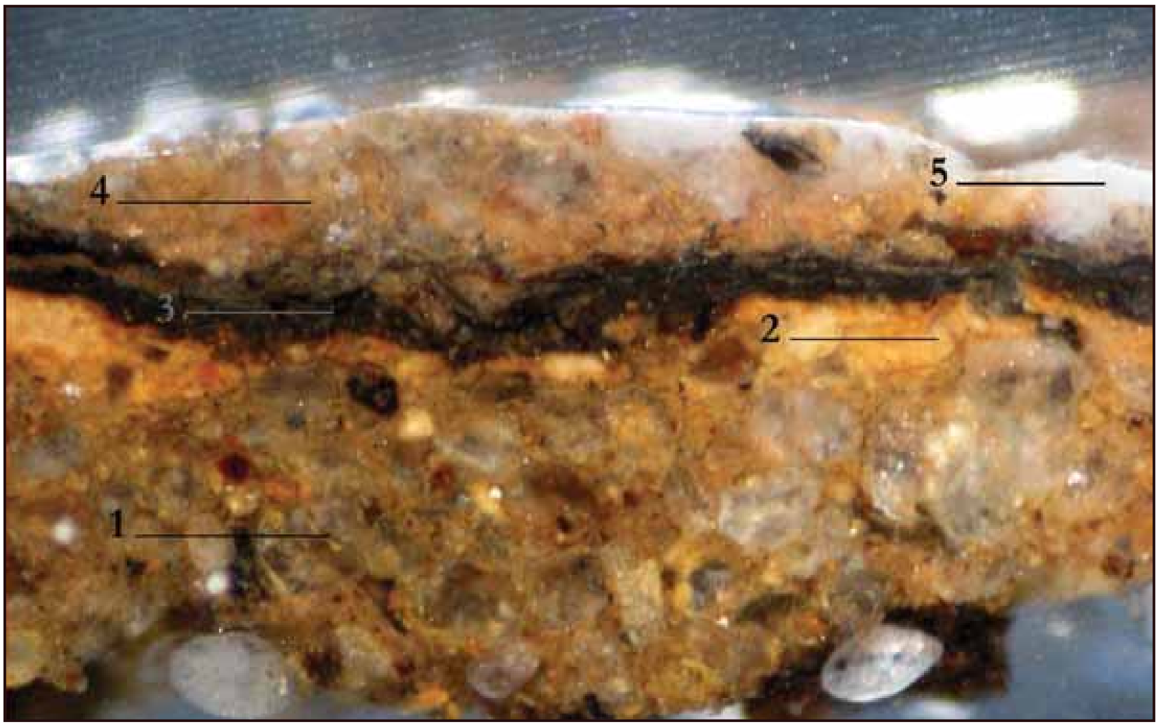
KEY: + thick layer - thin layer / soot or soiling ^ fracture

Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M08 (a)	
Sample Location: Banquette face below Pilaster 1, top course	
Date Sampled: August 2006	
Date of Analysis: March 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 40x	
Type of Illumination: Reflected	
Mircoscope: Nikon Alphaphot-2 YS2	
Photomicrograph: Cannon PowerShot S400 Digital Elph	

Support: Stone and Mortar				
Layer	Color	Thickness		Scheme
1	pink-tan	++	plaster substrate	Scheme 1
2	black	- ^	soot	Scheme 2-3

KEY: + thick layer - thin layer / soot or soiling ^ fracture

Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M08 (b)	
Sample Location: Banquette face below Pilaster 1, top course	
Date Sampled: August 2006	
Date of Analysis: March 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 40x	
Type of Illumination: Reflected	
Mircoscope: Nikon Alphaphot-2 YS2	
Photomicrograph: Cannon PowerShot S400 Digital Elph	

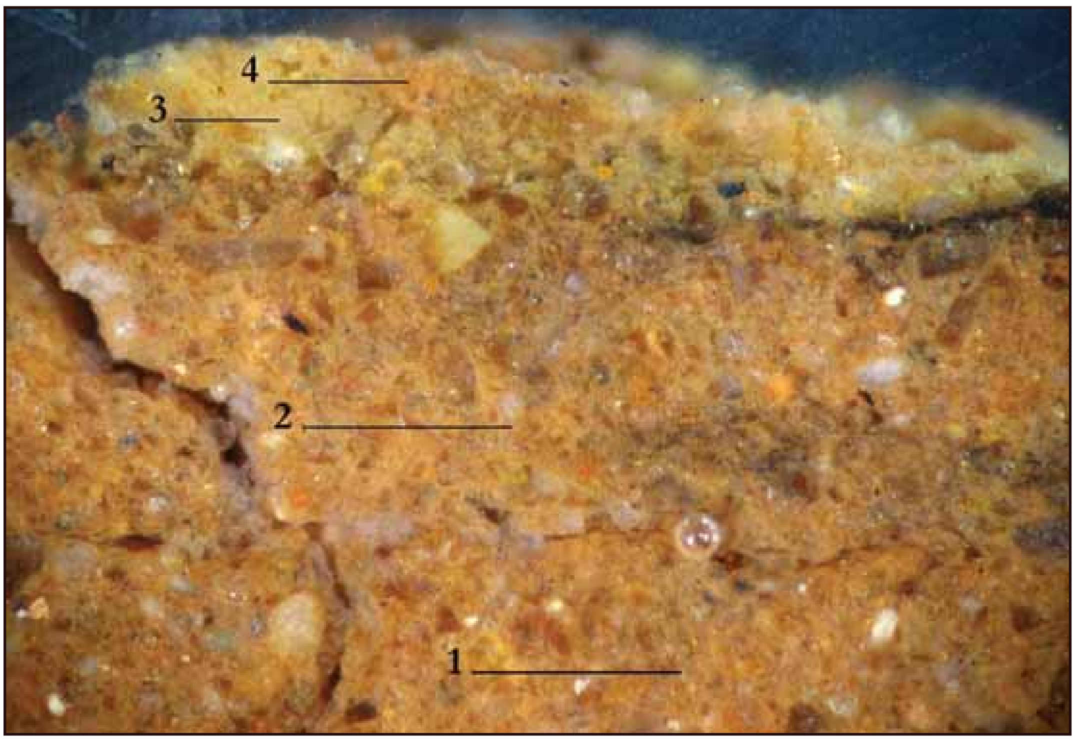


Support: Stone and Mortar

Layer	Color	Thickness		Scheme
Note: Partial layer of soot occurs before layer 1, presumably from sample M08 (a)				
1	light brown	++	plaster	Scheme 4
2	cream-white	- - ^	wash	Scheme 5
3	black	- ^	soot	Scheme 5
4	pink-tan, lt brown	++ ^	plaster	Scheme 6
5	bright white	- - - ^	incomplete	indeterminate; inclusions in layer 4?

KEY: + thick layer - thin layer / soot or soiling ^ fracture

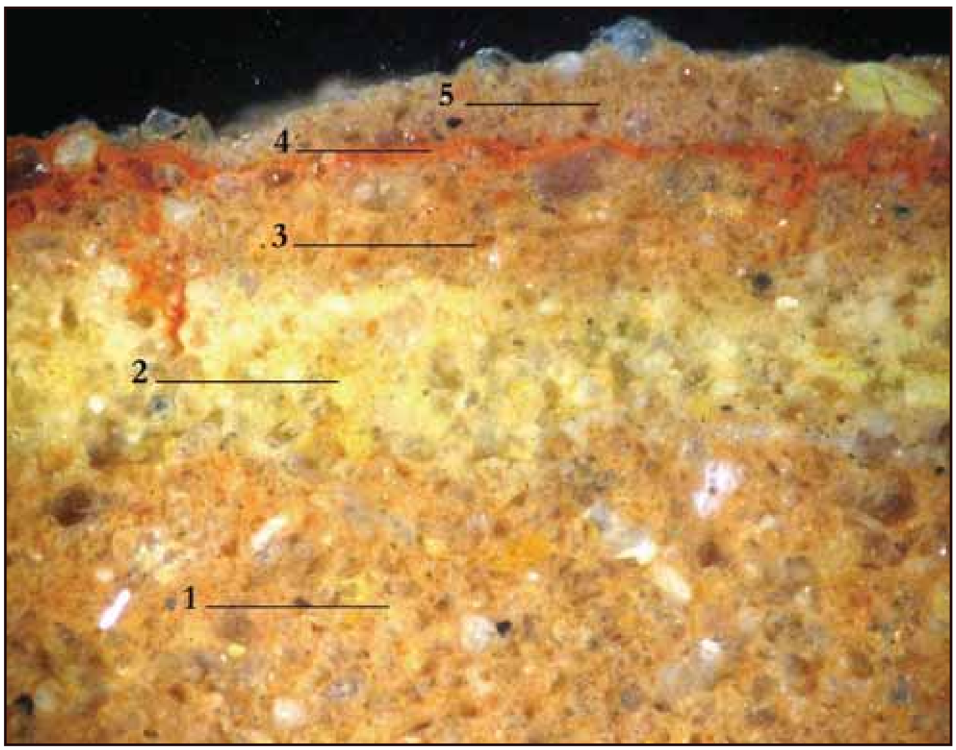
Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M09	
Sample Location: Banquette mid-face, field below Pilaster 1	
Date Sampled: August 2006	
Date of Analysis: March 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 50x	
Type of Illumination: Reflected	
Mircoscope: Nikon Optiphot 2-POL	
Photomicrograph: Cannon PowerShot S400 Digital Elph	



Support: Mortar				
Layer	Color	Thickness		Scheme
1	pink-tan	+++ ^	plaster substrate	Scheme 1-2
2	pink-tan	+/ ^	plaster	Scheme 3
3	creamy-white	- ^	wash	Scheme 4
4	pink-tan	- - ^	wash	Scheme 4
Note: Fracture occurred during cutting of embedded sample				

KEY: + thick layer - thin layer / soot or soiling ^ fracture

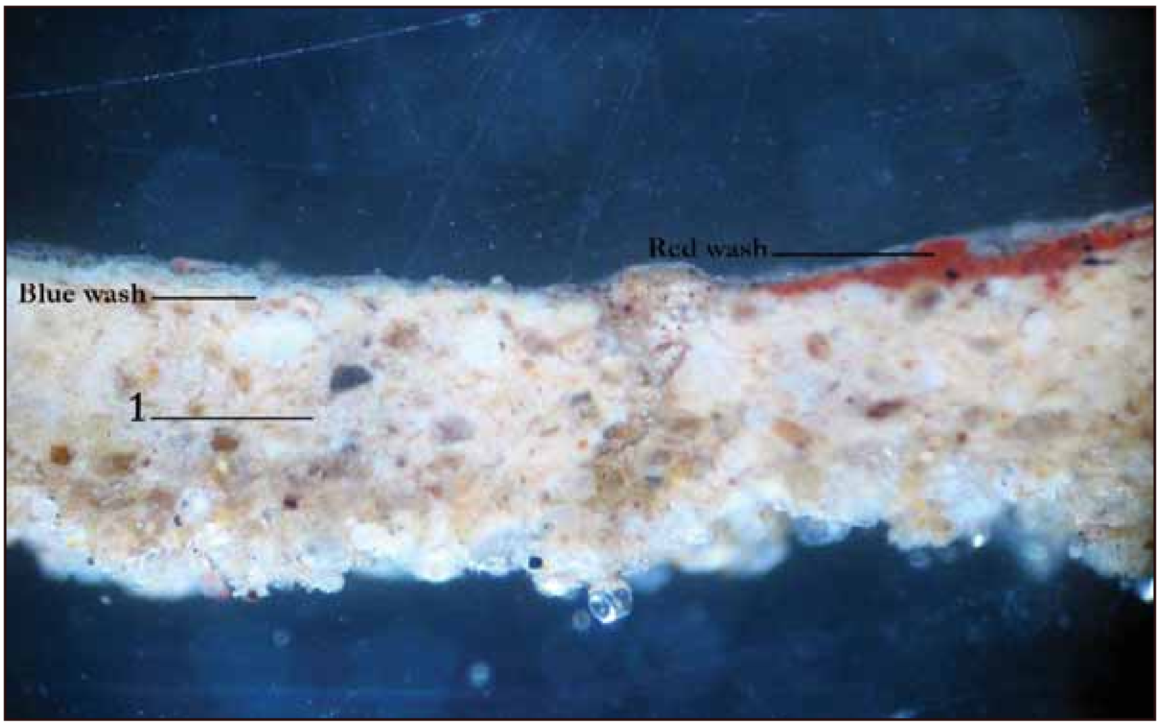
Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M10	
Sample Location: Lower banquette face below Pilaster 1, red dado	
Date Sampled: August 2006	
Date of Analysis: March 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 50x	
Type of Illumination: Reflected	
Mircoscope: Nikon Optiphot 2-POL	
Photomicrograph: Cannon PowerShot S400 Digital Elph	



Support: Mortar				
Layer	Color	Thickness		Scheme
1	pink-tan	+++	plaster substrate	Schemes 1-3
2	creamy-white	++	plaster	Scheme 4
3	pink-tan	+ ^	plaster	Scheme 4
4	bright red	- - -	wash	Scheme 5
5	pink-tan	+ ^	plaster	Scheme 6

KEY: + thick layer - thin layer / soot or soiling ^ fracture

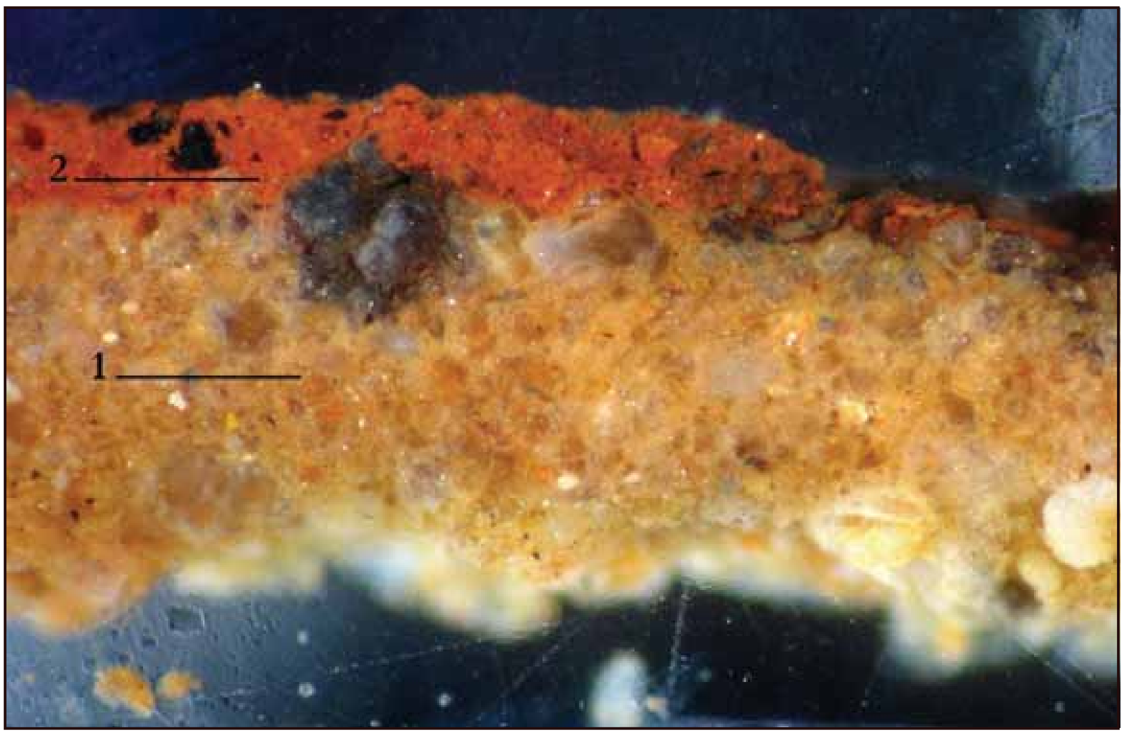
Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**
Sample Number: M11
Sample Location: Design on banquette, south of Pilaster 4
Date Sampled: August 2006
Date of Analysis: March 2007
Analysis completed by: Lauren R. Hall
Magnification: 40x
Type of Illumination: Reflected
Mircoscope: Nikon Alphaphot-2
Photomicrograph: Canon PowerShot S400 Digital Elph



Support: Stone and Mortar				
Layer	Color	Thickness		Scheme
1	white	+ / ^	plaster	Scheme 5
2	blue/red	- /	wash	Scheme 5

KEY: + thick layer - thin layer / soot or soiling ^ fracture

Project Site: **Kiva E, Long House (5MV1200), Mesa Verde National Park**	
Sample Number: M21	
Sample Location: Lower banquette beneath Niche 4	
Date Sampled: August 2006	
Date of Analysis: March 2007	
Analysis completed by: Lauren R. Hall	
Magnification: 100x	
Type of Illumination: Reflected	
Mircoscope: Nikon Optiphot 2-POL	
Photomicrograph: Cannon PowerShot S400 Digital Elph	



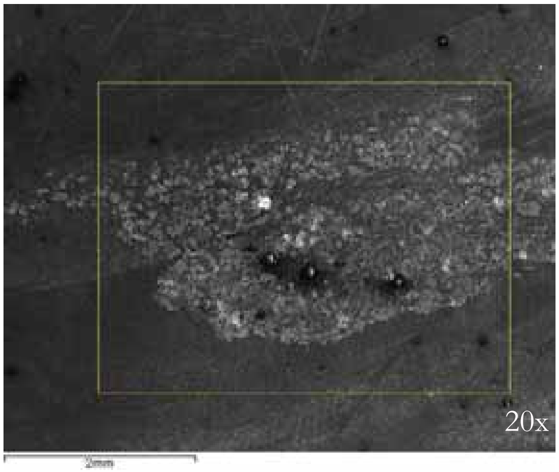
Support: Stone and Mortar				
Layer	Color	Thickness		Scheme
1	cream-buff	- - - ^	partial layer	Scheme 4
2	pink-tan	+/ ^	plaster	Scheme 4
3	bright red	- ^	wash	Scheme 5

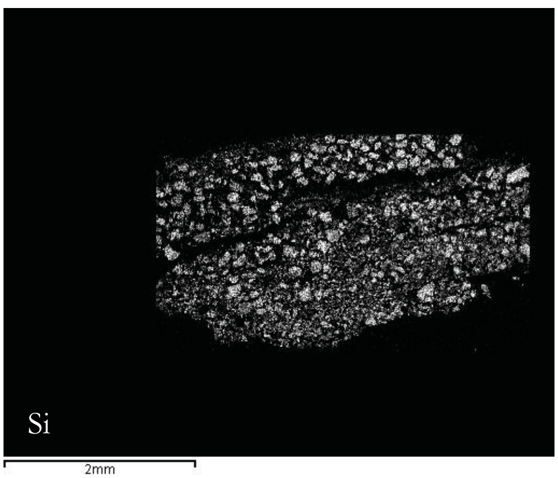
KEY: + thick layer - thin layer / soot or soiling ^ fracture

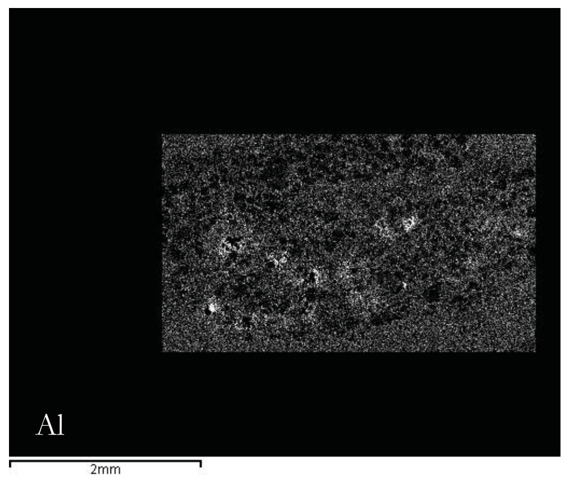
APPENDIX C:

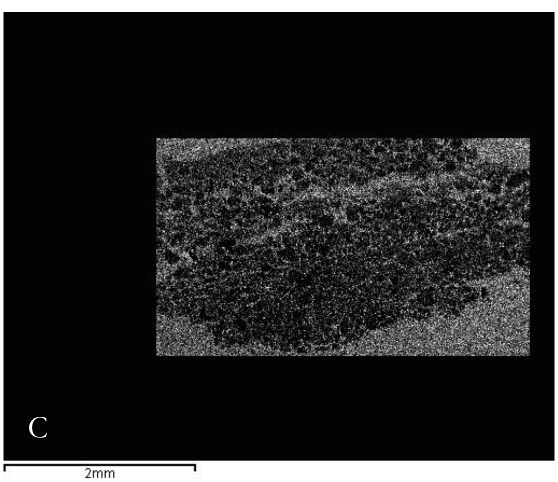
SEM-EDS Dot Maps and Spectra

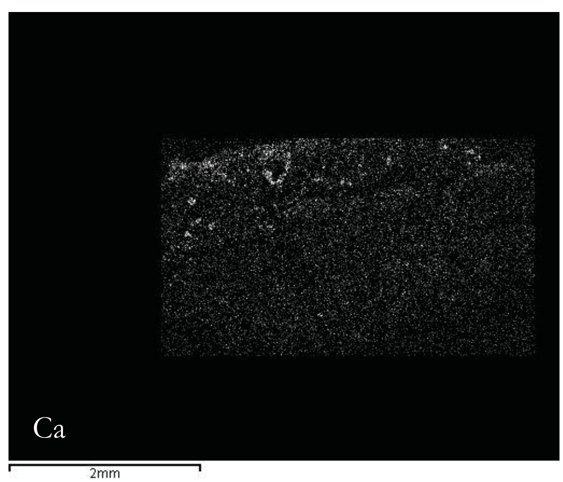
Sample M06



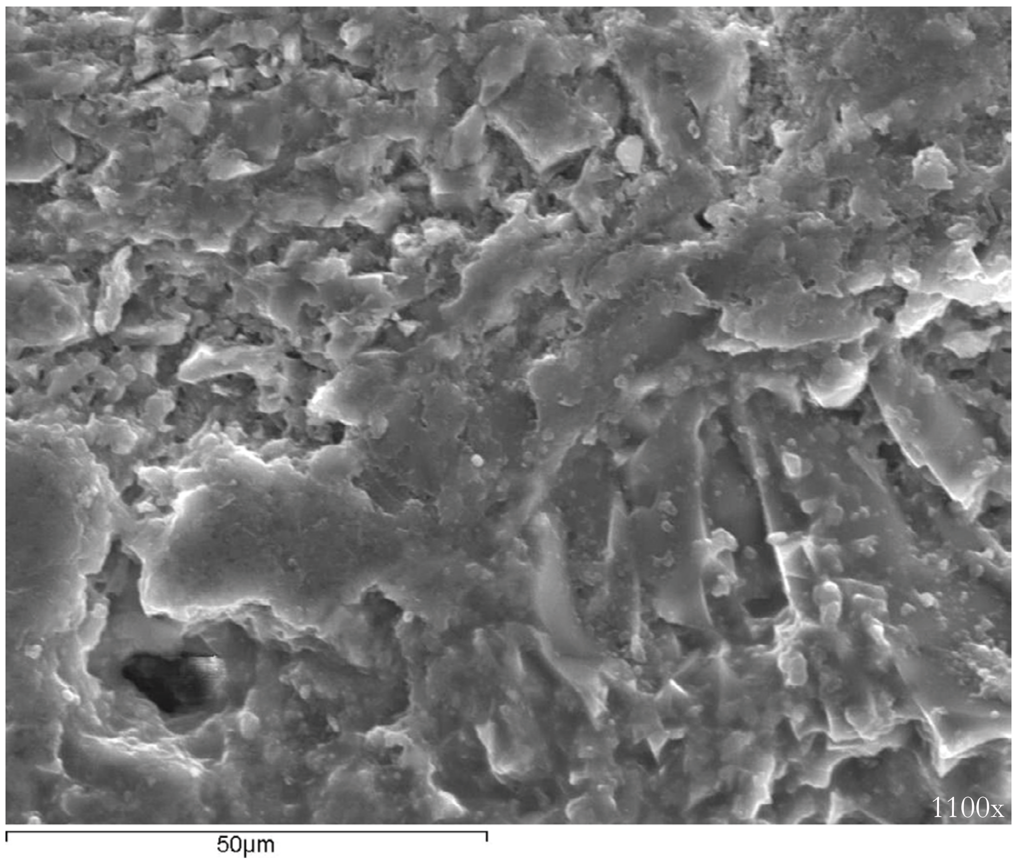


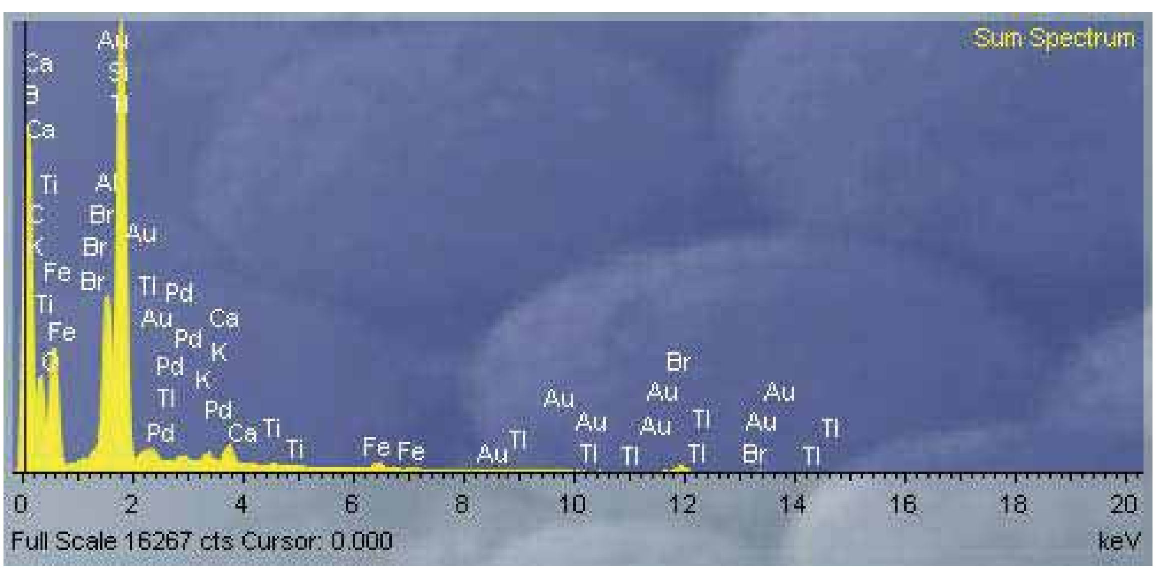




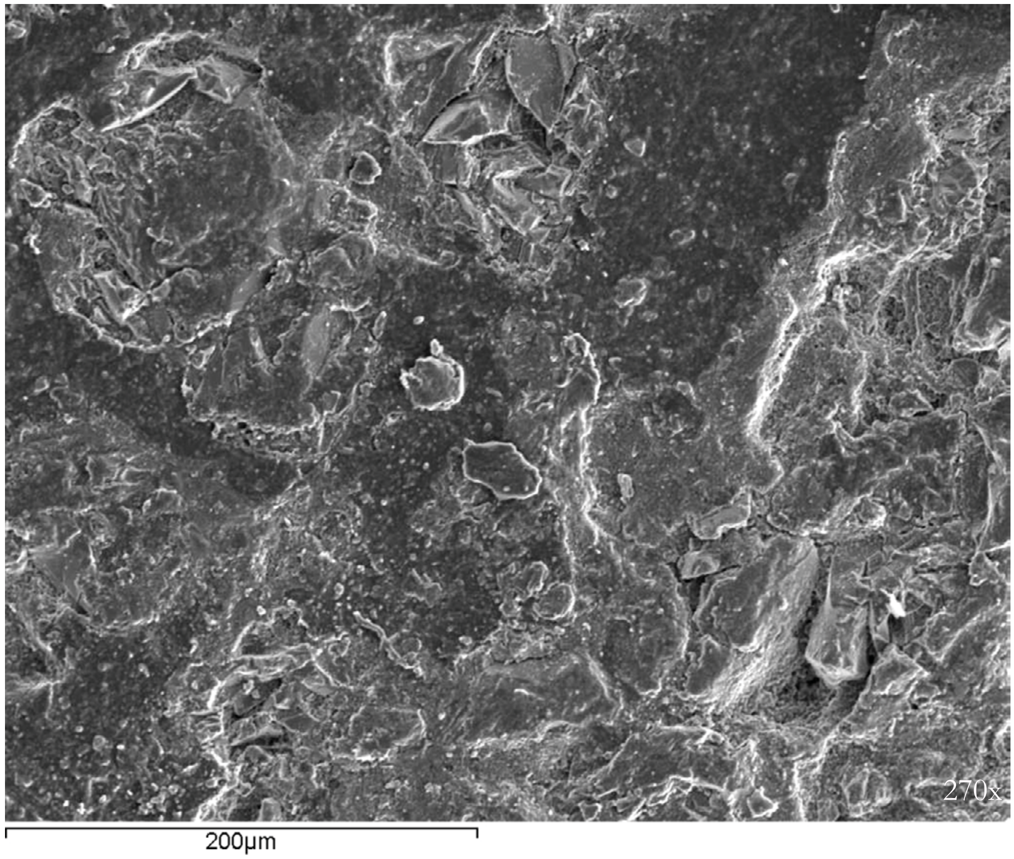


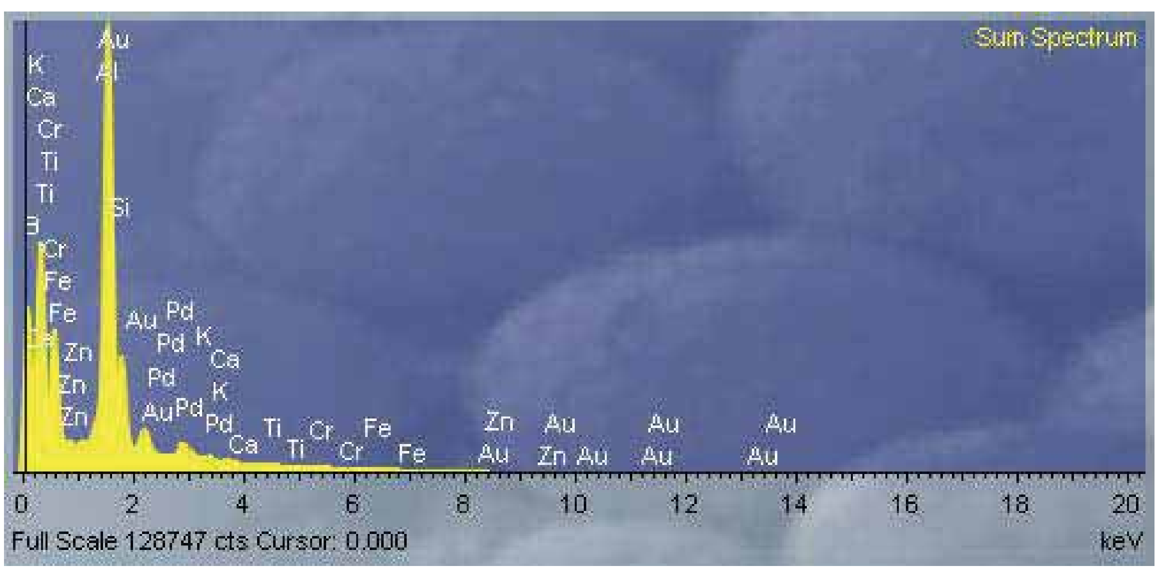
Sample M09 Preparatory Plaster Layer



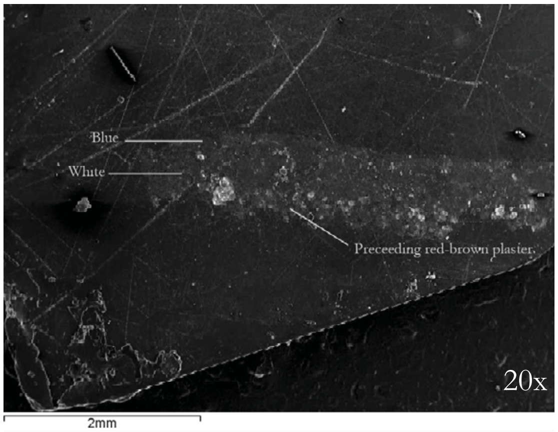


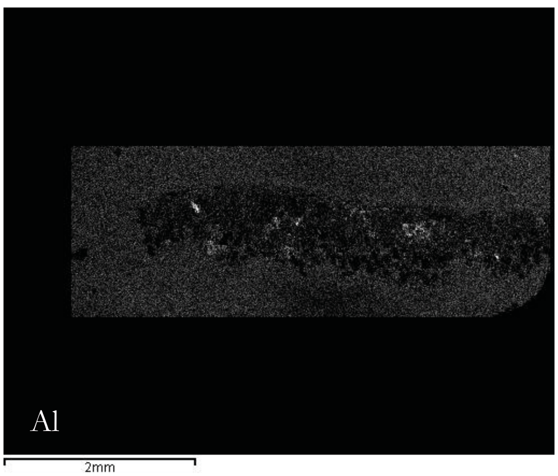
Sample M10 Preparatory Plaster Layer



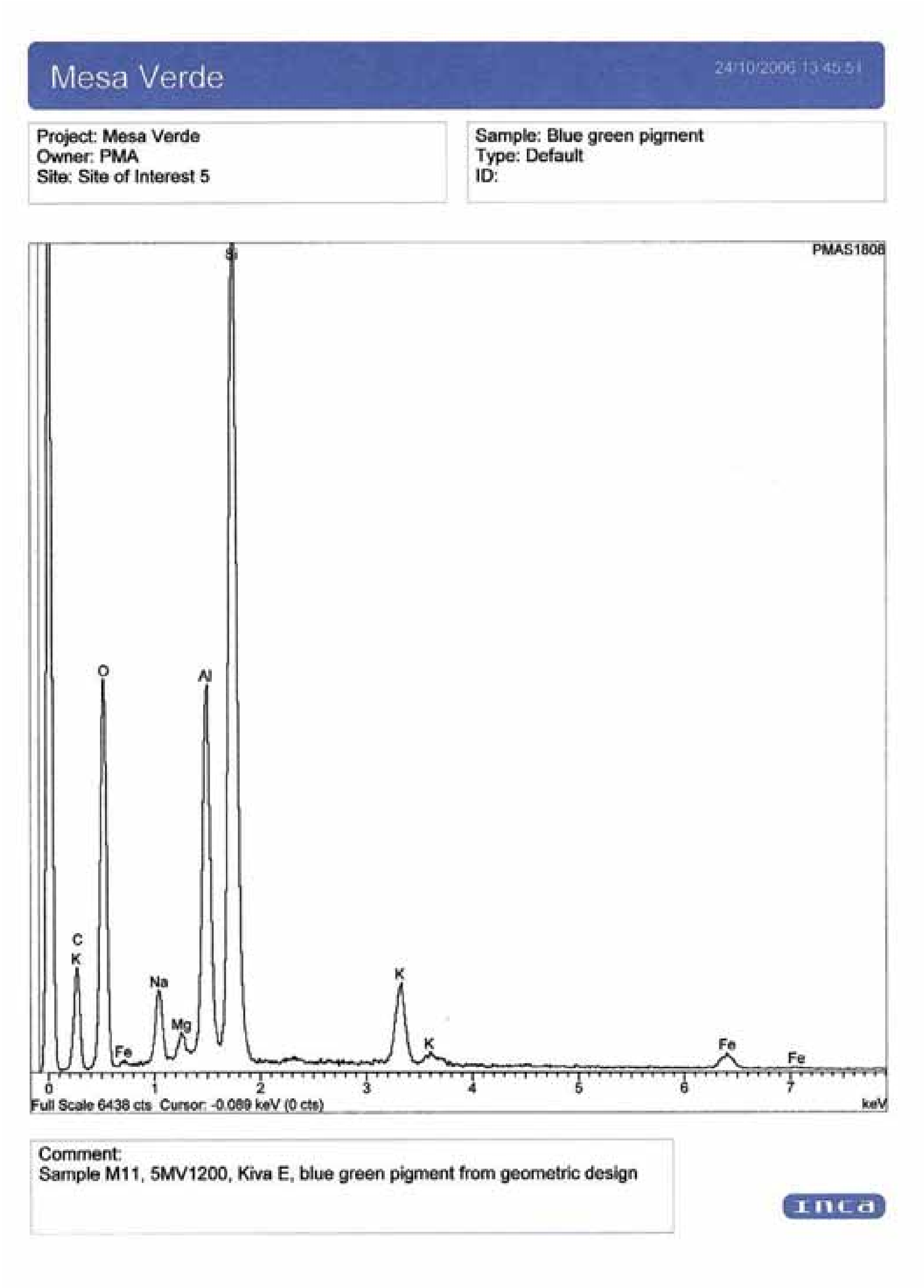


Sample M11 Blue Pigment

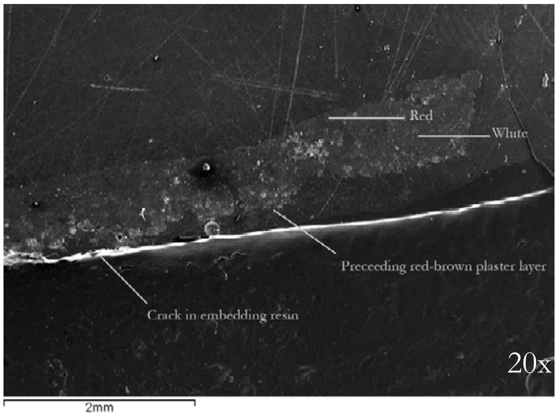


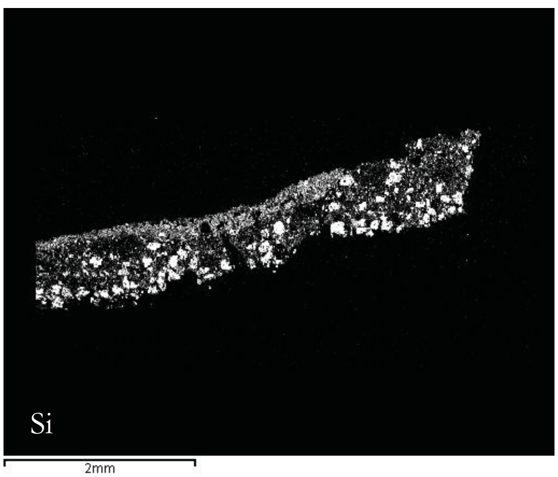


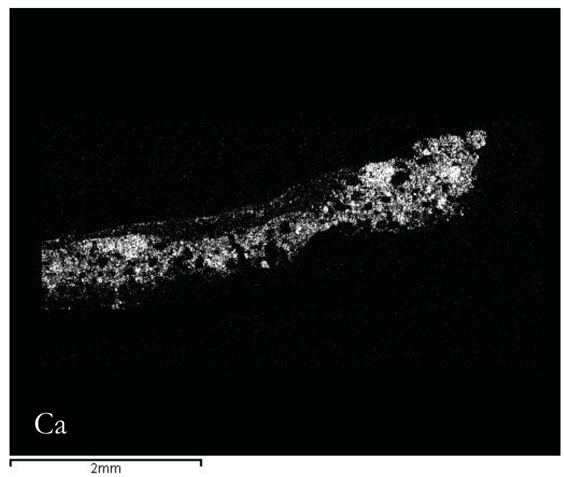
Sample M11 Blue Pigment

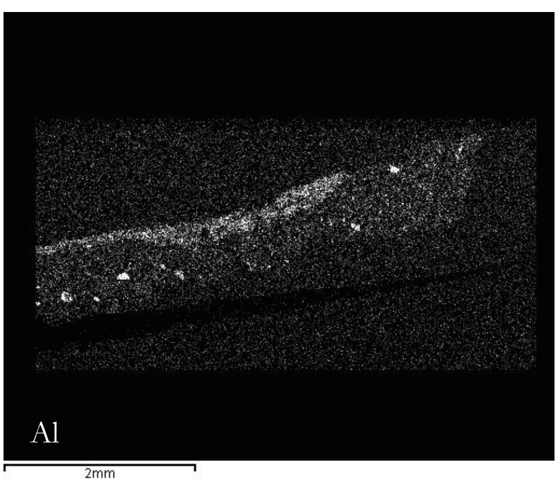


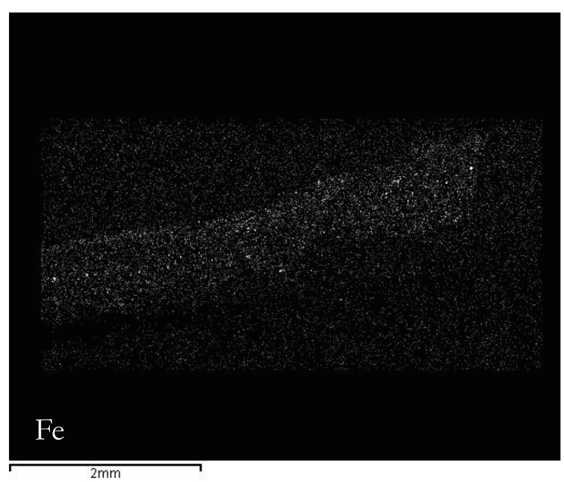
Sample M11 Red Pigment



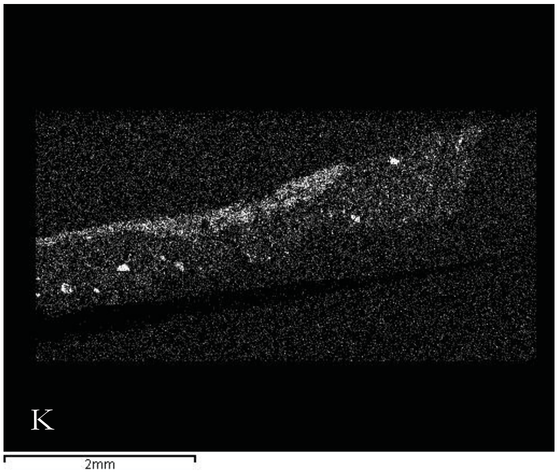


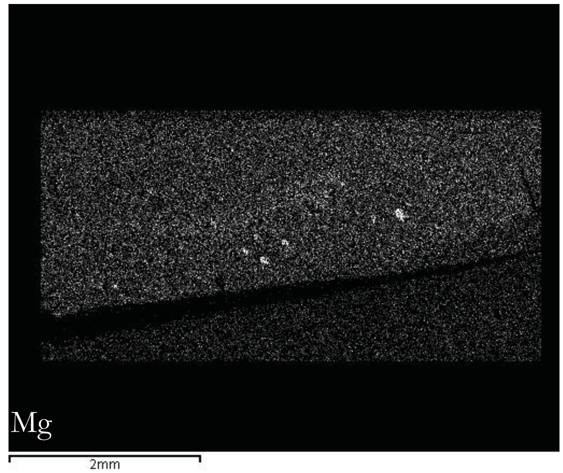


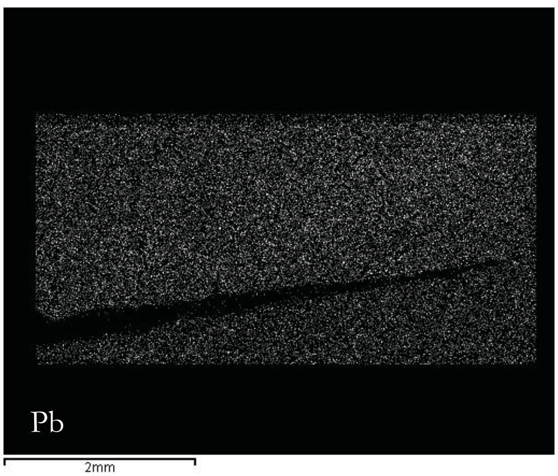


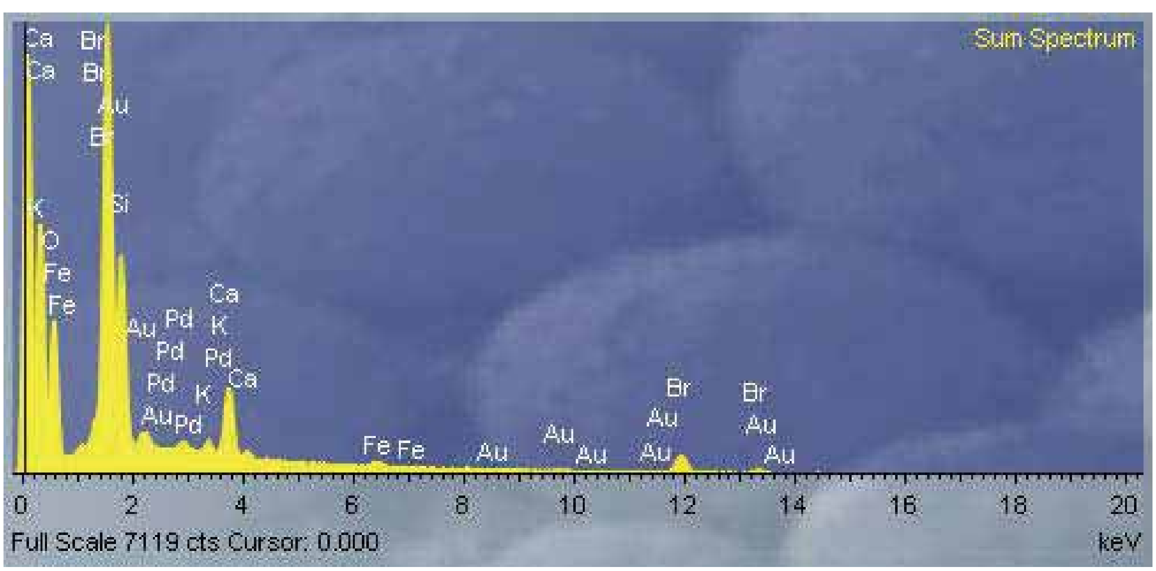


Sample M11 Red Pigment

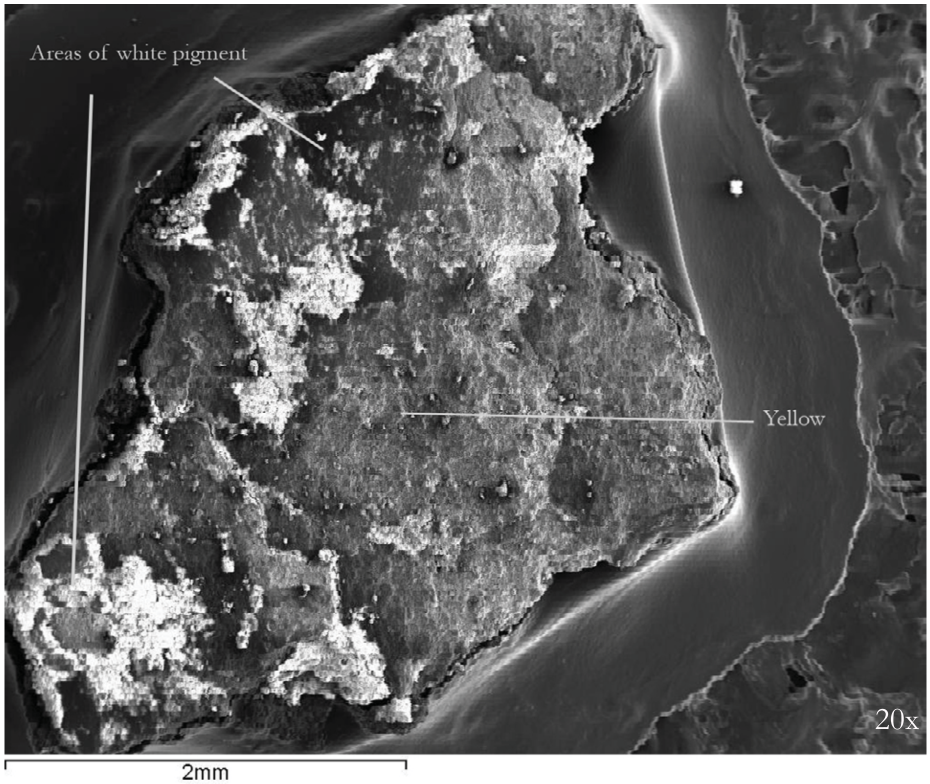


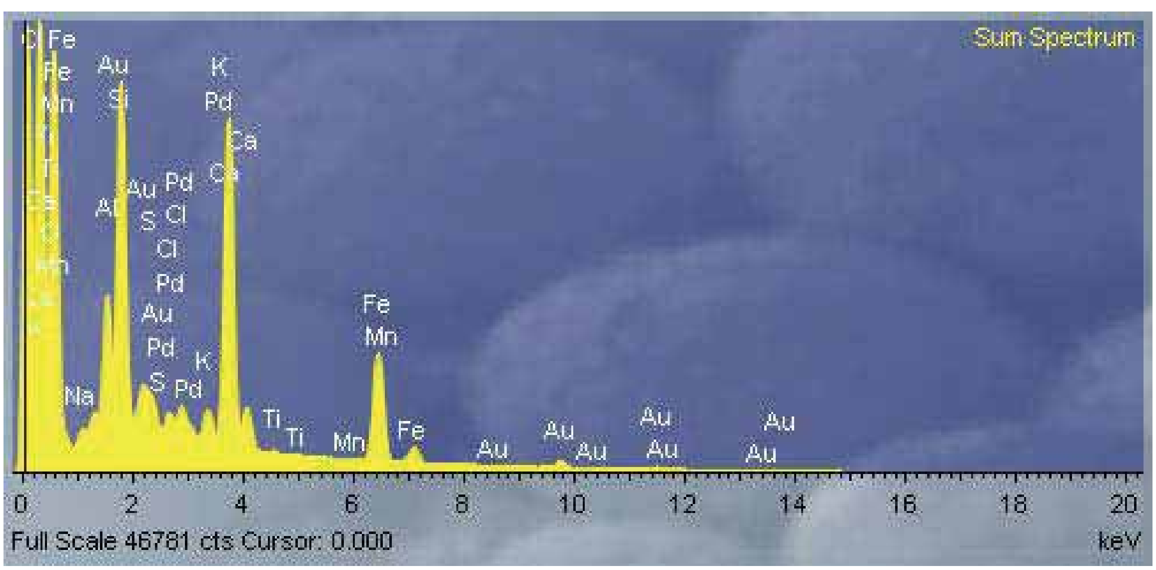




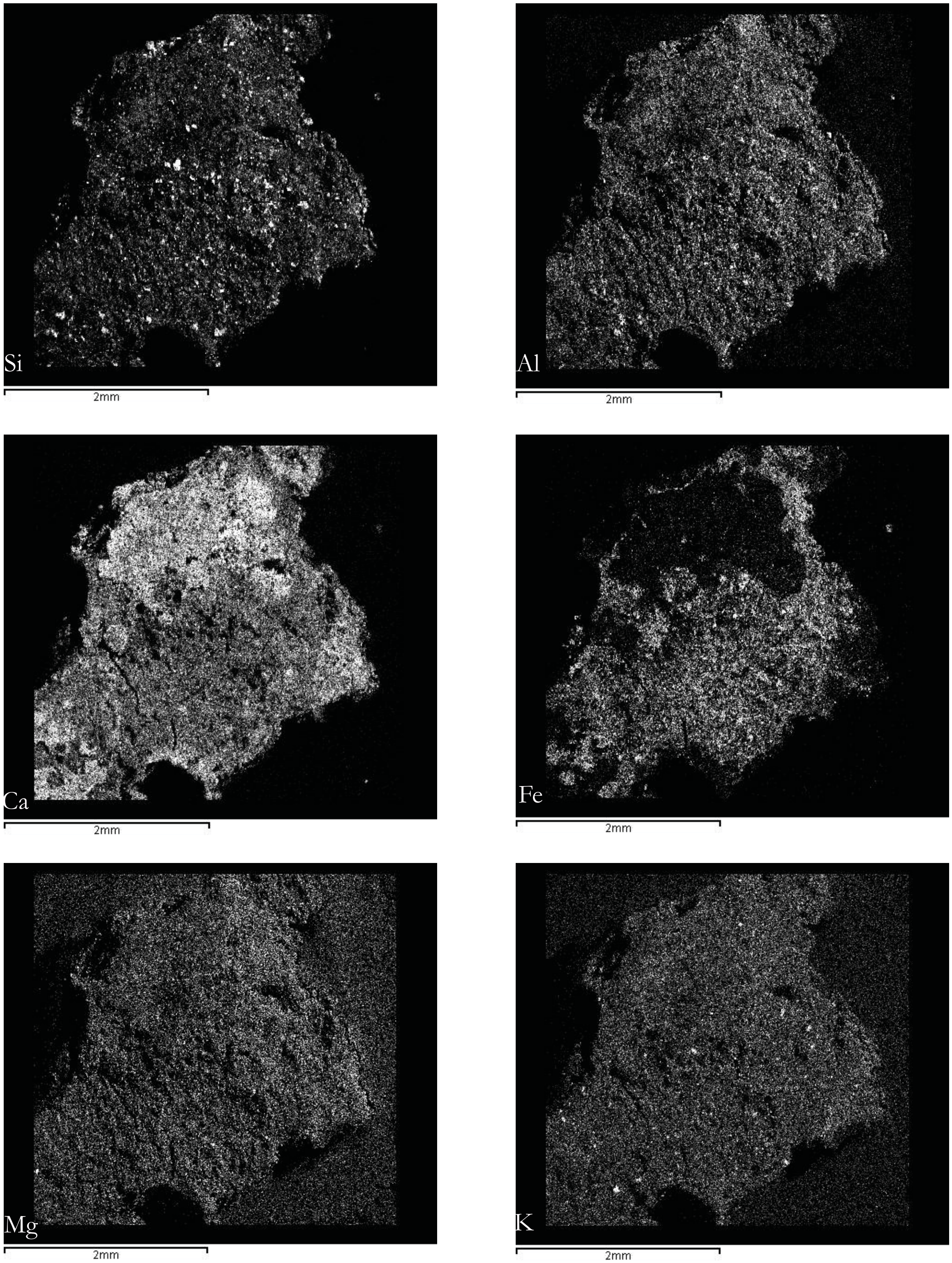


Sample M11 Yellow Pigment





Sample M11 Yellow Pigment



APPENDIX D:

Product Manufacturers and Material Suppliers

APPENDIX D

BUEHLER
41 Waukegan Rd. P.O. Box 1
Lake Bluff, IL 60044-1699
847.295.6500
800.283.4537
http://www.buehler.com
Isomet Low Speed Saw and polishing supplies.

CARGILLE-SACHER LABORATORIES, INC.
55 Commerce Rd.
Cedar Grove, NJ 07009
973.239.6633
http://www.cargille.com/index.shtml
Meltmount used for sample mounting.

FISHER SCIENTIFIC
Liberty Lane
Hampton, NH 03842
800.766.7000
http://www.fishersci.com
Salt testing strips, all reagent chemicals, and other laboratory supplies unless otherwise noted.

TALAS
20 West 20th Street
5th Floor
New York, NY 10011
212.219.0770
http://www.talasonline.com
Acryloid (Paraloid) B67 (Rohm & Haas Company) used as a consolidant.

WARD'S NATURAL SCIENCE
PO Box 92912
Rochester, NY 14692-9012
800-962-2660
http://www.wardsci.com
Liquid Bio-plastic polyester resin and peroxide catalyst used for embedding samples.

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