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Characterization and Analysis of Prehistoric Earthen Plasters, Mortars, and Paints from Mug House, Mesa Verde National Park Colorado

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CHARACTERIZATION AND ANALYSIS OF PREHISTORIC EARTHEN PLASTERS, MORTARS, AND PAINTS FROM MUG HOUSE, MESA VERDE NATIONAL PARK COLORADO

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INTRODUCTION

The primary objective of this thesis is to characterize the earthen plasters, mortars, and paints at Mug House, an Anasazi cliff dwelling located in Mesa Verde National Park. This information will be used by others to develop an in-situ conservation treatment for deteriorating plaster.

Mesa Verde National Park, located in the southwest corner of Colorado, is the largest archaeological preserve in the United States. The northern San Juan Anasazi lived on the mesa for more than seven centuries, from approximately A.D. 600 to A.D. 1300, until they migrated to the south and southeast. Little human activity disturbed the mesa for the next 600 years, until a Mancos Valley ranching family introduced the site to a wider audience of cowboys, curiosity seekers, and amateur archaeologists in the late nineteenth century. Mesa Verde was made a national park in 1906 to protect these fragile ruins of the Anasazi from treasure hunters. Since then, 4,000 Anasazi sites have been identified within the park, and millions of visitors have been awed by the wonders the Anasazi left behind.

Mug House dates to the Classic Pueblo period (circa A.D. 1100-1300). It is located on Wetherill Mesa, the western boundary of the park. This cliff dwelling occupies a west-facing alcove approximately 200 feet long and up to 40 feet deep. The alcove, 90 feet below the mesa top, is situated in the sheer sandstone cliff face of Wetherill Mesa. Below the alcove, a steep, rugged talus slope descends 600 feet to the bottom of Rock Canyon. Mug House, comprised of 80 rooms, two round towers, eight

kivas, and eight courtyards, is a medium-sized site in relation to other cliff dwellings within the park. The architecture of Mug House is typical of the Classic Pueblo period. The above-ground, rectilinear, unit-style pueblos conform to the shape of the alcove and are constructed of sandstone blocks laid up in earthen mortar. They range in height from one to three stories. The kivas are round, subterranean structures linked to the pueblos by courtyards. Earthen plaster covers the interior walls of the kivas and above ground rooms, and some of the exterior walls.

The National Park Service is charged with the preservation and maintenance of the Anasazi legacy at Mesa Verde. This responsibility extends beyond the structural stability of the ruins to include preservation of the more ephemeral plasters and paints which are rapidly deteriorating and being lost. In 1994, the Park Service, in cooperation with the University of Pennsylvania, embarked on a phased pilot project to develop a system for documenting and stabilizing prehistoric earthen plasters at Mesa Verde. Mug House was selected as the model site because it has been fully excavated and documented, and because it contains some of the most significant and intact Anasazi wall and floor plasters in the park. Application methods and the sequence of finishes over time were studied using a range of analytical techniques. Plaster, paint, and mortar from Kiva C were the primary focus of the study. The surface finishes on the west exterior wall of Room 28 and soil from nearby Adobe Cave were also characterized for comparative purposes. Characterization of samples involved archival research, on-site investigation, light microscopy, geo-physical tests, x-ray diffraction analysis, and scanning electron microscopy with x-ray analysis. General questions posited for

characterization and analysis included:

1) How were the plasters made — both in terms of composition and method of application?

2) Are plasters and mortars similar in composition?

3) How do plaster layers differ?

4) What colorants were used?

5) Do finishes in Kiva C differ from those in Room 28?

6) Was Adobe Cave the soil source for Mug House plasters as posited by Arthur Rohn?

Chapter 2

HISTORY OF MESA VERDE

The great escarpment rising from and dominating Colorado's Montezuma Valley between Mancos and Cortez is the northern edge of the Mesa Verde. The visible mesa is composed of interbedded layers of sandstones, siltstones, shales, limestones, and coal laid down 80 million years ago by the Cretaceous inland sea as it rose and fell. About 25 million years ago, the series was tilted and uplifted 2,000 feet above the Montezuma Valley. Stream water and wind then steadily cut deep canyons into this once solid block, forming a series of long, finger-like projections on the south side of the mesa. The major geological formations of the mesa include Mancos Shale (the lower-most exposed formation), the Point Lookout, the Menefee, and the Cliff House. The latter three formations are collectively referred to as the Mesa Verde Group because they form the major topographic features of the mesa: steep talus slopes, sheer cliffs, flat mesa tops, and deep narrow canyons.[1] The soils of Mesa Verde developed from the erosion products of these geological formations, particularly the sandstones, and from water-borne sediments and wind-blown loess deposits of silt and clay.

Precipitation falls sparingly in this semi-arid region. Average moisture accumulation on Mesa Verde fluctuates unpredictably from year to year but generally ranges between 36 and 46 cm.[2] Most of the mesa's annual precipitation falls as snow

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[1]Mary O. Griffitts, *Guide to the Geology of Mesa Verde National Park* (Mesa Verde National Park, CO: Mesa Verde Museum Association, 1990), pp. 32 - 76.

[2]Gilbert R. Wenger, *The Story of Mesa Verde National Park* (Mesa Verde National Park, CO: Mesa Verde Museum Association, 1991), p. 16.

in the late winter but intense summer thunderstorms also contribute significantly to the water supply. Springs, seeps, and pot holes on the mesa fill with water after the snow melt or after heavy rains, but the only permanent natural body of water in the region is the Mancos River which snakes along the southern base of the mesa. Temperatures on Mesa Verde vary from mesa top to canyon bottom but are usually moderate for the season, given the region's high altitude. The average annual temperature on the mesa is 50.6°F; the average monthly temperature for January is 28.5°F; in July it is 73.1°F.

Many different types of vegetation populate the mesa because of its varied topography. A dense piñon-juniper forest covers the mesa tops and reaches down the slopes of the upper canyons. A mountain-brush community of Gamble oak serviceberry and mountain mahogany covers the southern slopes of the canyons, below the mesa rim, across the entire width of the park. Douglas fir trees grow in the higher elevations along the north rim of the mesa and in certain canyon bottoms where moisture levels are high. Along the canyon floors, big sage brush flourishes along with cheat grass, flowering plants, and cactus.[3]

In addition to the vegetation, a diversified animal population inhabits Mesa Verde. Mule deer, coyotes, grey rock squirrels, turkey vultures, ravens, lizards, and rattlesnakes are just a few of the many animals that commonly dwell on the mesa.

2.1 THE ANASAZI

The Anasazi were the prehistoric indigenous inhabitants who occupied the Four

[3]James A. Erdman, "Pinyon-Juniper Succession After Natural Fires on Residual Soils of Mesa Verde, Colorado," *Brigham Young University Science Bulletin*, Biological Series 11, no. 2 (June 1970), p. 3.

Corners area of southwest Colorado, southeast Utah, northeast Arizona, and northwest New Mexico. *(See Fig. 1)* In addition to Mesa Verde, important Anasazi sites include Chaco Canyon, Hovenweep, and Canyon de Chelly. Anasazi settlements are identified by five characteristics: 1) farming, 2) permanent dwellings, 3) kivas, 4) pottery, and 5) burial patterns.[4] Anasazi culture evolved over a thousand years through several distinct stages including Basketmaker, Modified Basketmaker, Developmental Pueblo, and Classic Pueblo.[5]

The Anasazi descended from the nomadic hunter-gatherers of the Archaic Period who came to the present southwestern United States more than 15,000 years ago. Over the centuries, these people evolved from hunter-gatherers into the primarily agricultural people with permanent dwellings and permanent and semi-permanent settlements we call the Anasazi. As their reliance on and refinement of agriculture progressed, their shelters evolved from the pit dwellings they had brought with them from the north to a form more appropriate to their new environment and lifestyle: into unit style residences consisting of blocks of rooms, a plaza or work space, and a kiva (a ceremonial room with pit house origins); in short, their distinctive pueblo. They also excelled at weaving baskets, sandals, and bags; and later at making hand-thrown pottery that is famous for its corrugated and geometric black-on-white finishes.

After settling in the Four Corners area for over a thousand years, the Anasazi

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[4]William M. Ferguson and Arthur H. Rohn, *Anasazi Ruins of the Southwest in Color* (Albuquerque: University of New Mexico Press, 1987), p. 4.

[5]For a general history of the pueblo southwest see Gilbert R. Wenger, pp. 27-75. For a more scholarly interpretation see Frank H. H. Roberts, Jr., "Archaeology in the Southwest," *American Antiquity* 3 (1937): 3-33; or Linda S. Cordell, *Prehistory of the Southwest* (Orlando: Academic Press, 1984).

migrated south to become the modern Pueblo Indians of New Mexico and Arizona. "Anasazi" is a Navajo word meaning "enemy ancestors", but is often translated to mean "ancient people".

The first settlers in the Four Corners area are known as the Basketmakers (A.D. 1-550) because of their basketry skills. The semi-nomadic Basketmakers lived in small groups in shallow rock shelters or pit houses and combined hunting and gathering with limited corn and squash cultivation. No evidence of Basketmaker remains has been found at Mesa Verde.

The first peoples to settle on the Mesa were the Modified Basketmakers (A.D. 550-750). Because they depended more heavily on agriculture, the Modified Basketmakers led more sedentary lives than their ancestors. They tended to live in communities of 40-150 people and built permanent pit house villages on the mesa top. Technological advancements of this period included pottery and the bow-and-arrow. The Modified Basketmakers were also the first Anasazis to cultivate beans, domesticate turkeys, and trade for goods.

The Developmental Pueblo (A.D. 750-1100) is characterized by increased cultural sophistication and the growth of communal living. As agricultural technology improved and the population grew, the Anasazi increasingly lived in small villages of up to 300 people surrounded by outlying settlements. During this period, ceremonial and domestic functions were segregated into separate buildings: storage and living quarters moved from below ground to above ground pueblos; subterranean pit structures were retained as kivas for ceremonial activities. The people of the Developmental Pueblo also developed two

types of pottery: grey corrugated vessels for cooking and storage, and black-on-white serving-ware decorated with simple geometric designs.

The apex of the Anasazi culture in the Four Corners area was the Classical Pueblo period (A.D. 1100–1300). Agricultural yields increased as the Anasazi improved their dry-land farming techniques and developed drought-resistant strains of corn. Their agricultural success was accompanied by steady population growth. At its peak, Mesa Verde's largest communities housed up to 800 residents. During this period, they deserted the mesa tops for natural alcoves in the cliff faces. Here, between A.D. 1200–1300, they built their great cliff dwellings. Elaborate, multi-storied versions of the Developmental Pueblo dwellings, some in virtually inaccessible locations, the Classical Pueblo cliff dwellings were the crowning architectural achievement of Mesa Verde's ancient inhabitants.[6] And then they left it all behind.

The Anasazi abandoned Mesa Verde along with many other sites in the Four Corners area sometime around 1300. This exodus is known as the Great Migration. It is unclear why they abandoned their ancestral homeland but several theories attempt to explain their departure including drought, climatic changes, disease, depleted resources such as wood supply and game animals, and social friction. The Anasazi probably abandoned the area for a variety of reasons, leaving in small groups rather than *en mass*. Whatever the reason for their departure, the Anasazi moved south along the Rio Grande River into New Mexico and Arizona. Although the precise descendants of Mesa Verde's ancient residents have not been pinpointed, the descendants of the Anasazi include the

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[6]Wenger, pp. 27-72.

modern Pueblo Indians of the Rio Grande Valley, the Zuni-Acoma region of west-central New Mexico, and the Hopi mesas of east-central Arizona.[7]

2.2 EARLY EXPLORERS

Following the departure of the Anasazi, Mesa Verde remained virtually undisturbed by humans for nearly 600 years. Spanish explorers are credited with christening the great escarpment Mesa Verde, or "green table," although no record of their visit is known. In 1868, the Ute Indians acquired Mesa Verde and the surrounding countryside through a treaty with the U.S. Government. The Utes, however, avoided the ancient cliff dwellings because of their association with Anasazi spirits. Geologist John S. Newberry was the first Anglo to publish an account of his 1859 visit to the mesa top structures and cliff dwellings of Mesa Verde. William Henry Jackson took the first photographs of Mesa Verde in 1874 while on assignment for the U.S. Geological and Geographic Survey of the Territories recording mining activities in the area. Jackson's party learned of the cliff dwellings from a miner who agreed to guide them on a sight-seeing tour. Jackson, a famous photographer, took pictures of several of the smaller cliff dwellings including Two Story House.[8] In 1885 and 1886, Virginia Donague (later McClurg), a reporter for *New York Graphic*, visited the area in search of a story on prehistoric civilizations. She later became an important figure in establishing Mesa

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[7]Stephen H. Lekson, "Tracking the Movements of an Ancient People," *Archaeology*, September/October 1995, 56-67.

[8]Jack E. Smith, *Mesas, Cliffs, and Canyons: The University of Colorado Survey of Mesa Verde National Park, 1971-1977* (Mesa Verde National Park: Mesa Verde Museum Association, 1987), p. 5.

Verde as an archaeological preserve.[9]

2.3 THE WETHERILL FAMILY

However, it was not until the late 1880s that exploration of Mesa Verde began in earnest. Benjamin K. Wetherill and his five sons, Richard, Albert, Winslow, Clayton, and John, were Quakers from Chester County, Pennsylvania. They moved to the Mancos area in 1880 where they established the Alamo Ranch. The family was on friendly terms with the Utes who allowed the Wetherills to winter their cattle in the lower canyons of Mesa Verde. The Utes told their new neighbors of the ancient cliff dwellings near the canyon's rims. The slow-paced winter months afforded the Wetherills, along with their brother-in-law Charles Mason, time to seek out and explore many of the Anasazi cliff dwellings. On December 18, 1888, they found Cliff Palace. The excitement of this discovery spurred them on to explore and name most of the major cliff dwellings and mesa top sites known today. The Wetherills initially explored the ruins for pleasure, and later glory, but soon discovered that selling artifacts and leading horseback tours of the sites offered financial rewards. In addition to selling individual relics from a shop they established, the brothers assembled and sold four large collections of Anasazi artifacts, all of which are in public museums today. Their customers included the Denver Historical Society, who bought the first collection for $3,000; the State of Colorado; Gustav Nordenskiold; and the C.D. Hazard and H. Jay Smith Exploring Company of Jackson, Illinois, who exhibited their collection at the 1893 Chicago World's

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[9]Wenger, p. 78.

Fair. Mrs. Phoebe H. Hearst purchased the exploring company's collection after the fair and donated it to the University of Pennsylvania, where it is today. Inspired by the treasures of Mesa Verde, Richard Wetherill eventually moved his family to Chaco Canyon in New Mexico where he continued to search for Anasazi ruins.[10]

2.4 THE POTTERY RUSH

Word of the Wetherills' success spread rapidly and inspired a rush to search for pottery at Mesa Verde. No protections were then in place to limit treasure hunters' access to the sites or to prevent them from removing artifacts. Many of the early explorers caused irreparable damage to the ruins while looking for riches by removing walls or using dynamite to access rooms.[11] By the time Mesa Verde became a national park twenty years later, many of the Anasazi artifacts were in private hands.

2.5 GUSTAV NORDENSKIOLD

One early adventurer was Gustav Nordenskiold, a 23-year-old Swedish nobleman and amateur archaeologist on an American tour financed by his father. Nordenskiold arrived at Mesa Verde in July of 1891 to spend a week. He hired the Wetherill brothers to guide him and, delighted by the ruins, spent the summer and autumn digging, collecting, and extensively photographing in many different ruins including Long House, Mug House, Step House, and Spruce Tree House. He ultimately recovered hundreds of

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[10]Frank McNitt, *Richard Wetherill: Anasazi* (Albuquerque: University of New Mexico Press, 1957), pp. 8-45.

[11]Don Watson, *Cliff Dwellings of the Mesa Verde: A Story in Pictures* (Mesa Verde National Park, CO: Mesa Verde Museum Association), p. 12.

artifacts which he shipped back to Sweden. Today they are in the National Museum in Helsinki, Finland. Following his return to Sweden, Nordenskiold published *The Cliff Dwellers of the Mesa Verde* in 1893 in which he described his visit to Mesa Verde and included many perceptive observations about the evolution of Anasazi culture.

2.6 THE CREATION OF MESA VERDE NATIONAL PARK

Locals protested the size of the collection Nordenskiold shipped home to Sweden. However, without laws to protect the artifacts, the local authorities could do nothing to stop the plunder of Mesa Verde.

Virginia McClurg, the reporter who visited Mesa Verde in 1885 and 1886, organized the Cliff Dwellers Association to educate the public about the ruins and to lobby for their legislative protection from looters. McClurg was joined in her mission by Lucy Peabody, who led the fight to establish Mesa Verde as a national park. Their effort was not in vain. On June 23, 1906, Congress authorized the creation of Mesa Verde National Park. President Theodore Roosevelt signed the bill into law six days later, creating one of the first national parks in the nation.

Development of the new park happened quickly. An agent to the Southern Utes appointed the first superintendent of Mesa Verde National Park because no federal agency existed at that time to run it. In 1908, the park had to renegotiate its borders with the Utes because its original boundaries failed to include the major cliff dwellings. The first road into the park opened in May 1914, allowing visitors to see the park in one day by car. Prior to the road opening, a visit to the ruins took a minimum of three days

on horseback. After its establishment in 1916, the National Park Service assumed responsibility for the park.[12] Over the past 80 years, the Park Service has been responsible for the preservation of Mesa Verde for and from the hundreds of thousands of people who flock there each year.

2.7 ARCHAEOLOGY AT MESA VERDE

Although the era of exploitation at Mesa Verde is over, controlled archaeological investigation continues within the park. Edgar L. Hewett, Director of American Archaeology for the Archaeological Institute of America and later Director of the School of American Archaeology, conducted a major survey of the park's resources in 1906 and 1907. The first scientific excavations in the park were led by Dr. Jesse Walter Fewkes, an archaeologist with the Bureau of American Ethnology of the Smithsonian Institution. Fewkes spent nine summers between 1908 and 1922 at Mesa Verde excavating and stabilizing many cliff dwellings including Cliff Palace, Spruce Tree House, Square Tower House and Far View House, but he kept minimal records. In the 1920s, Superintendent Jesse Nusbaum directed a number of winter excavations financed by John D. Rockefeller, Jr. to search for artifacts in previously disturbed sites to gather objects for a museum. The winter expeditions investigated both cliff dwellings and mesa top sites. The growing number of visitors to Mesa Verde inflicted constant damage on the ruins. This need for constant stabilization launched the Ruins Stabilization and Repair Program, in 1933, directed by Earl Morris; and the Ruins Survey Program, led by Lyle E. Bennett, to

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[12]Wenger, pp. 85-87.

clearly record repairs. The following year, James A. (Al) Lancaster replaced Morris as head of the Ruins Stabilization and Repair Program. Lancaster stayed at the job until 1965. A number of small excavations were undertaken over the next two decades. In 1958, the Wetherill Mesa Archeological Project began. The most extensive archaeological program ever carried out in the park, the project lasted seven years and sought to open up Wetherill Mesa to visitors. The project, financed in part by the National Geographic Society, included thorough surveys, major excavations, and salvage projects. Since 1965, small scale research projects have been carried out. The park also employs a stabilization crew to maintain the sites.

Chapter 3
ANASAZI ARCHITECTURE

The cliff dwellings and mesa top ruins are the chief attractions for modern visitors to Mesa Verde. For the Anasazi, they were primarily utilitarian structures with very specific functions. Although the architectural forms of Mesa Verde evolved different functions, the basic elements did not change once they were established.

3.1 PIT HOUSES

3.1.1 *Basketmaker*

The hunter-gatherers of the Archaic period, the ancestors of the Anasazi, acquired food when they needed it and carried their main food storage units (their stomachs) with them. As farmers, the Anasazi collected large quantities of food all at once which created the need for a storage unit to hold their harvest until the next crop ripened.

What we call Anasazi architecture began with the storage unit.[13] Like farmers the world over, the Anasazi built the barn first. Although the early Basketmaker Anasazi relied on rock outcroppings to shelter themselves, for their food stores they dug shallow pits, lined them with stone, and sealed them with sticks, stones, and mud. Inside, they stored their harvest: dry, safe from rodents, and hidden from prying eyes. Later, they built their storage units larger, and moved themselves inside. They were rude, drafty dwellings clustered in twos and threes. A solitary pit house was more rare, and not more

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[13]For a detailed introduction to Anasazi architecture see William M. Ferguson and Arthur H. Rohn, *Anasazi Ruins of the Southwest in Color* (Albuquerque: University of New Mexico Press, 1987), pp. 25-40.

than an hour's walk from its neighbors. The pit structures were probably only occupied a few months of the year, when it was too cold to farm.[14] But the pit house is the foundation of Anasazi architecture and lies at the heart of Anasazi culture.

3.1.2 *Modified Basketmaker*

The Basketmaker's descendants, the Modified Basketmakers, formalized pit house architecture, established the first Anasazi villages, and formalized village structure. Pit houses functioned as both domestic and ceremonial structures. Developed from the simple dwellings of the Basketmakers, their major features were established by the Modified Basketmakers. These early pit houses were circular, semi-subterranean dwellings consisting of one or two rooms. Approximately 10 feet in diameter, they were excavated about a foot below ground level and were just high enough to accommodate a standing adult. Like the Basketmaker storage units, the sides of the excavated pit were lined with stone slabs. Storage chambers were within the structure or nearby in above-ground units. Cribbed horizontal timbers served as the side walls and formed a dome-shaped roof. The entire structure was weatherproofed with small sticks, bark, and mud and heated by a fire in a central fire pit.

Over time, the Modified Basketmakers enlarged and strengthened their pit houses. By 700 A.D., pit houses were excavated to depths of three or four feet. Pit houses of this period generally consisted of a main room and a small antechamber which often served as a store room or entrance way. Rooms were circular or square with rounded

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[14]Patricia A. Gilman, "Architecture as Artifact: Pit Structures and Pueblos in the American Southwest," *American Antiquity* 53, no. 3 (1987): 555.

edges. Four wooden posts set into the floor supported the roof and walls. Horizontal logs rested on the posts to establish the base of the square roof, while sloping poles leaned against the logs to form the walls. Layers of sticks, bark, and earth were used to protect the structure from the elements; an opening in the roof allowed smoke to escape. Interior features included a central fire pit, ash pit, and a sipapu. A sipapu is a cylindrical depression in the floor; in modern pueblos, it is believed to be the gateway to the underworld and plays an important roll in religion. Eventually, the antechamber was replaced by a ventilating tunnel to allow fresh air into the chamber; a deflector, a low wall between the fire pit and the ventilator, diverted drafts from the fire. Also during this period, the Modified Basketmakers began plastering the floor, walls, and fire pit with clay. *(See Figs. 2 and 3.)*

Two other structures debuted during the Modified Basketmaker period: the granary and the ramada. By 600 A.D., the Anasazi began building above ground granaries for food storage. These granaries were constructed of jacal, small sticks woven together and plastered with earth. Ramadas were simple canopies supported by four posts. They provided sheltered, above-ground work areas for sunny or rainy days.

The first Anasazi communities formed during the Modified Basketmaker period. After centuries of living in isolated groups, Anasazi farmers moved to mesa top pit house villages. These new communities were built to a particular design, the Unit Pueblo, which proved both enduring and pervasive. The Unit Pueblo was a standardized pattern of building based on a north-south axis that dictated village layout and pit house alignment. Under this design, storage units were situated on the north side of the settlement. South of the storage units, ramadas were constructed in rows and often

attached to the north side of pit houses. The plaza and trash pit were south of the pit house. Inside the pit house, the sipapu, fire pit, ash pit, deflector, and ventilating tunnel were aligned along the same north-south axis. Villages built to these specifications sprung up all over the Four Corners area.

3.2 **KIVAS**

The Anasazi kiva, evolved from the humble pit house, is a hallmark of pueblo culture. The word "kiva" is a modern Hopi term for their subterranean ceremonial chambers, similar in both form and function to the below-ground structures of the late Developmental and Classic Pueblos, and early archaeologists adopted Hopi nomenclature.

Much of what archaeologists know about Anasazi kivas has been gleaned through ethnographic studies of modern Pueblo Indians. Based on this research, archaeologists believe that individual kivas functioned as ritual meeting places, club houses, and workshops for matrilineal kinship groups. Although they were probably the domain of men, women and children probably used them as well. They were undoubtedly the warmest, most comfortable places in an Anasazi village on a cold winter night.

Defining a kiva is more complicated than describing one. The participants of the watershed Pecos Conference of 1927 tried in vain to establish the essential features. Their task was a difficult one because there is no tell-tale characteristic of a kiva, no single feature or group of features present in kivas, yet absent from non-kiva structures. In fact, the purely ceremonial functions assigned to kivas must be inferred.[15] Not only

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[15]Watson Smith, "When Is a Kiva?" in *When Is a Kiva? And Other Questions About Southwest Archaeology*, ed. Raymond H. Thompson (Tucson: University of Arizona Press, 1990), pp. 59-75.

are no two kivas alike, but there are also many regional differences between kivas. This may reflect differences in the religious practices of different kin groups.

The transition from pit house to kiva is identified as the point at which the subterranean structures ceased to serve as dwellings. Archaeologists, with some dissent,[16] generally believe this transition occurred during the Developmental Pueblo period (circa 900), making it contemporary with the rise of the pueblos.

The transition from pit house to kiva was subtle and more a function of use than form. Kivas were reserved for social and ceremonial purposes; pit houses also had domestic functions. Kivas retained many pit house features and no physical change marked the transition. Like pit houses, kivas were generally circular, subterranean structures with a sipapu, fire pit, deflector, and ventilating tunnel aligned along the north-south axis. At Mesa Verde, six stone pilasters rose from a banquette and supported a flat roof constructed of cribbed logs. Sticks, bark, and earth were used to make the roof top level with the surrounding plaza. An opening in the roof served as both a smoke hole and entrance. Earthen plaster and paint decorated the stone-lined kiva interior and may have been applied as part of a religious ritual. Other kiva features included benches, wall pegs, loom anchors, shelves, stone anvils, and tunnels leading to rooms, other kivas, or towers.

Although kivas retained the central pit house features virtually without change, new features were gradually incorporated into the structure. By A.D. 800, pit houses became almost entirely subterranean except for a domed roof to shed water. The cribbed roof did not appear until changes occurred in the roof support system. As pit house

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[16]Stephen H. Lekson, "The Idea of the Kiva in Anasazi Archaeology," *The Kiva* 53, no. 3 (1988): 213-34.

floors became deeper, their builders left a banquette, a ledge extending around the inside wall of the pit, during excavation. This allowed them to shorten the wall posts and place them directly on the banquette. By 900, the walls had disappeared altogether, allowing the four roof support posts to be shortened and set into the front edge of the banquette. Eventually, stone columns replaced the posts and cribbed logs were laid between the columns. By 1100, the columns were set flush against the kiva side and constructed of stone. Builders filled the area above the cribbing with sticks, bark, and earth to make a level courtyard. *(See Figs. 4 and 5.)* Inside the kivas, stone lining along the banquette replaced clay plastering as a means of stabilizing weak spots. Earthen plaster was applied directly to the stone and often painted with two or more different colors. By 1200, painted murals appeared on kiva walls.

Differences in kiva construction are numerous and included everything from location within the pueblo compound, to shape, to internal features. Kivas occasionally were built above ground, particularly when pueblos stood on bedrock. Although most kivas are round, many are square. Classic Pueblo kivas typically contain six pilasters but can have as many as ten or none at all. Sipapus, because of their association with the underground spirit world, are usually found on the kiva floor; many kivas lack them altogether while others contain two or more. Regional differences abound. Kivas at Mesa Verde are noted for their keyhole shape and banquette niches holding religious objects. In the Kayenta region, kivas are typically small, square, and lack a banquette. Chacoan kivas are typically larger than those at Mesa Verde and Kayenta. They also lack a deflector because the ventilator opens below the floor level; and they contain long vaults set into the floor, possibly for foot drums or storage.

3.3 PUEBLOS

3.3.1 *Developmental Pueblo*

The pueblo replaced the pit house as the main habitation structure during the Developmental Pueblo period. The transition from pit house to pueblo was spurred by rapid population growth and increased group reliance on agriculture, domesticated animals, and food stores. These changes prompted the Anasazi to develop a new building type more appropriate to their changing life style.[17] Once it was adopted, the pueblo remained with the Anasazi and their descendants, the modern Pueblo Indians, until today.

In its final form, the Developmental Pueblo dwelling unit was an above-ground, rectilinear block of contiguous rooms. *(See Fig. 6.)* Constructed of jacal, stone, or adobe, the structure incorporated small rooms for storage and provided work space on the flat wooden roof. The pueblo was composed of interconnected suites of rooms; each suite probably housed a nuclear family. Suites were arranged around kivas, subterranean ceremonial lodges organized by familial ties.

The pueblo evolved from the ramada of the Modified Basketmakers early in the Developmental Pueblo period. By adding jacal walls to the open sides of ramadas, Anasazi builders created the first enclosed, above-ground spaces. Like the granaries or storage units of the Modified Basketmakers, a stone foundation supported the jacal walls. A small hearth, the lone interior feature, warmed the room. Spaces such as these soon functioned as dwelling units.

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[17]Gilman, p. 555.

By 800, stone masonry began replacing jacal on the back and side walls. The front wall continued to be made of jacal to accommodate the door. More durable and providing better insulation, stone walls were laid with thick mud mortar in irregular courses of cobblestones or roughly shaped blocks. These first masonry pueblos were one story tall, the walls one stone thick, and they had flat roofs constructed like pit house roofs with corner posts supporting a cap of beams, bark, sticks, and mud. By 1100, stone masonry entirely replaced jacal in pueblo construction (except in the Kayenta area). As knowledge of stonework grew, Anasazi masons learned to build walls up to three stones thick, and strong enough to support upper stories. They also began dressing stones with at least one face pecked or ground smooth, and laying them in regular, horizontal courses. At Mesa Verde, masons used similar sized blocks on each wall, although stone sizes varied from wall to wall. Larger blocks were reserved for exterior walls. Small chinking stones, placed carefully in the mortar joints, provided both resistance to shrinkage and a decorative touch. Wall surfaces were plastered with mud and frequently painted, inside and out.

3.3.2 *Classic Pueblo*

When they relocated to alcoves in the sheer cliff faces of Mesa Verde during the Classic Pueblo period, the Anasazi took their stone pueblos with them. Pueblos continued to be built in the same above ground, rectilinear, unit-style pattern as those of their mesa-top predecessors. However, the confines of the alcoves and growing population dictated a few basic alterations. Pueblos had to conform to the shape of the alcove, and infill was often brought down from the mesa tops to level the cave beds.

The growing population and limited alcove floor space forced Anasazi masons to built their villages upward. Alcove pueblos could be four stories tall and house 200 residents.

3.4 VILLAGE LAYOUT

The Unit Pueblo continued as a means of village layout during the Classic Pueblo period. As with pit house villages, pueblo villages were aligned along a north-south axis with storage and dwelling units placed on the north side of the site, while kivas, work areas, and trash pits were located on the south side. (*See Fig. 7.*) In addition to directional orientation, site planning was oriented around the kiva. Typically, there was one kiva for several rooms and several kivas per village.

Chapter 4

EARTHEN PLASTERS IN THE PREHISTORIC SOUTHWEST

The primary architectural surface finish employed by the Anasazi was earthen plaster. Simple earthen plasters, often painted and incised, decorated and insulated Anasazi pueblos from the Basketmaker to the modern pueblo period.

4.1 HISTORY OF EARTHEN PLASTERS IN THE SOUTHWEST

Earth has long been used as a building material, especially in the American southwest. The first Anasazi buildings, Basketmaker storage units, were rendered and sealed with earth. Earth, applied to the exterior, protected pit structures from the elements. The earliest plaster fragments date to the Basketmakers, who spread thin layers of mud on the earthen and stone-lined walls of their pit structures.[18] However, it was not until the Modified Basketmaker period that the practice became widespread, and pit house builders began to plaster the floor and fire pit in addition to the walls.

Although they perform different functions, the same mixture for mortar and plaster were often employed by the Anasazi. Defacto plaster was a surface finish created by smearing excess amounts of mortar, which had squeezed out between the masonry blocks, onto the stone face. Defacto plaster occurs in discrete areas and often retains handprints and tool marks.[19] Full wall plasters may have evolved from the defacto plasters.

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[18]Constance S. Silver, "Architectural Finishes of the Prehistoric Southwest: A Study of the Cultural Resource and Prospects for its Conservation," (Master's Thesis, Columbia University, 1987), p. 7.

[19]Ibid, p. 23.

Plaster assumed a more decorative function during the Developmental and Classic Pueblo periods. The Developmental Pueblo Anasazi plastered the interior walls of both kivas and pueblos. Although, generally, the plasters were unadorned, kiva interiors at a few sites were decorated with mural paintings and incised designs. By the Classic period, a formal system of architectural decoration emerged. Plaster finishes covered the interior and exterior of various building types. Exterior plaster was usually limited to auras around doors and windows. Interior surfaces were often fully plastered and painted with elaborate murals featuring complex iconographic designs.

4.2 MURAL PAINTINGS

The Anasazi began decorating their plasters with painted murals during the Developmental Pueblo and Classic Pueblo periods. Although murals remained fairly simple and abstract, they represented the birth of a pueblo mural tradition that matured after the Anasazi abandoned the Four Corners area.[20]

The first plaster walls were bare but, drawing from both contemporary rock art and pottery designs, the Anasazi painted selected kiva interiors during the Developmental Pueblo period. The earliest known murals date between 950 and 1100 and are limited to a few sites around Mesa Verde and Chaco Canyon. These early kiva paintings featured non-figurative designs of simple bands and horizons. Geometric shapes incorporated into the murals included horizontal and diagonal lines, triangles, and stepped forms. Both spatial organization and mural composition were probably drawn from contemporary pot and basketry designs.

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[20] J.J. Brody, *Anasazi and Pueblo Painting* (Albuquerque: University of New Mexico Press, 1991), pp. 45-68.

Classic Pueblo muralists were prolific, and their work more sophisticated than their predecessors. Pottery probably provided the limited repertory of geometric designs and the highly structured approach to organizing design elements. Common decorative flourishes included triangles, dots, rectangles, diamonds, line patterns, and border elements. Kivas, in particular, often imitated pottery bowl interiors with encircling bands of decoration. Classic Pueblo muralists began decorating pueblo walls with zoomorphic and, less frequently, anthropomorphic figures similar to rock art designs. Typically, these figures were crudely drawn silhouettes.

In the Classic period, the practice of mural painting extended to non-kiva spaces and proliferated throughout the Anasazi world. Distinct regional differences developed. Mesa Verde mural painters executed hundreds of simple and austere murals between 1200 and 1300. Interior murals generally featured a bichrome color scheme with a red lower dado and a white or buff upper field. Although other colors such as yellow, green, black, and grey were available to mural painters, they were rarely used for color fields at Mesa Verde. Triangles in groups of twos and threes often projected from the lower dado into the upper field. Chaco Canyon muralists were not as prolific as their Mesa Verde counterparts but employed a more varied color palette.

The work of the Gallina district muralists in northern New Mexico was more detailed; their most famous works are a series of framed panels on a pit house/kiva wall. Each panel contains a unique image including sunflowers, an evergreen, and a series of triangles. The most ornate mural of the Classic period was discovered at Atsinna in western New Mexico. Only a few fragments of this mural survived excavation (and, sadly, have since disintegrated); but it displayed a complex geometric arrangement of

rectangles and symmetrical patterns executed in black, red, yellow, and white. The intricacy of this mural anticipated the highly wrought designs of later pueblos.

4.3 **PLASTER**

Anasazi plaster is remarkably durable. Surprisingly large quantities of this fragile surface finish have survived for over seven hundred years despite exposure to extreme environmental conditions. The tenacity of these plasters is testament to the care and skill of Anasazi plasterers.

Little is known about the techniques employed by the Anasazi to manufacture and apply plaster and paint, but much can be inferred from the ethnographic study of modern Pueblo Indians. Watson Smith and Constance S. Silver offer the most thorough examination of Anasazi techniques and materials.[21]

4.3.1 *Constituents and Preparation*

Soil and water are the primary constituents of earthen plasters. Soil — an assemblage of sand, silt, and clay particles — comprises the bulk of the plaster. Clay is the binder, providing both cohesion between the soil particles and adhesion between the plaster layers and the wall. Sand and silt contribute bulk, although sand also helps control shrinkage and cracking.

The relative proportions of soil particles, known as the grain size distribution, influences a soil's behavior and its suitability as a building material. Soil constituents

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[21]Watson Smith, *Kiva Mural Decorations at Awatovi and Kawaika-a*, Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol. 37, (Cambridge: Peabody Museum, 1952) and Constance S. Silver, "Architectural Finishes of the Southwest," 1987.

are generally defined by their size or diameter because it is this feature that principally determines the soil's behavior. The clay fraction of the soil, in particular, affects a soil's performance. Clay particles measure less than 2 μm in diameter. Their high surface area allows them to attract water easily and hold it tightly. Clayey soils are smooth to the touch, plastic, and easy to manipulate while wet because water allows the clay particles to slide past each other; but they also tend to shrink and crack upon drying. Sand particles range in size from 75 μm to 4.75 mm. They cannot readily adsorb or retain water because of their limited surface area. Sandy soils are coarse textured and difficult to work but exhibit dimensional stability.

Mineralogy of the clay fraction also plays a role in soil behavior.[22] Clay particles are hexagonal crystal lattices composed of alternating layers of aluminum oxide (Al_2O_3: alumina) and silicon oxide (SiO_2: silica). Together, the alumina and silica form sheets which stack together creating the lattices. Water is able to penetrate between the sheets, pushing them apart. The crystal expands, the clay swells. When the water evaporates, the crystal shrinks back to its original dimensions.

Clay minerals are classified into groups based on their crystalline structure which affects their behavior in the presence of water. Three of the most common clay groups are kaolin, illite, and smectite.[23] Kaolin is a very pure and stable clay that does not readily react in the presence of water because it contains few impurities and has a stable

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[22]Giorgio Torraca, *Porous Building Materials: Materials Science for Architectural Conservation*, 3rd edition (Rome: ICCROM, 1988), pp. 97-101.

[23]The smectite group of clays was formerly referred to as the montmorillonite group. Montmorillonite is now classified as a mineral of the smectite group. Robert L. Bates and Julia A Jackson, eds., *Dictionary of Geological Terms*, 3rd edition (Garden City, NY: Anchor Press, 1984), p. 473.

two-layer structure — one of alumina and one of silica. Strong hydrogen bonds and a distance of 1 Å between the sheets prevent water from penetrating or swelling the crystal. Illite is a more active clay that swells slightly in the presence of water. It has a three-layer structure — one alumina sandwiched between two silicas. The sheets, 10 Å apart, allow some water entry. Calcium and other impurities often replace alumina in the lattice, attracting additional water. Smectite is a more volatile clay. Like illite, it has a three-layered structure prone to substitutions in the alumina layer. However, the sheets are 14–20 Å apart and their interlamellar bonds are weak. Consequently, smectite is very unstable and susceptible to dramatic swelling and shrinkage.

Because soil is the most important constituent in the plaster, it is carefully selected for known properties such as grain size distribution, color, texture, and lime content. Further, it may be sifted and refined to achieve the optimum blend of clay and sand particles.[24]

Water transforms the soil into plaster. Too little makes the paste unworkable; too much, and the plaster shrinks and cracks as it dries. Just enough water creates a spreadable paste that dries to an unbroken skin.

In many cultures, additives are mixed into the paste to enhance the physical and aesthetic properties of the plaster. Organics — blood, animal glues, and urine — improve cohesion. Because of the fugitive biological nature of the organics, it is difficult to confirm their presence in prehistoric plaster. Calcium carbonate, including lime and chalk, is a cementing agent that provides a set and increases plaster's durability.

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[24]Smith states that the wall plasters in the kivas at Awatovi contained 10% clay and 90% sand although he did not cite the method he used to determine grain size distribution.

Additives that create a fibrous web within the plaster layer — straw, hair, grass, and twigs — enhance cohesion and tensile strength. The color of the plaster is primarily imparted by the clay and sand fractions of the soil but color can be enhanced by the addition of crushed pigments.

4.3.2 *Application*

The prepared plaster mix is applied to the wall in a succession of layers. In some kivas, woven reed mats were attached to the walls as lathe to maximize the mechanical bond between the wall surface and the fresh plaster coat, but, more typically, the base coat was applied directly to the wall in a thick layer to even out construction irregularities; the mortar joints between the stone blocks sometimes provide a key for the plaster.

Each coat was smoothed with bare hands working in a circular motion. Occasionally, a flat tool was used: a rock, stick, shell, potsherd, or gourd. Individual coats ranged in thickness from one to six millimeters. The base coat was the thickest because it had to compensate for unevenness in the bare stones beneath it. Two to three coats were often required to create a uniform surface. Well-laid masonry required less plaster; irregular masonry required additional coats.

4.4 **PAINT**

Following application, earthen plaster was allowed to dry before being decorated. Color was an important element of prehistoric mural designs. Prevalent colors included red, white, black, brown, orange, and gray. Color undoubtedly held symbolic

significance for the Anasazi, as it does for modern Pueblo Indians, and they made a wide range of paints which they applied in often predictable patterns and locations. Some type of color theory clearly dictated color use. For example, at Mesa Verde, red dados with white or buff upper fields were the rule. Although black pigment was available, it was never used in combination with red or white color fields, nor was it employed on auras around doors or windows.[25]

4.4.1 *Constituents*

Paint is a surface finish that both protects and embellishes earthen plasters. It is applied as a liquid but eventually transforms into a thin, solid coating. Paint is composed of three key ingredients: colorant, binder, and carrier.

The colorant is the most visual constituent because it imparts color to the paint film. Pigments, the most common colorants employed by the Anasazi, are finely divided insoluble substances which are suspended as discrete particles in the binding medium. Pigments also contribute opacity, gloss control, and strength to the paint layer. The Anasazi derived all of their pigments, with the exception of the blacks, from inorganic mineral sources.

In his 1952 study, *Kiva Mural Decorations at Awatovi and Kawaika-a*, Watson Smith characterized 125 paint samples from kiva walls. Microscopy and microchemical tests revealed that the majority of prehistoric pigments were oxides and carbonates of iron, magnesium, and copper. Other common constituents were silicon, magnesium,

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[25]Brody, p. 67.

aluminum, iron, calcium, manganese, and titanium.[26] The following list of pigments is summarized from Smith's study:[27]

Black: Anasazi muralists used many types of black paint. Black pigments, unlike other colors, derived almost entirely from organic sources. Wood fibers in some of the samples indicated the presence of charcoal. Other samples tested positive for phosphate and were characterized as lamp black, a nearly pure, amorphous carbon created by burning oil, tar, pitch, or resin. Other organic sources of black pigment proved difficult to pinpoint, and some specimens contained mineral inclusions such as iron and manganese.

White: Murals frequently featured white color fields or designs. White siliceous materials, especially kaolin ($Al_2O_3\ 2SiO_2 \cdot 2H_2O$) — a hydrated silicate of aluminum — were the primary components of many white paints. Other raw minerals incorporated into white pigments included fine silica sand, chalk or calcium carbonate ($CaCO_3$), and gypsum ($CaSO_4 \cdot 2H_2O$).

Yellow: A wide variety of yellows appear on kiva mural paintings. Goethite ($H\ Fe\ O_2$) or Limonite [$Fe_2O_3 \cdot n(H_2O)$] are the principle mineral sources of yellow pigments and can be obtained from solid minerals or from clay or sandstone stained with these minerals. Impurities in the mineral deposits account for the range of shades and intensities of yellow paint.

Red: One of the most commonly employed colors in prehistoric mural paintings, the Anasazi derived all red pigments at Awatovi from the red iron oxide hematite (Fe_2O_3) — a nearly pure variety of anhydrous ferric oxide. Red iron oxide is very stable and unaffected by light or alkalis. Like yellows, red pigments range in color and intensity because of impurities in the hematite.

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[26]Paint samples were analyzed by a team of experts. Rutherford J. Gettens of the Fogg Art Museum, Harvard University and Dr. Harry Berman of the Department of Mineralogy, Harvard University, examined the paints under the microscope. Harriet H. Greene of the Massachusetts Institute of Technology conducted the microchemical tests. Spectrographic analysis of the samples was carried out by Dr. Rockwell Kent, III of the Department of Mineralogy, Harvard University.

[27]Smith, *Kiva Mural Decorations*, pp. 22-24. For additional information about pigments see Rutherford J. Gettens and George L. Stout, *Painting Materials: A Short Encyclopaedia* (New York: Dover Publications, 1966), pp. 91-181.

Orange:	The Anasazi combined yellow and red iron oxide to create orange pigment. White particles, probably clay minerals, were often incorporated into the mixture as well.
Pink:	Pink pigment resulted from the mixture of red iron oxide with white clay. Pink was commonly used in mural painting but some examples of it may originally have appeared red.
Vermillion:	A rare color in Anasazi mural decoration, vermillion was probably an accidental variant of red created by mixing red ochre with clay or silicious material that closely resembled cinnabar in color.
Brown:	Smith identified a variety of brown pigments. Burnt iron oxide and iron oxide mixed with carbon particles were the two most common types.
Purple/ Maroon:	Various shades of purple and maroon appeared on kiva walls at Awatovi. Red iron oxide proved to be the primary component of all of the purples; anhydrous ferric oxide (Fe_2O_3) is dark purple-red or maroon. One sample tested positive for manganese, suggesting that the pigment was probably red iron oxide and manganese dioxide while other samples had no manganese but did contain a mixture of carbon and clay.
Blue:	Smith identified two blue pigments at Awatovi. Copper carbonate ($CuCO_3$), probably derived from azurite minerals, was rare and produced a bright blue paint. Dark gray-blue, a more widely-used color, proved to be a mixture of carbon and a white silicious material.
Green:	The Anasazi rarely painted with green but they manufactured two types of green paint. A bright green pigment proved to be copper carbonate ($CuCO_3$) from malachite minerals. A dull, grayish-green color tested positive for iron and was an impure mixture of yellow iron oxide and carbon.
Gray:	Black and white particles mixed together create gray pigment. Many areas that now look gray, originally may have been black.

The binder and carrier are collectively referred to as the vehicle. The vehicle allows the colorant to be applied to the wall.

The binder forms the film; it binds the pigment particles together into a continuous mass and attaches them to the substrate. Traditional organic binders for architectural paints include oils and resins such as animal glues, plant gums and resins, and egg. Organic binders disintegrate through natural biological processes and are extremely difficult to detect in 700-year-old paints. Clays and lime also work as inorganic binders — whether as intrinsic or intentionally added components to the system.

The carrier, a volatile solvent, enables the paint to be applied as a liquid by carrying the binder and allowing it to be spread as a thin, continuous film. The carrier then evaporates, leaving behind a solidified film of paint. The evaporation rate of the carrier controls the film-formation time. Carriers available to Anasazi mural painters were probably limited to water, so most Anasazi paints were probably clay-based materials.

4.4.2 *Manufacture and Application*

The paint making process began by collecting pigment-rich mineral nodes, rocks, and clays of the desired color. Anasazi muralists then ground the pigments to a fine powder using a mano and matate. Pigment-stained manos and matates and lumps of source minerals are often discovered during excavations.

The vehicles used by the Anasazi have rarely survived 700 years of weathering and biological attack. Consequently, their identification is largely based on speculation. Clay washes resembling pottery slips, made by diluting clay to a watery slurry, were used to cover large wall surfaces. Many vehicles were undoubtedly organic in origin.

Animal parts could have been boiled to produce glue-based vehicles such as hide glue, bone glue, and gelatine. Vegetable matter was readily available and easily manufactured into a variety of resins. To produce a gummy mix of saliva, pulp, and juice, vegetable matter such as seeds and yucca could have been chewed. The water remaining from boiling squash may also have been used as a vehicle. The use of the latter two vehicles is inferred from turn-of-the-century ethnographic accounts of modern Pueblo Indian paint making techniques.[28]

New paint was made for each wall painting. Ground pigment was mixed with the freshly prepared vehicle to form paint. The paint was ready for immediate application.

A variety of applicators were used to apply the paint to the wall. Striations left behind on the plaster surface suggest that the Anasazi used a stiff brush or animal skins on the painter's hands to apply most paint. Hypothetical brushes include strips of yucca which were chewed to remove the leaf pulp until the fibrous material of the leaf were left exposed, and green corn husks wrapped around the painter's finger. In historic times, modern Pueblo Indians use mittens made of sheepskin to apply paint to large areas. The use of such mittens would account for the fine, long, continuous striations that are evident in the color washes. Fingers and hands were no doubt used to apply much paint. Finger tips made dots, and hand prints were just that, a hand spat on or dipped in paint.[29]

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[28]Smith, *Kiva Mural Decorations*, pp. 30-31. Much of the above information on paint manufacture and application is speculative and based largely on ethnographic accounts of 19th and 20th century Pueblo Indian painting techniques.

[29]Ibid.

4.5 RENEWAL OF PLASTER COATS

The Anasazi continually renewed and repaired their plasters. Up to 100 layers of plaster exist on some prehistoric walls. While many structures exhibit replastering, kivas typically exhibited significantly more layers than other wall surfaces.

The frequency of and motive behind plaster renewal remains a mystery but the two are undoubtedly related. Because the number of plaster layers is often greater than the estimated number of years of occupation at a some of sites, it seems likely that new coats were applied annually or seasonally. The large number of plaster layers in kivas compared with other wall surfaces suggests that the practice had a ceremonial or ritual function. Watson Smith proposed four motives for plaster renewal: maintenance of plaster to prevent deterioration and loss; replacement of soot-blackened surfaces; seasonal renewal; and ritual obliteration of sacred but obsolete wall paintings.[30] Whatever the reason, the practice of renewing plaster coats was widespread in Anasazi culture.

4.6 DETERIORATION OF EARTHEN PLASTERS AND PAINTS

Plaster loss is a common problem at archaeological sites in the Southwest. Symptoms of deteriorating plaster include cracking, flaking, blistering, and detachment. Although earthen plasters degenerate for many reasons, human factors and site conditions are the most common causes.[31]

The human causes of plaster deterioration can be traced to both the Anasazi and to modern interventions. An inattentive Anasazi plasterer could easily create an inferior

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[30] Smith, p. 19.

[31] Silver, *Architectural Finishes of the Prehistoric Southwest*, pp. 107-115.

plaster. Too much clay or water in the plaster mix promoted shrinkage and cracking while careless application procedures could result in an inadequate bond between the plaster and the wall. In modern times, insensitive excavation techniques often damage or destroy plaster. Even in carefully excavated sites, plasters often collapse when the support provided by centuries of fill material is removed. Over-zealous tourists and trouble-makers endanger plaster survival through abrasion or vandalism.

There are many site conditions that jeopardize the integrity of plasters. Water is the chief enemy of earthen building materials. Its direct exposure to plaster can quickly erode both the plaster and its painted finish. Rising damp wicks ground water up through the plaster's pores via capillary action, causing the plaster to soften and disintegrate along the lower elevation of the wall. Environmental fluctuations cause damaging weathering cycles that jeopardize plasters. Freeze-thaw cycles, in particular, cause water trapped in the pore space to freeze and melt, thereby disrupting the plaster's internal cohesion as well as its ability to adhere to the wall surface. Low relative humidity over long periods of time can dehydrate prehistoric plasters. If the dehydration becomes severe, the cementing material in the plaster loses its ability to either maintain intergranular bonds or adhere to the wall. Structural movement of the site results in mechanical damage to plasters through abrasion and loss of substrate.

Salt contamination accelerates plaster decay. Salts, either naturally in the rock and soil or artificially introduced into the plaster through ill-advised stabilization practices such as utilizing Portland cement repairs, migrate through intergranular pore spaces in the plaster. They eventually crystallize on the plaster surface as efflorescence or below the surface as subflorescent deposits. Crystallization pressure is the primary cause of salt

decay in earthen plasters. Salts expand in volume as they crystallize from solution. When the salt crystal is larger than the pore in which it is deposited, the salt can burst the pore, disrupting the plaster skin. In this way, large pieces of plaster dislodge from the wall after excavation. Salts often crystallize on plaster because of fill removal and the activation of wetting-drying cycles.

Plant growth can also be a major hazard to plaster finishes. Plants often have long roots that reach down through the fill in an unexcavated site. Roots take the path of least resistance which is often between the plaster surface and the wall or between plaster layers. A fine network of rootlets force plaster away from its substrate.

Animals create many problems for earthen plasters. Although they favor the organic building materials such as wooden beams for food and nesting, they often inflict severe mechanical damage on plaster surfaces by digging tunnels and building nests. Excrement staining of the plasters is also problematic.

The principle mechanism by which paints on earthen plaster deteriorate is through loss of the mechanical strength. As a result, paints can loose adhesion to the wall, between layers, or internal cohesion whereby the paint disintegrates and powders. Water can also obliterate painted finishes by reactivating clays and washing the plasters away. Organic binders, if and where present, can be affected by biodeterioration, resulting in similar mechanical failure of plasters and paints.

4.7 CONSERVATION TECHNIQUES FOR DETERIORATING PLASTERS

Published research on the conservation of earthen plasters is limited. Giacomo Chiari used a "mixed technique" to stabilize a Pre-Columbian adobe frieze in Peru. He

used ethyl silicate to consolidate the friable plaster followed by injections of Primal AC 33, an acrylic emulsion, to re-adhere the frieze to its adobe block support. Finally, applications of Acryloid were used to consolidate the friable surface.[32] Watson Smith used pieces of plaster which had fallen off the wall to re-adhere loose plaster fragments to the wall. He wet the detached piece just enough to create a workable, slightly sticky paste. He then placed a bit of the paste between the loose fragment and the wall where it acted as an adhesive.[33] Constance Silver conducted a pilot program at Mesa Verde in the early 1980s to determine the most effective methods for stabilizing deteriorating adobe plasters and paints *in situ*. Testing a variety of adhesives and consolidants, she determined that Polyvinyl acetate (PVA) is a viable adhesive for emergency and long-term treatment of friable, detached plasters.[34] Frank Matero and Angelyn Bass researched injection grouting as a means of reattaching lime plasters to adobe walls. She concluded that a hydraulic lime-based grout best met the essential performance criteria identified at the beginning of her research and was physically and chemically compatible with the lime plasters and adobe walls.[35]

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[32]Silver, p. 137-38.

[33]Smith, p. 34-35.

[34]Silver, p. 159. See Section 5.2 for a more detailed description of Silver's research.

[35]Frank G. Matero and Angelyn Bass, "Design and Evaluation of Hydraulic Grouts for the Reattachment of Lime Plasters on Earthen Walls." *Conservation and Management of Archaeological Sites*, 1, no. 2 (1996). The grout is composed, by weight, of 1 part microspheres, 1 part sand, 2 parts hydraulic lime, 1/10 part acrylic emulsion.

Chapter 5

MUG HOUSE: CHARACTERIZATION OF EARTHEN PLASTERS AND MORTARS

Mug House is a medium-sized cliff dwelling with architecture typical of the Classic Pueblo period at Mesa Verde. Archaeological evidence suggests that there were at least three sequential Anasazi construction campaigns or components on the Mug House site. The present structures are almost entirely a product of the most recent campaign and tree ring dates suggest that they were built between 1200 and the late 1270s. Based on the number of rooms in Mug House, archaeologist Arthur Rohn estimates that approximately 20 suites — each comprised of three to nine contiguous rooms and organized around four courtyard units — occupied the site at its peak; the maximum population of Mug House was between 80 and 100 people. The presence of numerous artifacts in the more inaccessible rooms of the upper ledge indicate that Mug House was occupied nearly to capacity up until abandonment around 1300 along with the rest of Mesa Verde.

Kiva C and Room 28 stand adjacent to each other and occupy an important position within Mug House. They are both well sheltered by the cave. Built at approximately the same time, they both belong to the Kiva C courtyard unit (which also includes Rooms 26 and 69) and appear to be closely affiliated with the Kiva D courtyard unit — the two courtyard units may have comprised one kinship group. Together, the Kiva C/D clan occupied a dominant position on the Mug House site. Their ancestors were among the first builders within Mug House, the clan had the largest number of members (based on the number of rooms), occupied a central location within Mug

House, and had the largest and most elaborately decorated kiva, Kiva C.[36]

Kiva C is a typical subterranean kiva. Constructed of sandstone blocks laid up in earthen mortar, the kiva is circular in shape and measures 366 cm (12.5 feet) in diameter. A banquette encircles the kiva interior. A recess on the southwest side above the banquette gives the kiva a keyhole appearance. Six pilasters, which once supported the kiva roof, ring the interior. Inside the kiva is the standard alignment of ventilator, deflector, hearth, and sipapu although they are oriented along the northeast-southwest axis rather than along the north-south axis. The walls of the kiva were plastered multiple times. The present finish is typical of painted kiva designs at Mesa Verde though not of Mug House. It features a bichrome design with a tan upper field and a red lower dado separated by a white band with upward projecting triangles. Evidence of at least two earlier triangle designs exists below the present design. Periodic replastering and painting of kivas was a common practice throughout the Anasazi southwest and probably relates to the ceremonial function of the kivas. This practice was not common in dwelling or storage units. The 700-year-old plasters are amazingly durable but are actively deteriorating and falling off of the wall — a process that has accelerated since Kiva C's excavation in the early 1960s. The major symptoms of plaster deterioration in Kiva C are cracking, blistering, efflorescence, plant growth, and detachment. There are also large areas of plaster loss within the kiva.

Room 28 stands just east of Kiva C; its exterior west wall forms part of the Kiva C courtyard. Room 28 is a rectangular dwelling unit measuring 189 cm (6.2 feet) long

[36]Arthur H. Rohn, *Mug House, Mesa Verde National Park, Colorado* (Washington, D.C.: National Park Service, 1971), pp. 31-41.

by 107–137 cm (3.5–4.5 feet) wide and 168 cm (5.5 feet) high at its tallest point. Like Kiva C, the walls of Room 28 are sandstone blocks laid up in an earthen mortar. The room abuts the back of the cave which forms its back wall. The exterior wall, although partially rebuilt in the 1930s by the National Park Service, is plastered and painted with a bichrome design of a white upper field and a red lower dado. Only one layer of plaster and one layer of paint exist. Deterioration symptoms in Room 28 are similar to those in Kiva C but the plasters are much more stable.

Adobe Cave is a rock shelter located less than 100 yards north of Mug House. Remnants of three rooms and two kivas, which pre-date many of the present Mug House structures, are within the cave and it was clearly part of the Mug House settlement. Evidence of mining in Adobe Cave, the color of the Adobe Cave soil, and close examination of the soil led Rohn to speculate that the Anasazi used Adobe Cave soil, sometimes modified with mesa-top soil, for building and plastering in Mug House, particularly in Kiva C.[37] This was not supported by laboratory analysis of the soil as reported below.

5.1 GENERAL METHODOLOGY

The study of Mug House surface finishes began outside the laboratory. Archival research provided insight into deterioration rates and past stabilization work at Mug House. On-site, an extensive conditions survey and an *in-situ* visual inspection of the plasters led to the establishment of the sequence of finishes. During the site visit, 20

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[37]Ibid, p. 47.

representative samples of plaster, paint, mortar, and soil, primarily from Kiva C, were collected for further investigation.

In the laboratory, characterization of the samples was based on light microscopy and geo-physical tests. Basic physical characteristics of each of the 20 samples were recorded using mounted cross sections examined with reflected light microscopy. Based on the results of this survey, eight samples were selected for further study of micromorphological features using thin section examination in polarized light and bright and dark field illumination.

Due to the limited quantity of sample material and the difficulty of separating plaster layers, geo-physical tests were limited to three gross samples: base-coat plaster from Kiva C, mortar from Room 28, and soil from Adobe Cave. The tests included grain size distribution, plastic limit, liquid limit, soluble salt content, pH, and color. Additional chemical information was gained through x-ray diffraction analysis and scanning electron microscopy with elemental dispersive x-ray analysis.

Paint finishes from both Kiva C and Room 28 were also characterized. Physical characteristics were examined using cross and thin sections, and color matched to a standard color system. Pigment composition was evaluated through the use of micro-chemical spot tests and confirmed with scanning electron microscopy with elemental dispersive x-ray analysis.

5.2 ARCHIVAL RESEARCH

The central files of the National Park Service (1907–1934), National Archives II; the National Anthropological Archives, Smithsonian Institution; and the stabilization records of the Research Center, Mesa Verde National Park, were searched for information and photographs relating to the extent and condition of Mug House plasters before and after excavation. This work was undertaken in an attempt to gauge the deterioration rate of the plasters, particularly since Mug House's excavation in the 1960s, and to learn about past stabilization efforts. From photographic evidence, it seems clear that plaster deterioration in Kiva C has accelerated rapidly since the kiva's excavation. Room 28 plasters are also deteriorating but loss is much less evident. Records and photographs relating specifically to Mug House are rare and more rarely deal specifically with the plasters. From the existing records, however, the following chronology of documentation and stabilization efforts at Mug House was developed.

Chronology of Archaeological Work at Mug House

1890	The Wetherill Brothers discover and explore Mug House. They name the site Mug House after finding several pottery mugs tied together with string.
1891	Gustaf Nordenskiold, with the assistance of John Wetherill, excavates in Mug House for a short period before moving on to other sites around Mesa Verde.
1890–1906	Period of exploration and exploitation of the Mesa Verde cliff dwellings including Mug House.
1906	Mesa Verde National Park established.

1907 First superintendent and rangers appointed to Mesa Verde, ending the period of commercial excavation.

1928 Superintendent Jesse L. Nusbaum leads the West Side Expedition to work on a number of sites on the west side of the park including Mug House. No details of their activities are reported.[38]

1932 Harry T. Getty dates construction of Mug House to A.D. 1066 based on dendrochronological analysis of wooden beam specimens.[39]

1935 J. A. Lancaster and his stabilization crew spend three weeks at Mug House leveling rubble fill and rebuilding support walls using a variety of cemetitious mortars. Lancaster keeps a daily log and takes an illustrative set of before and after photographs.[40]

The Lancaster team discovers a burial site in Adobe Cave while removing soil to make mortar. The burial site is excavated by Paul R. Franke and Robert F. Burgh.[41]

1941 Deric Nusbaum of the Gila Pueblo Survey Team collects and dates additional beam samples for Mug House using dendrochronology. He finds tree-ring dates ranging from A.D. 848 to 1236.[42]

1960–62 Arthur H. Rohn and an archaeological field crew fully excavate and stabilize Mug House over two summers for the purpose of opening the site to the public.[43] Unstable walls are rebuilt using a Portland cement bedding mortar and a pale imitative clay pointing mortar.

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[38]Jesse L. Nusbaum, *Superintendent's Monthly Reports, 1928,* Mesa Verde National Park.

[39]Harry T. Getty, "New Dates from Mesa Verde," *Tree-Ring Bulletin* 1, no. 3 (1935): 21-23, and "New Dates for Spruce Tree House, Mesa Verde," *Tree-Ring Bulletin* 1, no. 4 (1935): 28-29.

[40]J.A. Lancaster's field notes and photographs are at the Research Center, Mesa Verde National Park.

[41]Paul R. Franke, *Archeological Investigations of 'Adobe Cave,'* October 1935, Records of the National Park Service, Mesa Verde National Park, National Archives II, College Park, MD, Record Group 79, Archeological Discoveries, 740-02.1.

[42]Results reported in a memo dated January 13, 1942, from Jesse L. Nusbaum, Senior Archaeologist, Department of the Interior, Santa Fe Regional Office, to the Superintendent, Mesa Verde National Park. Records of the National Park Service, Mesa Verde National Park, National Archives II, College Park, MD, Antiquities (General), Archaeology, 732-740.02.

[43]Arthur H. Rohn, *Mug House, Mesa Verde National Park, Colorado* (Washington, D.C.: National Park Service, 1971).

1981 Constance S. Silver, with the assistance of Paul Schwartzbaum, conducts a pilot conservation treatment at Mug House to determine the most effective methods for stabilizing deteriorating adobe plaster and paint on site. Confining her tests to Kiva C and the west wall of Room 28, she uses a water-alcohol mixture and Japanese tissue paper to soften deformed plasters and mold them back into plane with the wall. She also experiments with injections of PVA solution as an adhesive for detached plasters. For consolidating friable plaster, she tests Tegovakon T, an alkoxysilane, and Acryloid B-72, an acrylic resin. During the treatment phase, she judges Acryloid B-72 to be an unacceptable consolidant because it dramatically darkens the decorative finishes on the plaster. During this pilot treatment phase, Silver also experiments with cleaning techniques. She successfully removes surface accumulations of crystallized salts, plant debris, and dirt through gentle brushing. She removes additional salt deposits with paper pulp wetted with a saturated solution of bicarbonate of soda applied to the affected area for five hours.[44]

1985 Constance Silver conducts a survey of the extant plaster at Mug House. The survey includes a visual inspection, written description, and photographic documentation of each plastered wall, including an estimate of the square footage of plaster and an assessment of the plaster's condition. Her report includes the following evaluation of the plaster in Kiva C and on the west exterior wall of Room 28.[45]

Room	Plaster Retained (sq. ft.)	General Condition of Plaster (sq. ft.)			Surface Condition of Plaster (sq. ft.)		
		Good	Fair	Poor	Good	Fair	Poor
Kiva C	98.0	0	19.6	78.4	29.4	29.4	39.2
Rm. 28	12.0	0	3.6	8.4	0	3.6	8.4

Silver also reviews her 1981 pilot conservation treatments and determines that the use of PVA as an adhesive for painted earthen plasters is a viable

[44]Constance S. Silver, "1981 Report on the Development of Methods for the Conservation of Pueblo Indian Mural Paintings in the American Southwest," February 1981. Report in the Curatorial files of the Research Center, Mesa Verde National Park.

[45]Constance S. Silver, "Summary of the Results of the 1985 Project Survey of Plaster and Rock Art at Mesa Verde National Park: MV 1229 - Mug House Ruin," vol. 6 (December 1985). Report in the Curatorial files of the Research Center, Mesa Verde National Park.

emergency and long-term approach to treating friable, detached plasters.[46]

1987 Constance Silver includes the results of her research at Mug House and other sites in the southwest in her Master's thesis.[47]

1965–95 Various pointing and capping campaigns by National Park Service stabilization crew with varying amounts of photo-documentation.

1992 Mary L. Griffitts studies plasters and mortars from Step House and Mug House using x-ray diffraction analysis. She finds that quartz is the major component of both the mortars and plasters. She finds calcite, feldspar, kaolinite, gypsum, and mica in lesser quantities.[48]

1992–94 Kathy Fiero and Angelyn Bass photograph the interior of Kiva C for future conservation.

1995–96 University of Pennsylvania summer field program conducts an extensive conditions survey of the plasters at Mug House using detailed photographs and graphic overlays.

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[46]Constance S. Silver, "Architectural Finishes of the Prehistoric Southwest: A Study of the Cultural Resource and Prospects for its Conservation," (Master's Thesis, Columbia University, 1987), p. 159.

[47]Ibid.

[48]Letter from Mary L. Griffitts to Allen Bonhart, March 27, 1990, Mesa Verde Research Center, Mesa Verde National Park.

5.3 ON-SITE OBSERVATIONS

On-site investigation consisted of a conditions survey, finishes survey, and sample collecting.

An extensive conditions survey was conducted as part of the University of Pennsylvania's summer field program. This survey documented the major symptoms of plaster deterioration at Mug House with photographs and graphic overlays. Kiva C and Room 28 served as prototypes. Major symptoms of deterioration observed in both spaces include cracking, blistering, efflorescent salt deposits, plant growth, and detachment. Large areas of total loss exist, especially in the areas just below the banquette and just above the floor.

The sequence of finishes in both Kiva C and Room 28 were documented through a visual survey. Surface deterioration in both rooms revealed the sequence of plaster and paint layers in many locations. Plaster surfaces were carefully examined with the unaided eye. By counting layers and noting features, 32 stratigraphies were observed by non-destructive means. (See Appendix A.)

During this survey, surface marks such as striations, incisions, handprints, etc. in the plaster surface were noted as evidence of application and post-application procedures. Careful comparison of the collected stratigraphies shed light on the finishes history of Kiva C and Room 28, and on Anasazi masonry finishing practices. Based on the results of the survey, the following speculative finishes history was created (See Appendix C for illustration), and later corroborated by laboratory analysis of samples.

Kiva C exhibits a complex sequence of finishes. Below the present finish lie a

minimum of 8 and a maximum of 14 additional layers. Initially, the walls of Kiva C were finished with unadorned tan-colored plaster. Typical of Anasazi base coats, the first thick coat of plaster, applied directly to the stone, varies in thickness from 3 to 20 mm to compensate for unevenness in the sandstone masonry. Irregularities in Kiva C's masonry are more pronounced than in the other Mug House kivas. The base coat is significantly thicker below the banquette than on the pilasters, presumably to level the wall surface. Heavy soot, produced by the open hearth fires and deposited on the plaster, suggests that the base coat was exposed for a prolonged period of time. Fire-reddening on the base coat, visible in many areas of the kiva, indicates that the plaster was exposed to high localized heat, suggesting a damaging fire early in its history. Following the fire, the entire kiva was replastered — probably several times — with similar monochromatic tan plaster applied in layers notably thinner than the base coat. Soot differentiates these subsequent campaigns.

Later, the walls of Kiva C were uniformly decorated white, including the pilasters and banquette. A white stratum, typically the third or fourth layer of the stratigraphy, is found throughout the kiva. It is consistently followed by a sequence of tan and white layers. The absence of soot between the white layers and the tan layers that immediately proceed them suggests that the monochromatic white finishes were applied as an adornment to fresh tan plaster.

Subsequently, a bichrome scheme was introduced in Kiva C, usually found around layer six or seven, and features an orange lower dado with triangles and dots projecting into a white upper field. This effect was achieved by covering the kiva interior with

fresh tan plaster and painting it white; then the triangle design was etched into the plaster and the dark orange finish applied with a brush. The triangle peaks, which vary in height, rise on average 17 ½" above the kiva floor. Inconsistencies in stratigraphies below 16" fail to establish whether this orange field was merely a band of color encircling the central portion of the wall, or whether the entire lower dado was orange.

A similar bichrome triangle and dot design was applied during the next replastering campaign. The color field of this period was a brighter orange color and clearly incorporated the entire lower dado. Eventually, the white upper field was replastered and again painted white while the orange dado was left intact. A sequence of tan plaster and orange paint that appears only in isolated areas of the lower wall indicates that repairs were made to the dado plaster, possibly at the same time that the upper field was renewed.

The last decorative scheme in Kiva C before abandonment is the most elaborate, featuring a red dado and tan upper field separated by a white band with upward-projecting triangles. Prior to being decorated, the entire kiva was probably refinished with a fresh coat of plaster and smoothed with a brush or skin-wrapped hands. The red paint on the dado was applied directly to the tan plaster with no intervening layer of white. The white band and triangles are etched into the plaster as before and the finish applied with a brush.

Room 28, roughly contemporary with Kiva C, displays only one decorative scheme: a bichrome design with a red dado and white upper field. Stratigraphies revealed that the wall has only two finish layers, a thick base coat of tan plaster and a

single bichrome finish layer of white above red design.

The finishes survey guided sample taking. Twenty representative specimens of plaster, paint, and mortar from Kiva C and Room 28, and soil from Adobe Cave were collected. Particular attention was paid to the most recent finishes, and to collecting complete stratigraphies. After removal, samples were taken to the Architectural Conservation Laboratory of the University of Pennsylvania for further investigation. (See Sample list in Appendix C.)

5.4 LIGHT MICROSCOPY

Reflected and transmitted visible light microscopy was used to gain a basic understanding of the structure and composition of the plasters, paints, and mortars from Mug House. Data compiled from the thin sections was compared with other test results to determine similarities and differences between plaster layers and between samples.

5.4.1 *Cross Sections*

Examination of the samples began with reflected light microscopy. A portion of each of the samples was embedded in Bioplast™, a commercial polyester/methacrylate resin polymerized with a methyl ethyl ketone peroxide catalyst, and cured under a tungsten lamp. The solidified samples were sectioned with a Buehler Isomet™ low speed saw and polished with 400 and 600 grit abrasive paper and a felt cloth. Because the samples were water sensitive, stoddard solvent was used as the lubricant during the polishing process.

The embedded, polished cross sections were examined in normal reflected quartz-halogen light using a Nikon SMZ-U variable magnification stereo microscope and a Nikon Optiphot 2. Basic stratigraphies and observations were recorded: color, number of layers, layer thickness, texture, inclusions, and unusual features were noted.

Under the microscope the various layers of tan plaster from Kiva C are similar. Fine particles of clay and silt form the plaster's brown matrix. A heterogeneous mixture of black, red, yellow, and clear grains of various shapes and sizes, distributed uniformly throughout the layer, impart additional color and the plaster's coarse texture. Plaster

from Room 28 and mortar from both rooms are similar to Kiva C's plaster, but contain many large inclusions. The mortars are less densely compacted than the plasters. In contrast to the plasters and mortars, the colored finishes, composed of monochromatic fine clay particles with few inclusions, are smooth and homogenous. These layers appear as thin washes on the relatively thick plaster layers. Although plaster layers vary in thickness both within samples and from sample to sample, they are consistently thicker than the colored washes. Similarly, the white finish layers are consistently thicker than the red and orange layers. The horizon between the plaster and finish coat is, in many cases, ambiguous, suggesting that the finishes were routinely applied when the plaster was still damp. Soot layers appear on many of the finish layers, verifying their exposure as final finishes. A fragment of wood was observed in a sample of bedding mortar from the upper lintel. The Adobe Cave soil shares the same brown matrix, but lacks the larger sand particles and has a finer texture.

5.4.2 *Thin Sections*

Based on the information obtained from the cross sections, eight samples were selected for further investigation. The selected samples included mortar, plaster, and paint specimens from both Kiva C and Room 28, and soil from Adobe Cave.

Petrographic Laboratory of Newark, Delaware, prepared the thin sections. They were examined using a Nikon Alphaphot 2 YS2 microscope with pseudo-reflected dark field illumination and transmitted light. Micromorphological features of each layer of the eight samples were noted including abundance of coarse particles, degree of sorting,

particle shape, porosity, surface texture, and related distribution.[49] Particle ratio, degree of sorting, and particle shape were determined by comparing the sample with charts. (See Appendix D for data sheets.)

Thin section examination confirmed the conclusions drawn from the cross sections. In general, it was observed that the plasters and finishes are composed of a homogenous matrix and a heterogeneous coarse fraction. They were applied in layers of even thickness with irregular surfaces. Finishes, however, are more likely than plaster layers to have a regular surface. Soot generally appears only on the earlier layers of tan plaster, suggesting that plaster renewal became more frequent once decorative finishes began to be applied to the wall. The horizon between preparatory and finish layers is often difficult to distinguish in thin section, again indicating that finishes were applied directly to wet plaster. The ratio of coarse to fine particles is the principle micromorphological difference between the plasters, the finishes, and the mortars. The plasters have an average ratio of 60:40 coarse to fine and appear relatively coarse, while the finishes average a 10:90 ratio of coarse to fine and appear more homogenous and smooth. The mortars and the Room 28 plaster are slightly more coarse than the plasters and contain a notable fraction of large coarse grains absent from the Kiva C plasters. In all other respects, however, the red and orange finishes more closely resemble the plasters than the white finishes in terms of the sphericity, roundedness, and degree of sorting of the course fraction. No organic particles were observed in any of the samples.

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[49]P. Bullock, et al, *Handbook for Soil Thin Section Description* (Albrighton, Wolverhampton, 1985), pp. 9-38; and Marie Agnes Courty, Paul Goldberg, and Richard Macphail, *Soils and Micromorphology in Archaeology* (Cambridge: Cambridge University Press, 1989), pp. 73-74.

The soil from Adobe Cave has a coarse to fine ratio of 10:90. The color and texture of its fine fraction resembles the plasters. The coarse fraction, which is significantly less abundant than in the plasters and mortars, is composed of black, orange, and red grains that are round, smooth, and well sorted. (See data sheets for information on individual samples.)

5.5 GRAIN SIZE DISTRIBUTION

Soils consist primarily of four types of particles: clay, silt, sand, and gravel. The American Society for Testing and Materials (ASTM) defines these particles principally by their diameter, as shown below.[50]

Gravel	4.75 mm - 76.2 mm
Sand	75 μm - 4.75 mm
Silt	2 μm - 75 μm
Clay	less than 2 μm

Soil particle behavior depends largely on its diameter, although mineralogy also plays a role. Clay and, to a limited extent, silt form the matrix of the soil by binding the larger particles together. Clay content also affects the plasticity and workability of a soil and controls the soil's tendency to swell in the presence of water. Sand and gravel act as fillers and help to control shrinkage.

Grain size distribution affects the behavior and durability of earthen plasters and mortars. Clayey soils, for example, are more plastic and easier to manipulate than sandy soils but they tend to shrink and crack while drying. Research suggests that the most dimensionally stable adobe blocks contain 70% sand and between 9% and 28% clay. The National Bureau of Standards recommends that adobe building blocks contain 70–80% sand and 20–30% of equal parts of silt and clay.[51]

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[50]ASTM D422 - Standard Test Method for Particle-size Analysis of Soils, (Philadelphia: ASTM, 1990).

[51]James R. Clifton, *Preservation of Historic Adobe Structures: A Status Report* (Washington, D.C.: U.S. Government Printing Office, 1977), p. 4.

Grain size analysis groups soil particles into size ranges and determines their relative proportions. The test was executed in two stages: a sieving procedure for the coarse sand and gravel fraction of the soil, and a sedimentation procedure for the fine clay and silt fraction.[52]

Due to the limited quantity of sample material, the test was run on only three samples: base coat plaster from Kiva C, mortar from Room 28, and soil from Adobe Cave. Data obtained from the two procedures is presented below.

[52]Jeanne Marie Teutonico, *A Laboratory Manual for Architectural Conservators* (Rome: ICCROM, 1988), pp. 73-95.

KIVA C PLASTER

Total Weight of Sample	62.0g
Weight of Coarse Material	31.6
Weight of Fine Material	30.4

SIEVE ANALYSIS OF KIVA C PLASTER				
Sieve No.	**Dia.**	**Wt. Retained**	**% Retained**	**% Passing**
8	2.36 mm	0	0	100
16	1.18 mm	0	0	100
30	600 μm	0	0	100
50	300 μm	0.1	0.2	99.8
100	150 μm	5.4	8.7	91.1
200	75 μm	24.9	40.2	50.9
Pan		0.5	0.8	50.1
TOTAL WEIGHT PASSED THROUGH SIEVES = 30.9 g				

GRAIN SIZE DISTRIBUTION - KIVA C PLASTER
Hydrometer Method

Date	Time of Reading	Elapsed Time (Minutes)	Temp. (°C)	Actual Hydrom. Reading R_a	Corrected Hydrom. Reading R_c	% Finer	Hydrom. Corrected Meniscus R	L from Table	L/t	K from Table	Particle Dia. (mm)
11/20	6:55 pm	1/2	22°	33	30.9	49.3	34	10.7	21.4	0.0131	0.0606
	6:56	1		31	28.9	46.1	32	11.1	11.1		0.044
	6:57	2		29	26.9	43.0	30	11.4	5.7		0.031
	6:59	4		28	25.9	41.1	29	11.5	2.875		0.022
	7:03	8		27	24.9	39.8	28	11.7	1.4625		0.016
	7:10	15		26	23.9	38.2	27	11.9	0.793		0.012
	7:35	40		25	22.9	36.6	26	12.0	0.3		0.0072
	8:05	70		24	21.9	35.0	25	12.2	0.174		0.0055
	8:55	120		23	20.9	33.4	24	12.4	0.103		0.0042
	9:40	225		23	20.9	33.4	24	12.4	0.055		0.0031
11/21	12:05 am	310		22	19.9	31.8	23	12.5	0.040		0.0026
	10:40 am	945		20	17.9	28.6	21	12.9	0.014		0.0016
	6:55 pm	1440		19	16.9	27.0	20	13.0	0.009		0.0012
11/22	6:55 pm	2880		18	15.9	25.4	19	13.2	0.0046		0.00089
11/23	3:00 pm	4085		17	14.9	23.8	18	13.3	0.0033		0.00075
11/24	6:55 pm	5760		17	14.9	23.8	18	13.3	0.0023		0.00063
11/26	11:30 am	8195		17	14.9	23.8	18	13.3	0.0016		0.00052

ROOM 28 MORTAR

Total Weight of Sample	62.6g
Weight of Course Material	25.9
Weight of Fine Material	36.7

SIEVE ANALYSIS OF ROOM 28 MORTAR				
Sieve No.	**Dia.**	**Wt. Retained**	**% Retained**	**% Passing**
8	2.36 mm	2.0 g	3.2	96.8
16	1.18 mm	0.1 g	0.2	96.6
30	600 μm	0 g	0	96.6
50	300 μm	0.1 g	0.2	96.4
100	150 μm	5.3 g	8.5	87.9
200	75 μm	17.7 g	28.3	59.6
Pan		0.4 g	0.6	59.0
TOTAL WEIGHT PASSED THROUGH SIEVES = 25.6 g				

GRAIN SIZE DISTRIBUTION - ROOM 28 MORTAR
Hydrometer Method

Date	Time of Reading	Elapsed Time (Minutes)	Temp. (°C)	Actual Hydrom. Reading R_a	Corrected Hydrom. Reading R_c	% Finer	Hydrom. Corrected for Meniscus R	L from Table	L/t	K from Table	Particle Dia. (mm)
11/20	6:15 pm	1/2	22°	38	35.9	56.8	39	9.9	19.8	0.0131	0.058
↓	6:16	1	↓	34	31.9	50.4	35	10.5	10.5	↓	0.042
	6:17	2		30	27.9	44.1	31	11.2	5.6		0.031
	6:19	4		28	25.9	41.0	29	11.5	2.88		0.022
	6:23	8		26	23.9	37.8	27	11.9	1.49		0.016
	6:30	15		25	22.9	36.2	26	12.0	0.8		0.012
	6:55	40		24	21.9	34.6	25	12.2	0.305		0.0072
	7:15	60		23	20.9	33.1	24	12.4	0.207		0.0060
	8:15	120		22	19.9	31.5	23	12.5	0.104		0.0042
	9:40	205		22	19.9	31.5	23	12.5	0.061		0.0032
11/21	12:15 am	360		21	18.9	29.9	22	12.7	0.035		0.0025
↓	10:40 am	985		20	17.9	28.3	21	12.9	0.013		0.0015
	6:15 pm	1440		19	16.9	26.7	20	13.0	0.0090		0.0012
11/22	6:15 pm	2880		18	15.9	25.1	19	13.2	0.0046		0.00089
11/23	3:00 pm	4125		18	15.9	25.1	19	13.2	0.0032		0.00074
11/24	6:15 pm	5760		17	14.9	23.6	18	13.3	0.0023		0.00063
11/25	11:30 am	8235		17	14.9	23.6	18	13.3	0.0016		0.00052

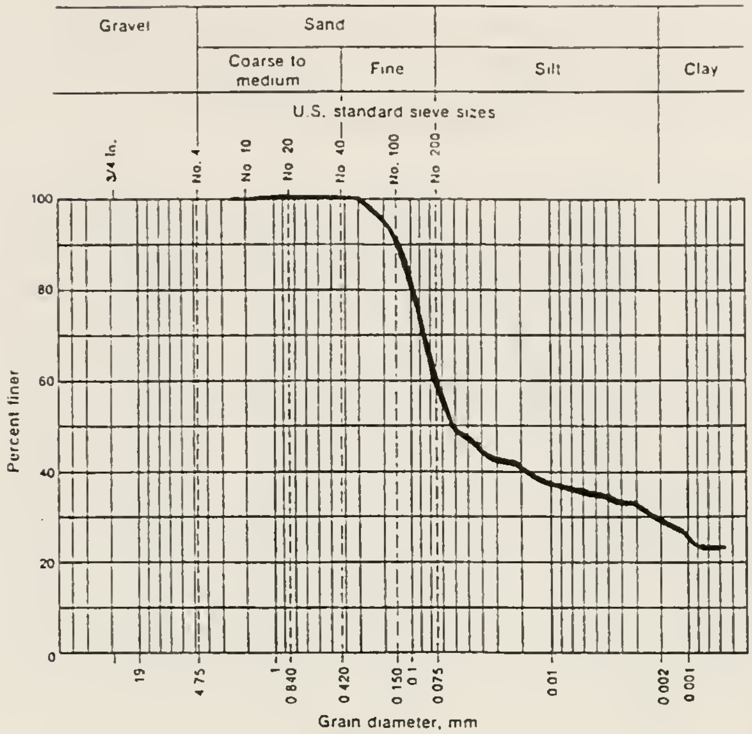
Total Weight of Sample	60.1g
Weight of Course Material	3.4
Weight of Fine Material	56.7

SIEVE ANALYSIS OF ADOBE CAVE SOIL				
Sieve No.	**Dia.**	**Wt. Retained (grams)**	**% Retained**	**% Passing**
8	2.36 mm	0	0	100
16	1.18 mm	0	0	100
30	600 μm	0.02	0.03	99.9
50	300 μm	0.01	0.02	99.9
100	150 μm	0.20	0.3	99.7
200	75 μm	2.9	4.8	94.9
Pan		0.30	0.5	94.4
TOTAL WEIGHT PASSED THROUGH SIEVES = 3.43 g				

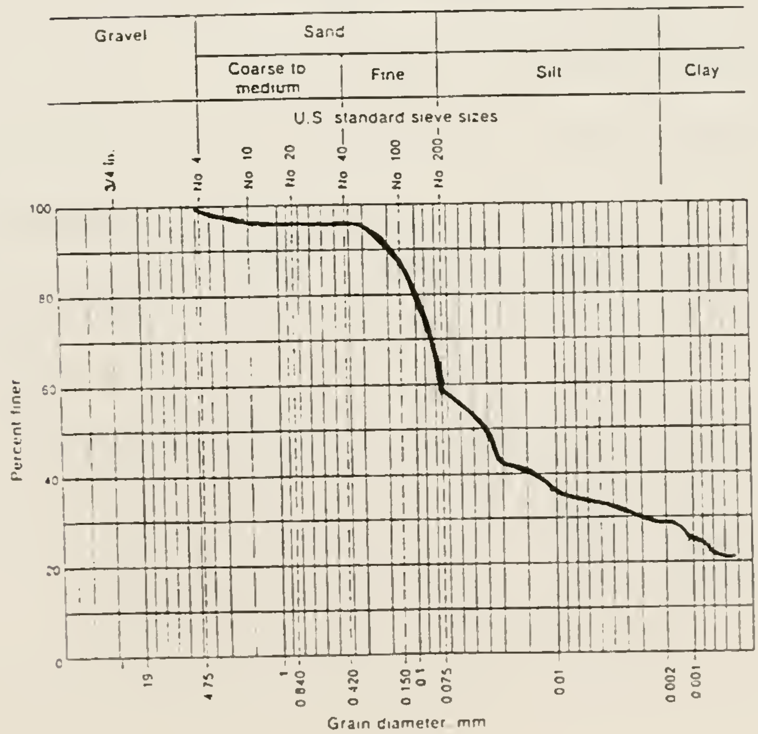
GRAIN SIZE DISTRIBUTION - ADOBE CAVE
Hydrometer Method

Date	Time of Reading	Elapsed Time (Minutes)	Temp. (°C)	Actual Hydrom. Reading R_a	Corrected Hydrom. Reading R_c	% Finer	Hydrom. Corrected for Meniscus R	L from Table	L/t	K from Table	Particle Dia. (mm)
12/8	6:05 pm	1/2	20°	57	54.5	88.9	58	6.8	13.6	0.0133	0.049
↓	6:06	1	↓	54	51.5	84.0	55	7.3	7.3	↓	0.036
	6:07	2		51	48.5	79.1	52	7.8	3.9		0.026
	6:09	4		47	44.5	72.6	48	8.4	2.1		0.019
	6:13	8		43	40.5	66.1	44	9.1	1.138		0.014
	6:20	15		39	36.5	59.6	40	9.7	0.647		0.012
	6:45	40		35	32.5	53.0	36	10.4	0.26		0.0068
	7:05	60		32	29.5	48.1	33	10.9	0.182		0.0057
	8:05	120		29	25.5	41.6	30	11.4	0.095		0.0041
	10:05	240		26	23.5	38.3	27	11.9	0.050		0.0030
12/9	12:10 am	365	19°	24	21.2	34.6	25	12.2	0.033	0.0134	0.0026
↓	1:05 am	420	18°	23	20	32.6	24	12.4	0.0295	0.0136	0.0023
	9:10 am	905	19°	21	18.2	29.7	22	12.7	0.014	0.0134	0.0016
	5:40 pm	1415	18°	20	17	27.7	21	12.9	0.009	0.0136	0.0013
12/10	11:10 am	2465	↓	17	14	22.8	18	13.3	0.005	↓	0.00096
12/11	12:35 am	3270	17°	15.5	12.5	20.4	16.5	13.5	0.004		0.0086
↓	11:30 am	3925	19°	15	12.2	21.1	16	13.7	0.0035	0.0134	0.00079

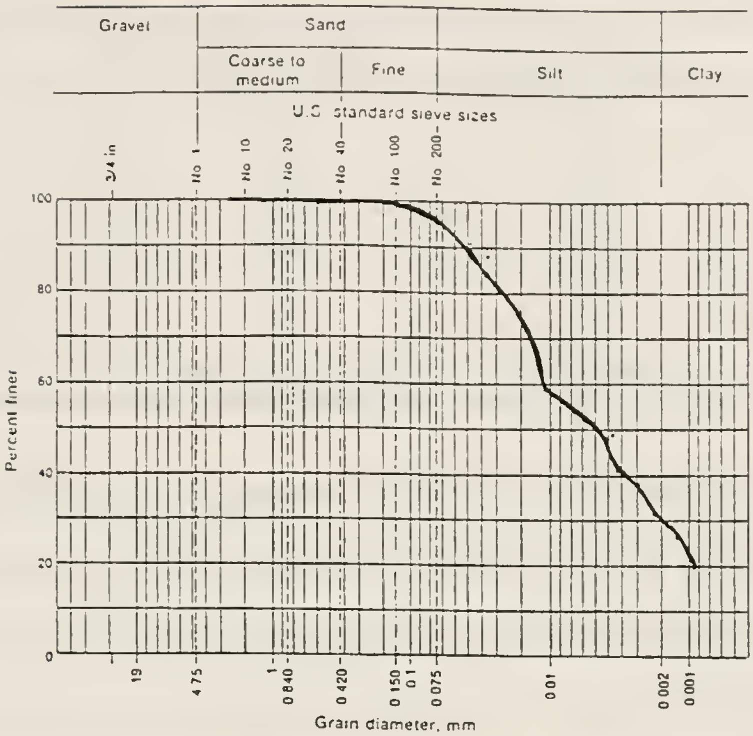
KIVA C PLASTER



ROOM 28 MORTAR



ADOBE CAVE SOIL



The test results are summarized in the following table:

	Kiva C Plaster	Room 28 Mortar	Adobe Cave Soil
Clay	30%	29%	30%
Silt	21%	31%	65%
Fine Sand	49%	36%	5%
Coarse Sand	0%	4%	0%
Soil Type	Sandy Clay Loam	Clay Loam	Silty Clay

All three soils contain approximately 30% clay, a relatively high clay content for any soil. This suggests that the soils would readily attract and hold water; be easily worked as building materials; and be subject to extreme expansion upon wetting, and shrinkage upon drying. The soil profiles of the Kiva C plaster and the Room 28 mortar are similar; both are clay loams. The plaster has a high sand content (approximately 50%) composed entirely of fine grains which would help control shrinkage and cracking during the drying process. The Room 28 mortar is probably less dimensionally stable because it has a lower sand content (40%) although it contains a notable fraction of very large coarse-sized grains which are entirely absent from the plaster. Although it would have less shrinkage resistance than the plaster, this was probably less important since its function is structural — to bind the sandstone wall together — rather than aesthetic and insulative like the plaster surface coating. The Adobe Cave soil is a silty clay and contains only 5% sand, all fine-sized grains, and would offer no resistance to shrinkage. The grain size distribution strongly suggests that the unmodified Adobe Cave soil is not the source of soil for the plasters or mortars in Room 28 or Kiva C.

5.6 PLASTIC LIMIT

Soils vary widely in their absorptive qualities. A dry soil behaves like a solid. As the water content increases, the soil becomes gradually more paste-like and moldable until, at high water content, soil behaves like a liquid. The water-content boundary at which soil changes phase from a plastic paste to a semi-solid state is known as the plastic limit.

In order to determine the plastic limit of the Mug House samples,[53] soil was crushed with a rubber-tipped pestle and passed through a No. 40 (425 μm) sieve. The mortar proved to be very difficult to crush; a chisel and hammer were necessary to break it into small pieces before it could be crushed. The sieved soil was mixed with enough deionized water to form a plastic ball. A few grams of the plastic soil were repeatedly rolled into a thread approximately 3 mm in diameter. This process drives the water from the sample. The process was repeated until the thread broke before reaching the 3 mm diameter — it now lacked the plasticity needed to sustain its cohesion at that diameter. The thread fragments were weighed, oven dried, and weighed again. The plastic limit of each sample was calculated according to the formula:

$$\text{Plastic Limit} = \frac{\text{Mass of Water}}{\text{Mass of Oven Dried Soil}} \times 100$$

The procedure was repeated four times for each sample. The results appear below.

[53]ASTM D4318-84 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, (Philadelphia: ASTM, 1990) and Teutonico, pp. 96-101.

PLASTIC LIMIT OF SOILS

KIVA C PLASTER					
Sample Number	1	2	3	4	Mean
Wt. Wet Soil + Cont. (M_2)	8.4g	9.4	7.9	9.7	8.9
Wt. Dried Soil + Cont. (M_3)	7.5	8.4	7.1	8.7	7.9
Water Loss (M_2 - M_3)	0.9	1.0	0.8	1.0	0.9
Wt. Container (M_1)	2.6	2.6	2.5	2.6	2.6
Wt. Dried Soil (M_3 - M_1)	4.9	5.8	4.6	6.4	5.4
Plastic Limit $\frac{(M_2 - M_3)}{(M_3 - M_1)} \times 100$	18.4	17.2	17.4	16.4	17.4
Mean Plastic Limit = 17.4 %					

ROOM 28 MORTAR					
Sample Number	1	2	3	4	Mean
Wt. Wet Soil + Cont. (M_2)	6.3g	7.2	10.0	7.0	7.6
Wt. Dried Soil + Cont. (M_3)	5.6	6.3	8.9	6.2	6.8
Water Loss (M_2 - M_3)	0.7	0.8	1.1	0.8	0.9
Wt. Container (M_1)	1.6	1.6	1.6	1.6	1.6
Wt. Dried Soil (M_3 - M_1)	4.0	4.8	7.3	4.6	5.2
Plastic Limit $\frac{(M_2 - M_3)}{(M_3 - M_1)} \times 100$	17.5	19.1	15.1	17.4	17.3
Mean Plastic Limit = 17.3 %					

ADOBE CAVE SOIL					
Sample Number	1	2	3	4	Mean
Wt. Wet Soil + Cont. (M_2)	12.4g	10.5	9.0	8.4	10.1
Wt. Dried Soil + Cont. (M_3)	9.7	7.9	7.1	6.8	7.9
Water Loss (M_2 - M_3)	2.7	2.5	1.9	1.6	2.2
Wt. Container (M_1)	2.7	2.6	2.6	2.8	2.7
Wt. Dried Soil (M_3 - M_1)	7.0	5.3	4.5	4.0	5.2
Plastic Limit $\frac{(M_2 - M_3)}{(M_3 - M_1)} \times 100$	38.6	47.2	42.2	40.0	42.0
Mean Plastic Limit = 42.0%					

The test results showed that the Kiva C plaster and the Room 28 mortar have very similar mean plastic limits of approximately 17% while the Adobe Cave soil has much higher mean plastic limit of 42%. The Adobe Cave soil requires the addition of a much greater quantity of water than either the Kiva C soil or the Room 28 soil before it transforms from a dry, solid mass into a plastic, workable material. This is undoubtedly related to the high silt content and lack of sand in the Adobe Cave soil, because clays and silts attract and hold water more readily than sands. Consequently, it takes a greater quantity of water to get a soil with a high clay and silt content to change physical states. This suggests that the Adobe Cave was not the soil source for the plaster and mortar samples, at least in an unmodified state, because of the great difference in the mean plastic limits, but also because the Adobe Cave soil would have required so much more water to make it plastic and workable. Not only was water an extremely scarce and precious resource, but the large quantity of water would have promoted shrinkage and

cracking of a pure Adobe Cave soil plaster, although this may have been partially controlled by carefully monitoring the amount of water used. The divergent mean plastic limits of the Adobe Cave samples, and the Kiva C and Room 28 samples suggests that Adobe Cave was not the sole source for the plaster and mortar samples, at least in its unmodified state. But the high plastic limit of the Adobe Cave sample — and its much greater water requirement to make a workable plaster, make the Adobe Cave soil an unlikely source for any plaster in the water-scarce Mesa Verde environment.

5.7 LIQUID LIMIT

The liquid limit is defined as the water-content boundary between the plastic and liquid states. It was determined[54] by placing a portion of the crushed, sieved, plastic soil remaining from the plastic limit test in the cup of a Casagrande device and dividing it in half with a grooving tool. The cup was lifted and dropped at the rate of two drops per second until the two halves of the soil cake slumped together, closing the groove over a distance of 13 mm. A sample was then taken across the diameter of the soil cake at a right angle to the groove. The sample was weighed, oven-dried, and reweighed. The moisture content at each drop count was calculated according to the formula:

$$\%\ Moisture = \frac{(Wet\ Soil + Container) - (Dry\ Soil + Container)}{(Dry\ Soil - Container)} \times 100$$

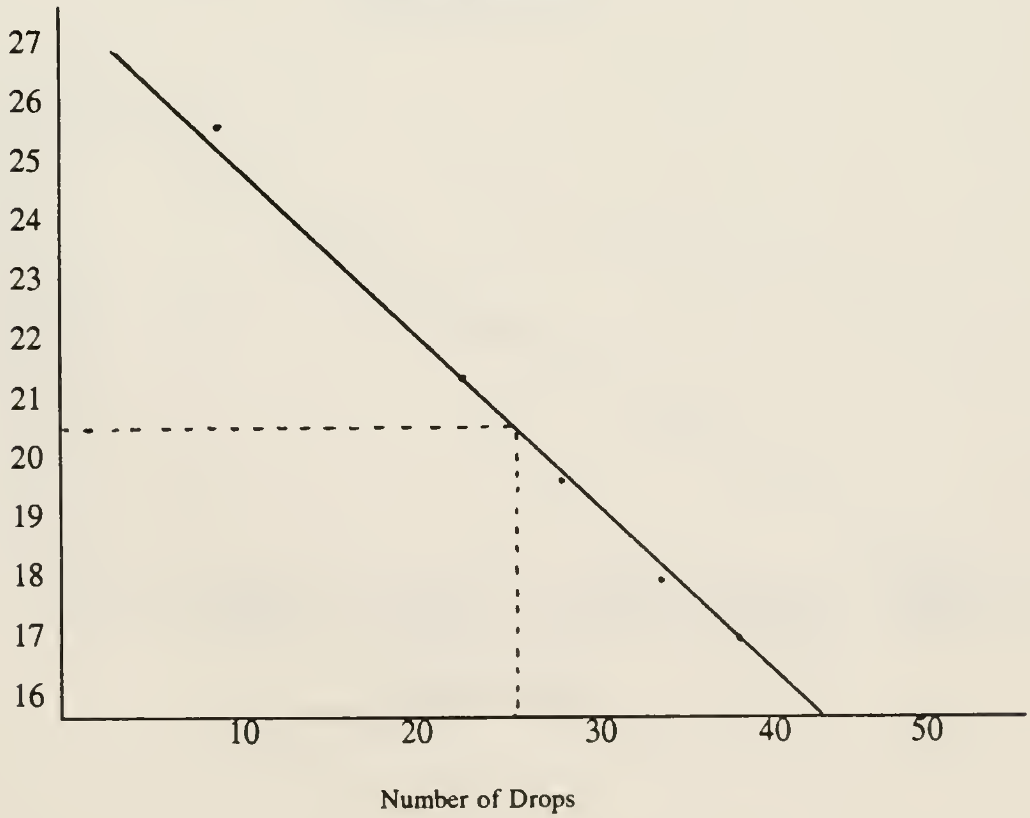
The procedure was repeated five times for each sample. Water was added to the soil between each procedure; the samples became increasingly wet as the test proceeded. The results were graphed to determine the liquid limit of each sample, defined as the moisture content at a drop count of 25. The results appear in the following tables.

[54]ASTM D4318-84 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, (Philadelphia: ASTM, 1990) and Teutonico, pp. 102-110.

MOISTURE CONTENT OF SOILS

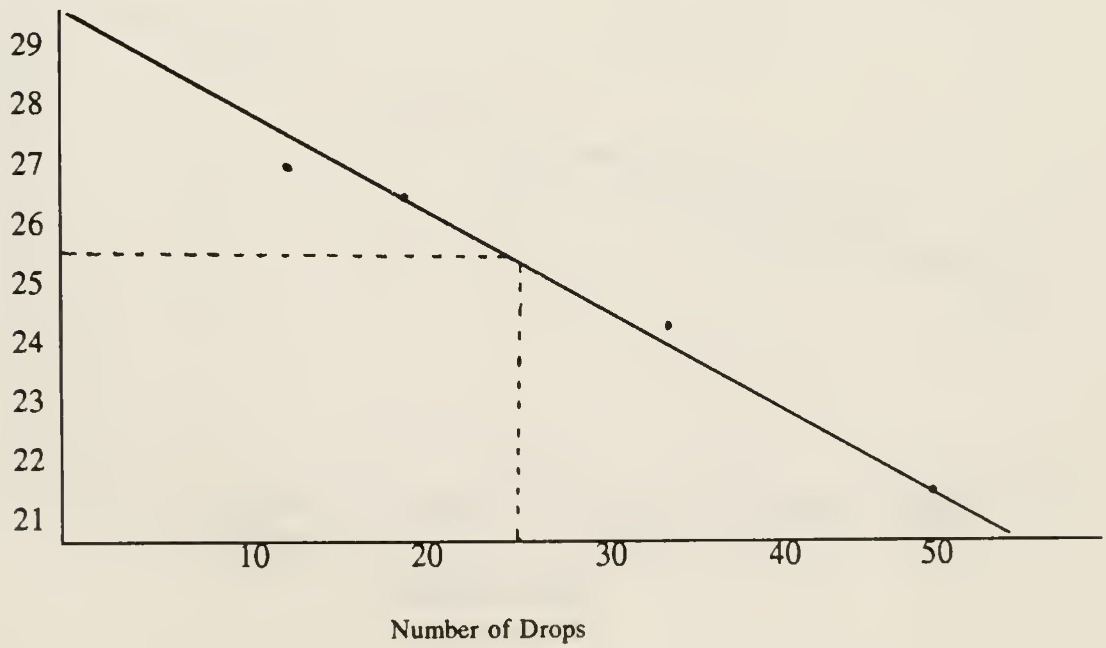
KIVA C PLASTER					
Container	A	B	C	D	E
Number of Drops	38	34	28	22	7
Wt. Wet Soil + Cont. (M_2)	13.99g	10.00	11.70	13.53	10.59
Wt. Dry Soil + Cont. (M_3)	12.36	8.75	10.04	11.6	8.77
Water Loss (M_2 - M_3)	1.63	1.25	1.66	1.93	1.82
Wt. Container (M_1)	2.62	1.68	1.65	2.70	1.70
Wt. Dry Soil (M_3 - M_1)	9.74	7.07	8.39	8.9	7.07
Moisture Content % $\frac{(M_2 - M_3)}{(M_3 - M_1)} \times 100$	16.8	17.7	19.8	21.7	25.7
Mean Moisture Content = 21%					

FLOW CURVE



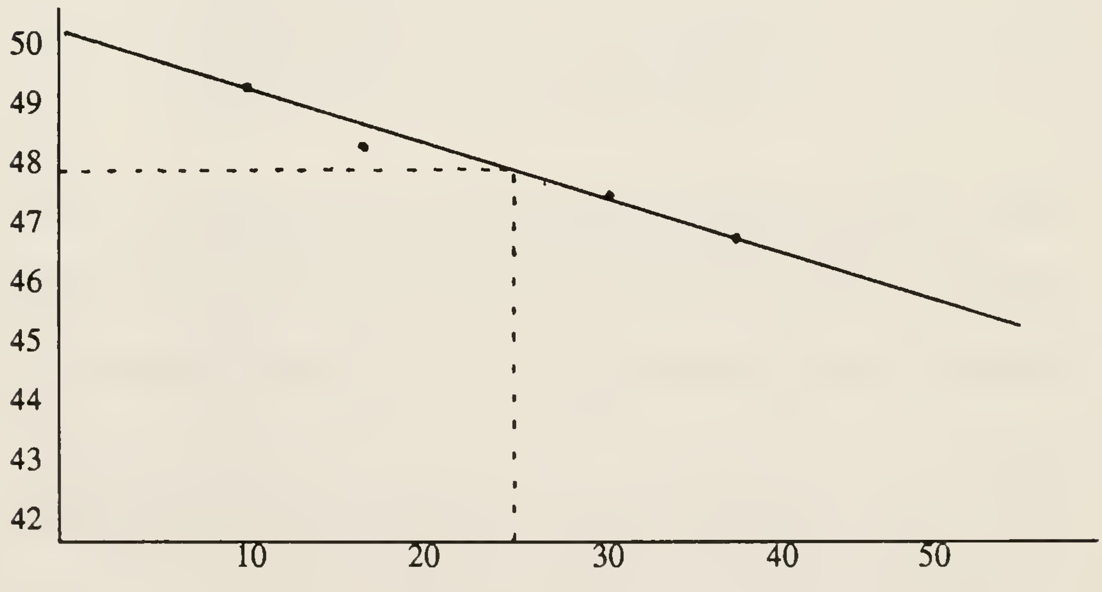
ROOM 28 MORTAR					
Container	A	B	C	D	E
Number of Drops	50	32	24	19	11
Wt. Wet Soil + Cont. (M_2)	15.53g	12.73	13.17	15.72	33.46
Wt. Dry Soil + Cont. (M_3)	13.24	10.55	10.77	12.77	31.02
Water Loss (M_2 - M_3)	2.29	2.18	2.4	2.95	2.44
Wt. Container (M_1)	2.65	1.63	1.61	1.64	21.97
Wt. Dry Soil (M_3 - M_1)	10.59	8.92	9.16	11.13	9.05
Moisture Content % $\frac{(M_2 - M_3)}{(M_3 - M_1)} \times 100$	21.6	24.4	26.2	26.5	27
Mean Moisture Content = 26%					

FLOW CURVE



ADOBE CAVE					
Container	A	B	C	D	E
Number of Drops	39	39	30	16	10
Wt. Wet Soil + Cont. (M_2)	43.92g	24.33	25.84	58.63	7.27
Wt. Dry Soil + Cont. (M_3)	42.88	23.59	24.61	57.26	5.76
Water Loss (M_2 - M_3)	1.04	0.74	1.23	1.37	1.51
Wt. Container (M_1)	40.66	22.01	22.03	54.42	2.70
Wt. Dry Soil (M_3 - M_1)	2.22	1.58	2.58	2.84	3.06
Moisture Content % $\frac{(M_2 - M_3)}{(M_3 - M_1)} \times 100$	46.8	46.8	47.7	48.2	49.3
Mean Moisture Content = 48%					

FLOW CURVE



Kiva C plaster and Room 28 mortar have similar liquid limits of 21% and 26% respectively. The Adobe Cave soil, in contrast, has a much higher liquid limit of 48%. As with the plastic limit, the vast difference in the liquid limit between the plaster and mortar on the one hand and the Adobe Cave soil on the other suggests that Adobe Cave soil was not the soil source for the building materials, at least not in its unmodified form. The Adobe Cave soil requires a significantly larger quantity of water to transform it from the semi-solid to the liquid state than do either of the other two soils. The high clay and silt content of the Adobe Cave soil and lack of sand allows it to hold more water than the other two soils before being transformed from one state to another. The Room 28 soil holds more water than the Kiva C soil because it has 10% less sand than the Kiva C soil.

5.8 PLASTICITY INDEX

The plasticity index is a measure of soil activity and a function of the percentage of clay present in the soil. Predominately clayey soils have relatively high indices of plasticity; they swell in the presence of water and contract as water evaporates. They also have greater cohesive strength than soils with a high sand content.

The plasticity index is calculated by subtracting the plastic limit from the liquid limit. It is reported to the nearest whole number.[55]

Plasticity Index = Liquid Limit - Plastic Limit

SAMPLE	PLASTICITY INDEX
Kiva C Plaster	4
Room 28 Mortar	9
Adobe Cave Soil	5

The Kiva C plaster has the lowest plasticity index of the three samples at 4 and the most dimensionally stable soil of the three tested samples. This would be a desirable quality for a wall plaster, especially one that is subterranean and exposed to ground moisture wicked in through the sandstone walls of the kiva and intended to be aesthetically pleasing. The Room 28 mortar is the most active soil tested, with a plasticity index of 9. A degree of dimensional instability may be more tolerable in a mortar because the mortar is intended to knit the wall together.

[55] Teutonico, p. 106.

5.9 SOLUBLE SALTS — QUALITATIVE ANALYSIS

Soluble salts are a dangerous agent of deterioration in earthen materials because they are capable of disrupting soil cohesion. Salts present in plaster or mortar can crystallize on the surface as powdery efflorescence or below the surface as subflorescent deposits.

Standard qualitative microchemical tests were used to test the Mug House samples for the presence of soluble salts.[56] A few grams of sample were ground to a fine homogenous powder using a mortar and pestle. Deionized water was added to dissolve the soluble material. After a few minutes, the solution was filtered using fine filter paper and a small funnel. The filtrate was tested for chloride, nitrate, sulfate, and phosphate anions. The insoluble material was tested for carbonates. Solutions of known salts were used as controls. All positives were confirmed with another reagent. All negatives were treated with a drop of the control solution containing that ion group. The test results appear in the chart below.

SAMPLE	ANIONS PRESENT
Kiva C Plaster	Sulfates, Carbonates
Room 28 Mortar	Nitrates
Adobe Cave Soil	Carbonates

Soils of the Mughouse Series, although usually free of lime, can be weakly calcareous.[57] Sulfates in the plaster are probably from gypsum as suggested by x-ray

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[56]Teutonico, pp. 58-69.

[57]Orville A. Parsons, *Wetherill Mesa Studies: Soil Survey of Wetherill Mesa, Mesa Verde National Park--Colorado*, Archaeological Research Series no. 7 (Washington, D.C.: National Park Service, 1974), p. 31.

diffraction analysis (see Sec. 5.12) but may also be due to sulfate contamination from Portland cement repairs. Nitrates typically originate from decaying organic material and were probably in the soil before or after its use as a plaster.

5.10 pH

The pH indicates the alkalinity or acidity of a solution. It is expressed as the logarithm of the reciprocal of the hydrogen ion concentration in grams per liter of solution. Alkali solutions possess a greater number of hydroxyl ions than hydrogen ions and have a pH value ranging from 8 to 14. Acidic solutions possess a greater concentration of hydrogen ions than hydroxyl ions and have a pH value ranging from 1 to 6. In neutral solutions, the number of hydroxyl and hydrogen ions are equal and the pH value is 7.

The pH of earthen materials is a guide to the stability of the clay fraction of the soil when exposed to water and may indicate the presence of soluble salts. Acidic solutions encourage flocculation of clay minerals leading to expansion and contraction of the soil matrix. Organic compounds in the soil can acidify their environment. Alkali solutions promote clay stability but may result from carbonate, sulphate, or chloride contamination.

The pH of the Mug House samples was determined by using a commercially available pH strips impregnated with indicator dye and confirmed with a pH meter. A few grams of sample were ground with a mortar and pestle to create a homogenous powder. Enough deionized water was added to create a solution. An indicator strip was then placed in the solution. After a few minutes, the strip was visually compared with a color chart on the back of the package to determine the pH of the solution. The pH meter was then placed in the solution until it registered a reading. The results appear in the following table.

SAMPLE	pH Strips	pH Meter
Kiva C Plaster	6.0	6.4
Room 28 Mortar	6.5	6.8
Adobe Cave	6.5	7.2
Water	6.0	6.1

The test results indicate that all of the samples are slightly acidic. The pH of the mortar, at 6.8, is consistent with the Mug House series of soils which have pHs ranging from 6.8 to 7.[58] The Kiva C plaster soil is slightly more acidic than the Mughouse series soils while the Adobe Cave soil is slightly more alkaline. It seems unlikely that the mild acidity of the plaster and mortar either contribute to or hinder their stability.

[58]Ibid, pp. 63-68.

5.11 COLOR

The Munsell system is a means of objectively describing color using three criteria: hue, value, and chroma. Hue (H) indicates principle colors (red=R, yellow=Y, etc.), value (V) signifies lightness or darkness, and chroma (C) specifies purity or grayness. Colors are noted with a system of numbers and letters written as H V/C. Key plaster, paint, and mortar samples were evaluated for color using the Munsell Color System. The Mug House samples were compared with standard color chips in the Munsell Soil Color Chart[59] using both dry and wet samples.

SAMPLE	MUNSELL NUMBER AND COLOR	
	DRY	WET
Kiva C		
Base Coat Plaster	7.5 YR 6/6 Reddish Yellow	7.5 YR 4/6 Strong Brown
White Plaster	7.5 YR 8/0 White	7.5 YR 8/0 White
Orange Plaster	7.5 YR 7/4 Pink	7.5 YR 4/4 Brown
Red Plaster	2.5 YR 6/8 Light Red	2.5 YR 5/8 Red
Mortar	7.5 YR 6/6 Reddish Yellow	7.5 YR 4/6 Strong Brown
Room 28		
Base Coat Plaster	7.5 YR 6/6 Reddish Yellow	7.5 YR 4/6 Strong Brown
White Plaster	10 YR 8/4 Very Pale Brown	10 YR 6/4 Light Yellowish Brown
Red Plaster	5 YR 7/6 Reddish Yellow	5 YR 5/6 Yellowish Red
Mortar	7.5 YR 6/6 Reddish Yellow	7.5 YR 4/6 Strong Brown
Adobe Cave		
Soil	7.5 YR 6/4 Light Brown	7.5 YR 4/4 Brown

[59] *Munsell Soil Color Charts*, (Baltimore: Macbeth Division of Kollmorgen Instruments Corp., 1988).

The plaster and mortar in Kiva C are very similar in color to the plaster and mortar in Room 28, suggesting that the base soil shared a similar, if not identical, source. Likewise, the red from Kiva C and Room 28 are virtually identical in color. The whites, however, are somewhat different; the Room 28 white is slightly more yellow in appearance than that found in Kiva C. Adobe Cave soil is a darker brown than the plasters or the mortars. But the color of the plasters and mortars compare favorably with the color of the mesa-top soils of Wetherill Mesa, which typically range in color from 5 YR 6/4 (light reddish brown) to 7.5 YR 4/4 (brown).[60]

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[60]Parsons, pp. 175.

5.12 X-RAY DIFFRACTION ANALYSIS

Clays are classified not only by their particle size diameter (see Section 5.4), but also by their mineral composition. X-ray diffraction analysis (XRD) identifies the clay and non-clay mineral groups present in a soil sample by bombarding the less than 2 μm fraction of the sample with x-rays. The crystalline structure of the clay within the sample diffracts the x-ray beam, producing a characteristic spectra. This spectrograph is compared with the spectra of known samples to estimate the relative abundance of the minerals present in the bulk sample. The analysis was executed by Dr. George Austin at the New Mexico Bureau of Mines and Mineral Resources.

For this analysis, approximately 30 grams of Kiva C plaster and 50 grams of Room 28 mortar were analyzed. Soil from Adobe Cave was not analyzed because, based on the physical tests, it is clearly not the soil source for the mortars and plasters. Because the mortar sample was large, it was also possible to perform a leaching test on it. A portion of the sample was placed in distilled water, stirred, and allowed to settle. After a specified time interval, a portion of the less than 2 μm fraction was removed from the top of the suspension, placed on a glass slide, and dried. The resulting coat consisted of the oriented clay-size fraction of the sample. The slide was examined with a Rigaku D/Max II x-ray diffraction unit from 2° to 40° 2θ, soaked in an ethylene glycol atmosphere, and examined again with x-ray diffraction. It was then heated to 350° C for 30 minutes and examined again with diffraction. The results are displayed in the table below. The results are reported in parts of ten — the method is only accurate to that extent. (See Appendix E for graph.)

Sample	Kaolinite	Illite	Chlorite	Smectite	I/S*	Others
Mortar	70%	10%	–	–	20%	Quartz
Plaster	80%	20%	–	–	Trace	Gypsum Quartz

**I/S = mixed layer illite and smectite*

The tests indicate that the clay mineralogy of the two samples is substantially the same. Well-crystallized kaolinite is the dominant clay mineral in both samples. Kaolinite is a common clay mineral of the kaoline group [$Al_2Si_2O_5(OH)_4$] composed principally of alumina and silica with a two-layered crystal lattice. It is a very stable mineral structure that does not readily absorb water or expand in its presence. Illite and/or randomly oriented mixed-layer illite/smectite is also present in lesser amounts in both samples. Illite, with its three-layered crystal structure, is a more active clay that adsorbs water into its outer layer, causing it to swell moderately. Smectite also has a three-layered crystal structure but it is a very unstable clay with weak interlamellar bonds that allow it to swell greatly in the presence of water. Relative data from the two samples suggests that the Kiva C plaster is more dimensionally stable than the Room 28 mortar because it contains a more stable mixture of 80% kaolinite, 20% illite, and only a trace of mixed layer illite/smectite, while the Room 28 mortar contains 70% kaolinite, 20% illite/smectite, and 10% illite.

The major difference in the samples is the non-clay minerals present. Both samples contain quartz (SiO_2). However, the plaster contains significant amounts of gypsum ($CaSO_4$) while the mortar has none. Gypsum may have been present in the plaster or deposited through groundwater percolation before or after Kiva C was buried

by debris after its abandonment. The gypsum in the plaster may have enhanced its setting properties and durability. These qualities would have been less desirable in the mortar and, intentionally or not, soil with gypsum content may have been selected for its superior setting properties.

An unusual finding was the absence of calcite ($CaCO_3$) in either sample. Most southwestern soils contain a significant amount of calcite and the identification of carbonate salts in the plaster suggests the presence of calcium carbonate in the soils. However, Mughouse series soils, like the sandstone of the northern part of Wetherill Mesa from which the soils developed, are generally free of lime.[61] The leaching test showed that there is no calcite in the mortar sample. Although a leaching test was not performed on the plaster due to the small size of the sample, there were no reflections in the diffractogram from calcite and the pattern appears to be the same as for the mortar.

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[61]Parsons, p. 31.

5.13 SCANNING ELECTRON MICROSCOPY

Scanning Electron Microscopy (SEM) coupled with an Energy Dispersive X-ray Analyzer (EDX) identifies the elemental composition of samples. A beam of electrons is focused on the sample, which is placed in an evacuated chamber. The electron beam excites the electrons present within the samples which gives off waves of energy. A computer reads and interprets the energy emission spectra. An EDX coupled with the SEM maps the precise location of each element identified.

Eight samples of plaster and mortar were examined with SEM and mapped with the EDX. Adobe Cave soil was not analyzed. The samples were embedded in a polyester/methacrylate resin (Bioplast™), sectioned with a Buehler Isomet™ low speed saw to reveal the cross section, and coated with gold prior to placement in the evacuation chamber. Samples were examined with a JEOL JSM 6400 Scanning Electron Microscope at 20x at 25 kV.

The elemental profile of the various samples were all quite similar and yielded no surprises. Test results revealed that the primary components of the tan plaster layers and mortar samples from both Kiva C and Room 28 were aluminum, silicon, and oxygen elements commonly found in soil. Trace amounts of iron and carbon, common accessory minerals in soil, are dispersed throughout the samples, but do not show up as distinct layers. The white plaster layers contain a high percentage of calcium from the calcium carbonate pigment. Minimal quantities of potassium and magnesium were also detected in clusters in all of the samples, suggesting salts in the soils. Traces of sodium and chlorine were detected in a few of the samples, but they were not mapped; their presence

may also indicate the presence of efflorescent salts. (See Appendix F for electron maps and spectra graphs.) While the samples were not tested for sulfur, its presence can be inferred from the gypsum ($CaSO_4$) identified in the XRD.

5.14 SUMMARY OF DATA RESULTS

5.14.1 *Kiva C*

Kiva C exhibits a complex sequence of finishes with 8–14 layers of plaster and thinner finishes. The Kiva possesses at least four decorative schemes. The plaster layers are very similar in composition and appearance with a homogenous brown matrix and a heterogeneous coarse fraction of colored sand grains. The finish layers, in contrast, are thinner and composed of monochromatic fine clay particles with few inclusions. The horizon between the plaster and finish coat is, in many cases, difficult to distinguish, suggesting that the finishes were routinely applied when the plaster was still damp. The mortar in Kiva C is very similar to the plasters but has a greater abundance of coarse particles in its coarse fraction. Physical tests indicate that the base coat plaster in Kiva C is a sandy clay loam composed of 30% clay, 21% silt, and 49% fine sand. The plastic limit of the soil is 17.1%, the liquid limit is 21%, and plasticity index is 4, suggesting that it is fairly resistant to expansion in the presence of water. The soluble salts present in the plaster are sulfates and carbonates. The soil is slightly acidic with a pH of approximately 6.2 and it was color matched to Munsell 7.5 YR 6/6, reddish yellow. The dominate clay minerals in the base plaster are kaolinite with lesser amounts of illite and smectite. Quartz and gypsum are also present in the clay fraction of the plaster. Aluminum, silicon, and oxygen are the primary elements in the soils with trace amounts of iron, carbon, calcium, potassium, and magnesium. The elemental profile of the base plaster and mortar are virtually indistinguishable with the exception of sulfur.

5.14.2 *Room 28*

The west exterior wall of Room 28 displays only one decorative scheme; a bichrome design with a red dado and white upper field. Stratigraphies reveal that the wall has only two finish layers, a thick base coat of tan plaster and a single finish layer of either red or white. The Room 28 plaster and mortar are generally similar in composition to the Kiva C plasters but they contain a notable fraction of coarse particles that are not present in the kiva plasters. The red and white painted finishes appear to be identical to those in the kiva. Grain size distribution analysis of the Room 28 mortar revealed that it is a clay loam with 29% clay, 31% silt, 36% fine sand, and 4% coarse sand. The mortar sample has a plastic limit of 17.3%, a liquid limit of 26%, and a plasticity index of 9, suggesting that it is much more active in the presence of water that the Kiva C plaster. The mortar contains nitrate salts, has a pH of approximately 6.6, and was color matched to Munsell 7.5 YR 6/6, reddish yellow. Kaolinite is the dominate clay mineral present in the mortar with lesser amounts of illite and smectite. Quartz is the only non-clay mineral in the clay fraction of the mortar. The elemental profile of the mortar is virtually identical to that of the plasters with aluminum, silicon, and oxygen as the principle components.

5.14.3 *Adobe Cave Soil*

Adobe Cave soil has a higher proportion of silt than the plasters and mortars. It is a silty clay with 30% clay, 65% silt, and 5% fine sand. It has a plastic limit of 42%, a liquid limit of 47%, and an overall plasticity index of 5, suggesting that it is more

active than the Kiva C plaster but more stable than the Room 28 mortar. Carbonates are the principle salts present in the soil. It has a pH of 6.8 and was color matched to Munsell 7.5 YR 6/4, light brown. Its elemental profile is very similar to the plasters and mortars.

SUMMARY OF DATA RESULTS

	KIVA C	ROOM 28	ADOBE CAVE
Number of Layers	8–14	2	–
Grain Size Distribution	Clay Loam/Sandy Clay Loam 30% Clay 21% Silt 49% Fine Sand	Clay Loam 29% Clay 31% Silt 36% Fine Sand 4% Coarse Sand	Silty Clay 30% Clay 65% Silt 5% Fine Sand
Plastic Limit	17.1%	17.3%	42.0%
Liquid Limit	21%	26%	47%
Plasticity Index	4	9	5
Soluble Salts	Sulfates, Carbonates	Nitrates	Carbonates
pH	6.2	6.6	6.8
Munsell Color	7.5 YR 6/6 Reddish Yellow	7.5 YR 6/6 Reddish Yellow	7.5 YR 6/4 Light Brown
Clay Minerals	Kaolinite with some Illite and Smectite	Kaolinite with some Illite and Smectite	–
Non-Clay Minerals	Quartz Gypsum	Quartz	–
Elemental Profile	Si, Al, O – primary Fe, C, Ca, K, Mg, S	Si, Al, O – primary Fe, C, Ca, K, Mg	Si, Al, O – primary Fe, C, Ca, K, Mg

Chapter 6

MUG HOUSE: CHARACTERIZATION OF PAINTED FINISHES

Kiva C is the most elaborately decorated kiva in Mug House. It features a final scheme of a red dado and tan upper field separated by a white band with upward-projecting triangles, a design typical of Mesa Verde kivas. Multiple layers of white and two layers of orange finishes with triangle and dot designs lie below this decorative design and there is a suggestion of blue paint on the east side of the kiva. The west exterior wall of Room 28, which is roughly contemporary with Kiva C, displays a full wall plaster, but with a less elaborate bichrome design — a red dado and white upper field. No additional paint layers lie below this surface. The white, red, and orange finishes displayed on the walls of Kiva C and Room 28 are among the most commonly used colors in the Anasazi palette; and at Mesa Verde, red dados with white or tan upper fields were the rule. Blue is less common but certainly not unknown. Representative paint samples from both rooms were analyzed to characterize the painted finishes and gain insight into Anasazi painting practices. The results were compared to determine similarities and differences between paints used in various spaces, and to compare Mug House paints with research done elsewhere.

6.1 METHODOLOGY

Characterization of the painted finishes involved laboratory analysis of the colorant and binding media of representative paint samples from both Kiva C and Room 28.

Samples of red, white, orange, and blue finishes were collected and a portion of each sample was prepared for microscopic examination, as described in Section 5.4. Gross characteristics and micromorphological features of paint samples were recorded using both cross and thin sections. Features studied included ratio of coarse to fine particles; color of the clayey matrix; inclusions; and degree of sorting, particle shape, texture, and related distribution of the aggregate fraction.[62] The ratio of coarse to fine particles was estimated by visually comparing the sample with a chart. Samples were examined with a Nikon AFX-IIA using both reflected bright and pseudo-dark field illumination. The paints were color matched to Munsell Soil Color Charts. Standard microchemical tests were used to identify the pigments.[63] Test results were confirmed using a scanning electron microscope equipped with an energy dispersive x-ray analyzer. Identification of binding media was attempted using autoflorescence and staining florescence.

6.2 GENERAL OBSERVATIONS

The painted finishes are easily distinguished from the plasters both *in situ* and in the laboratory. On the wall, the finishes stand out as brightly colored layers in the contrast to the tan plasters. Under the microscope, similarities between the finishes and plasters are apparent: both contain a monochromatic matrix of fine clay and a heterogeneous coarse fraction, and their basic micromorphological features are similar,

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[62] P. Bullock, *Handbook for Soil Thin Section Description* (Albright, Wolverhampton: Waine Research Publications, 1985), pp. 20-38.

[63] Alberto A. Tagle, "Laboratory Exercises: Qualitative Pigment Analysis," Laboratory Exercises, Historic Preservation Program, Architectural Conservation Laboratory, University of Pennsylvania.

suggesting that they are composed of essentially the same materials. However, the ratio of fine to coarse particles is significantly higher in the finishes than in the plaster, suggesting that finishes are essentially clay washes. Their smooth, clayey texture with few inclusions, intense color, and thin layers make the finishes easy to distinguish from the thicker, coarser plaster layers. The thinness of the finish layers suggests that the clays were applied as diluted washes. This is consistent with previous research.[64] The horizon between the plaster layer and the finish layer is often difficult to distinguish, indicating that the finishes were applied to the plaster while it was still wet.

The nature of the binding media for all of the samples remains unclear. Autoflorescent and florescent staining in ultraviolet (UV) light proved difficult to interpret even with the assistance of an experienced murals conservator. Binding media, particularly organic materials, tend to degrade more rapidly than other components of the paint. Also, the high clay content of the washes may have provided adequate adhesion of the paint to the wall, making organic additives unnecessary.

6.3 RED PAINT

Red was one of the most commonly employed colors in prehistoric mural paintings and it is key to the present decorative schemes in both Kiva C and Room 28, adorning the lower dados of both spaces. It does not appear in earlier layers of the stratigraphies. Under the microscope, samples of the red paint from both rooms are virtually indistinguishable from each other and have many similarities to the plasters.

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[64] Watson Smith, *Kiva Mural Decorations at Awatovi and Kawaika-a* and Constance S. Silver, "Architectural Finishes of the Southwest."

The paints are composed principally of a clayey matrix of fine red particles. The modest aggregate fraction closely resembles that of the plasters. The ratio of coarse to fine particles is approximately 30:70, giving the red paint a smoother texture than the plasters. The thinness of the red layers suggests that they were applied as washes on the relatively thick plaster layer.

On site, the red paints are very similar in color. The Kiva C sample was color matched to 2.5 YR 6/8, light red. The Room 28 sample was matched to 5 YR 7/6, red.

Microchemical analysis of the samples of the red paint from both Kiva C and Room 28 identified them as iron oxides (Fe_2O_3). Iron oxide was commonly used as a red pigment by the Anasazi and, in fact, has been the only red pigment identified at Awatovi[65] and at Aztec National Ruins Monument.[66] Furthermore, the Mug House excavation team found 39 paint stones made of hematite, a mineral form of iron oxide. These paint stones ranged in color from pink to red to red-brown and many of them had been shaped into cylindrical or rectangular sticks and had abraded surfaces at both ends.[67] Iron oxide is very stable in the presence of light or alkalis, suggesting that the color has not changed much over the last 700 years. Scanning electron microscopy confirmed the presence of iron and oxygen elements in the red layers and they showed up in layers consistent with the paint.

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[65]Watson Smith, *Kiva Decorations at Awatovi and Kawaika-a*, p. 22.

[66]Mirna Eliana Goldberger, "A Conservation Study of an Anasazi Earthen Mural at Aztec Ruins National Monument," (Master's Thesis, University of Pennsylvania, 1992), p. 47.

[67]Arthur H. Rohn, *Mug House, Mesa Verde National Park, Colorado* (Washington, D.C.: National Park Service, 1971), p. 128.

6.4 ORANGE PAINT

The orange paint is similar to the red in every respect except for the orange color of the matrix. It was color matched to 7.5 YR 7/4, pink. It too tested positive as iron oxide. The Anasazi commonly combined red and yellow iron oxides to create orange pigment.[68] SEM confirmed the presence of iron and oxygen in the orange layers although individual red and yellow pigment particles were not observed under the microscope.

6.5 WHITE PAINT

Anasazi murals frequently featured white color fields or designs similar to those found at Mug House. *In situ*, the white band in Kiva C is translucent and bright white, while the white upper field in Room 28 is opaque and has a yellowish cast. Under the microscope, the white finish was significantly finer in texture than the plasters or the red or orange paints and appears in significantly more layers than the colored finishes. Like the red, it is smooth and individual pigment particles are difficult to distinguish. It has a lower ratio of coarse to fine particles than the red and orange paints, approximately 10:30. The aggregate fraction is similar in appearance to that of the plasters and the red and orange paint. All of the white layers appear to be similar and are probably a white clay diluted with water to create a wash which was applied to the wall. Microchemical tests revealed that the white pigment is calcium carbonate ($CaCO_3$), a common Anasazi

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[68]Ibid.

white pigment.[69] SEM confirmed that large quantities of calcium, carbon, and oxygen are in the white layers but also showed the presence of sulfur in these layers. The white in the Kiva C band and the white upper field in Room 28 looks very different on the wall but proved to be the same in composition. The multiple layers of white paint in Kiva C were color matched to 7.5 YR 8/0, white. The white paint in Room 28 was matched to 10 YR 8/4. The principal difference between the two is the thickness of the layer. The white band in Kiva C is very thin and at times difficult to see in cross section while the white upper dado in Room 28 is thick which causes it to be more opaque.

6.6 BLUE PAINT

Examples of what may be a blue paint exist only in a very localized area of Kiva C. Under the microscope, individual particles of blue paint were impossible to discern. Microchemical tests and SEM failed to identify any known blue pigments.

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[69]Ibid.

Chapter 7

CONCLUSIONS AND RECOMMENDATIONS

In situ examination and laboratory analysis of plasters, mortars, and finishes from Kiva C and Room 28 provided insight into Anasazi building practices at Mug House and can provide a guide for future preservation work there. Clear differences exist in the earthen plasters and mortars, but the composition of the finishes used in both spaces is the same.

In the interest of preserving the nation's cultural assets, the Park Service restricted sample collection at Mug House; conclusions about the plaster and mortar samples are limited by the small quantity of sample material. Only 16 samples, many weighing less than 10 grams, were removed from the site. Consequently, it remains open to conjecture whether variations in the kiva and room samples were random, temporal, or relate to behavioral choices such as the variant functions of the two spaces. The sample pool was limited to Kiva C and Room 28 at Mug House; although Kiva C and Room 28 are typical of Classic Pueblo architecture, caution should be used in applying these findings to other structures within Mesa Verde or at other Anasazi sites.

7.1 CHANGE IN APPEARANCE

The wall surfaces of Kiva C and the exterior of Room 28 were treated in different ways by the Anasazis who occupied Mug House. Both spaces were a part of the Kiva C courtyard unit and, according to archaeologist Arthur Rohn, constructed at roughly the same time. The residents of the courtyard and adjacent buildings were probably

members of the same kinship group. Rohn speculates that Room 28 functioned as a dwelling unit for a single nuclear family while Kiva C served as a ceremonial and social space and was probably used, from time to time, by all members of the Kiva C clan. The interior of Kiva C was plastered at least five times and elaborately painted in the later periods of its occupation; evidence of at least three separate triangle designs is clearly visible on the kiva walls. Soot generally appears only on the earlier layers of tan plaster, suggesting that plaster renewal became more frequent once decorative finishes began to be applied to the wall. In contrast, the west exterior wall of Room 28 received only one coat of plaster and one coat of paint. No finishes remain on its interior. The practice of frequently replastering kiva walls and not dwelling units/courtyards is common throughout the prehistoric southwest. Variations in treatment almost certainly reflect the uses of and attitudes toward the spaces by their inhabitants.

7.2 PLASTERS

The overall performance and durability of the Mug House plasters over the past 700 years suggests that the Anasazi had an empirical knowledge of the critical properties required for durable plasters. Laboratory analysis of plaster samples from both Kiva C and Room 28 provide insight into plastering practices at Mug House and into the properties that made these plasters durable.

Anasazi plasterers used different, although similar, recipes in Kiva C and Room 28. The same orange-brown clay matrix composes the fine fraction of virtually all of the plaster samples, regardless of their location within the stratigraphy, or whether they

came from Kiva C or Room 28. Similarly, the coarse fraction of all of the plaster samples is a well-sorted, heterogenous mixture of black, red, clear, white, and orange sand-sized particles. Elemental analysis produced similar compositional profiles for all of the plaster samples.

The gross principal differences between the Kiva C plasters and the Room 28 plasters are the number of layers applied to the wall, layer thickness, and the grain size distribution. Up to seven layers of plaster, with interceding, thinner layers of white, orange, and red finishes, are found on the walls of Kiva C, while Room 28 has only one plaster layer and one finish coat: a red dado and white upper field. The average plaster layer in Kiva C measures approximately 0.8 mm although the base coat ranges in width from 3 to 20 mm; the plaster layer in Room 28 averages around 11.5 mm. The texture of the Kiva C plasters is relatively uniform with a well-sorted sand fraction and few anomalies or blebs. In contrast, the aggregate fraction of Room 28 plaster is less uniform in size, contains more anomalies, and has a notable percentage of very large grains. Although the Room 28 plaster samples were too small to perform physical tests, and it was impossible to separate individual plaster layers in the Kiva C sample, visual analysis suggests that the grain size distributions of the Kiva C plasters had more in common with each other than any had to the Room 28 plaster.

Compositional analysis provides insights into some of the critical properties that make plaster durable. The base coat plaster is a sandy clay loam (39% clay, 4% silt, 49% fine sand), a recipe that approximates the National Bureau of Standards' recommendations for a stable adobe mix. The fine sand controlled shrinkage — an

important performance property for a surface finish that is aesthetic as well as insulative. The plaster's liquid limit (17%), plastic limit (20%), and low plasticity index (4) also suggest that the plaster is fairly resistant to swelling and shrinkage in the presence of water. The mineral composition of the clay fraction supports its stability as well — the dominant clay mineral is kaolinite, a stable clay mineral, with only small amounts of the more reactive clay minerals illite and smectite. Gypsum in the plaster may have enhanced its setting properties and continues to enhance its durability.

Disparate, though similar, soils were used to prepare the earthen plasters for the two rooms, or the same soil was enhanced through sifting or the addition of sand to better suit its intended use. The larger grains in the Room 28 plaster added bulk to the plaster mix and enhanced its dimensional stability, an important feature in a plaster that was both exterior (although under cover of the rock shelter) and not intended to be frequently renewed. The kiva plaster was protected by the kiva roof and regularly replastered; it displays a finer texture, possibly for aesthetic or ceremonial reasons. Perhaps the Kiva C soil was gathered from a particular place or prepared in a consistent manner which would account for the lack of variation between layers in Kiva C and the gross differences in Room 28 plaster.

7.3 MORTARS

Although mortar is frequently difficult to distinguish from base coat plaster on site, and defacto plaster is often incorporated into the base coat, mortars and plasters were clearly distinguished in the laboratory. Similarities between the plaster and mortar

samples include the basic features of the fine and coarse fractions of the samples, color, pH, clay mineralogy, and elemental composition. Contrasts between plasters and mortars relate largely to grain size distribution and its effect on texture and soil behavior, and in the non-clay minerals in the soil. Mortars appear coarser in texture than the plasters and contain anomalies and inclusions not observed in the plasters. Physical tests showed that the mortars and plasters contain approximately the same percentage of clay (roughly 30%) but deviate in their ratios of silt and sand. The Kiva C plaster contains a greater percentage of sand (49% fine sand) than the mortar (40% sand: 36% fine sand, 4% coarse sand) — a feature that minimizes shrinkage. The mortar has a higher plasticity index (9) than the plaster (4), indicating that the mortar is less dimensionally stable in the presence of water. XRD revealed the presence of gypsum, a non-clay mineral commonly found in southwestern soils, in the Kiva C plaster, but not in the mortar sample. The gypsum may be an intrinsic component in the plaster soil, which suggests a different soil source was used, or it may be a contaminant from ground water migrating through the wall. The large inclusions and moderately sorted sand fraction of the mortar suggests that the soil used to make the mortar had come from a separate location than that used for the plasters or was prepared differently. The variations found were what one might expect, given the structural function of the mortar (knitting together the sandstone wall) versus the decorative and insulative function of the plaster. Other factors that could influence material selection are the ceremonial versus domestic function of the two spaces; the importance of shrinkage resistance in the plaster (not quite as important in the mortar), and preparation at different times or by different people.

7.4 ADOBE CAVE SOIL

Laboratory characterization of the Adobe Cave soil indicates that it is not the primary soil source for the plasters and mortars in Kiva C and Room 28 as posited by Arthur Rohn. Although the basic micromorphological features of the fine fraction of the Adobe Cave soil, the plasticity index, and the elemental profile resemble those of the plasters and mortars, the coarse fraction is less abundant, smaller in diameter, and lacks the colorful orange, red, and clear particles. The physical tests provide convincing evidence that Adobe Cave was not the source of soil for Kiva C and Room 28 mortars and plasters or was modified through the addition of sand and silt. The grain size distribution of the Adobe Cave soil (a silty clay with 30% clay, 65% silt, and 5% fine sand) does not resemble the mortars and plasters except for the clay content and would make a poor building material because the low quantity of sand would promote shrinkage and cracking. The liquid limit, plastic limit, soluble salt content, and color of the Adobe Cave soil all varied significantly from the plasters and mortars, providing further evidence that Adobe Cave soil, at least in its unmodified form, was not the source for the earthen materials in Kiva C and Room 28.

7.5 PAINTED FINISHES

Basic painting techniques in Kiva C and Room 28 were quite similar. *In situ* observation of the walls in both rooms and microscopic examination of cross and thin sections indicate that the general practice in Kiva C was to cover the sandstone wall with tan plaster by hand, paint it white, incise the decorative design into the plaster with a

pointed instrument, and apply orange paint with brushes. Striations in the plaster and the difficulty of clearly distinguishing the horizon between plaster and paint in many of the samples lead to the conclusion that the incised designs and fresh paint were applied to the wall while the plaster was still damp. In the most recent decorative campaign, red paint was applied directly to the freshly plastered lower dado in the kiva without an intervening white layer, and red paint was applied directly to tan plaster on the west exterior wall of Room 28. The white paint is restricted to the upper field, and is not found under the red layer except in a narrow band of overlap where the two color fields meet.

The painted finishes are essentially washes of diluted clay, probably derived from paint sticks (mineral nodes) found during the excavation of Mug House, rocks, and clays of the desired color. Under the microscope, the finishes have a smooth, clayey texture with few inclusions, intense color, and appear in thin layers. The presence of organic binding media in the finishes remains unknown. Clay and microcrystalline calcite are the likely binders. Microchemical tests showed that paint pigments are derived from mineral sources and were the same pigments employed by Anasazi muralists in other southwestern settlements.

The red finish in both rooms is iron oxide, a mineral pigment commonly used by the Anasazi. The fine fraction of the finish layer is a red clay but the aggregate fraction closely resembles the plasters in size, shape, and color. It is applied in a very thin layer, approximately 0.13 mm thick. Similarities between the red finishes (micromorphological features, layer thickness, and color), and the lack of other red finish layers in Kiva C suggest that the two red dados were painted at roughly the same time.

The orange finish is very similar to the red finish except for the orange color of its clayey matrix. It too is iron oxide and applied in a thin coat.

The white layers are all calcium carbonate. On the wall, the translucent white band in Kiva C and the opaque upper field in Room 28 look dissimilar. Whites are typically thicker, possibly to increase their opacity and hiding power, but the band in Kiva C is a very thin, translucent wash. Scanning electron microscopy revealed the presence of sulfur in the whites. Possible sources of the sulfur include gypsum, bacteria, ground water or alteration of calcium carbonate.

7.6 RECOMMENDATIONS FOR FURTHER RESEARCH

Many unanswered questions about the plasters, mortars, and paints in Kiva C and Room 28 remain. The most important avenues for further investigations are:

1) *Further Sampling*: The conclusions drawn from this study were limited by the small amount of sample material available for laboratory analysis. Additional sampling of Kiva C and Room 28 plasters and mortars would confirm or disprove the findings presented above and create a more statistically valid study. This could also be the beginning of a data base of plasters. Sampling should be extended to other kivas and rooms within Mug House and Mesa Verde. A larger sample pool would shed light on questions raised by this study such as whether gypsum, found in the Kiva C plaster but not in the Room 28 mortar, was an intrinsic component of the soil, or the result of water migration after plaster application.

2) *Additional Analytical Testing of Painted Finishes*: Although basic pigment identification of the finishes was achieved through microchemical testing, x-ray diffraction analysis would provide information about the mineralogy of the pigments which were almost certainly clay washes. This was not possible at the University of New Mexico laboratory which is only equipped to deal with large soil samples, but it could easily be accomplished by someone experienced in pigment identification for fine arts conservation. FTIR and gas chromatography may provide insights into any additional binding materials or organics added to the finishes.

3) *Provenance Study of Plaster and Paint Soil Sources*: Mesa-top soil in the vicinity of Mug House should be characterized and compared with the plasters and mortars to determine their soil source.

4) *Stabilize Plasters with Compatible Consolidants and Adhesives*: Plasters are cracked and delaminating. A water-based system to re-adhere the plasters to the wall and prevent further deterioration would probably be most practical given the limits of the site — lack of environmental control and difficulty of access — and considering that the plasters and mortars should be relatively stable for earthen materials in the presence of water. Backfilling is another measure worthy of consideration for subterranean rooms affected by ground water as a means of controlling decay.

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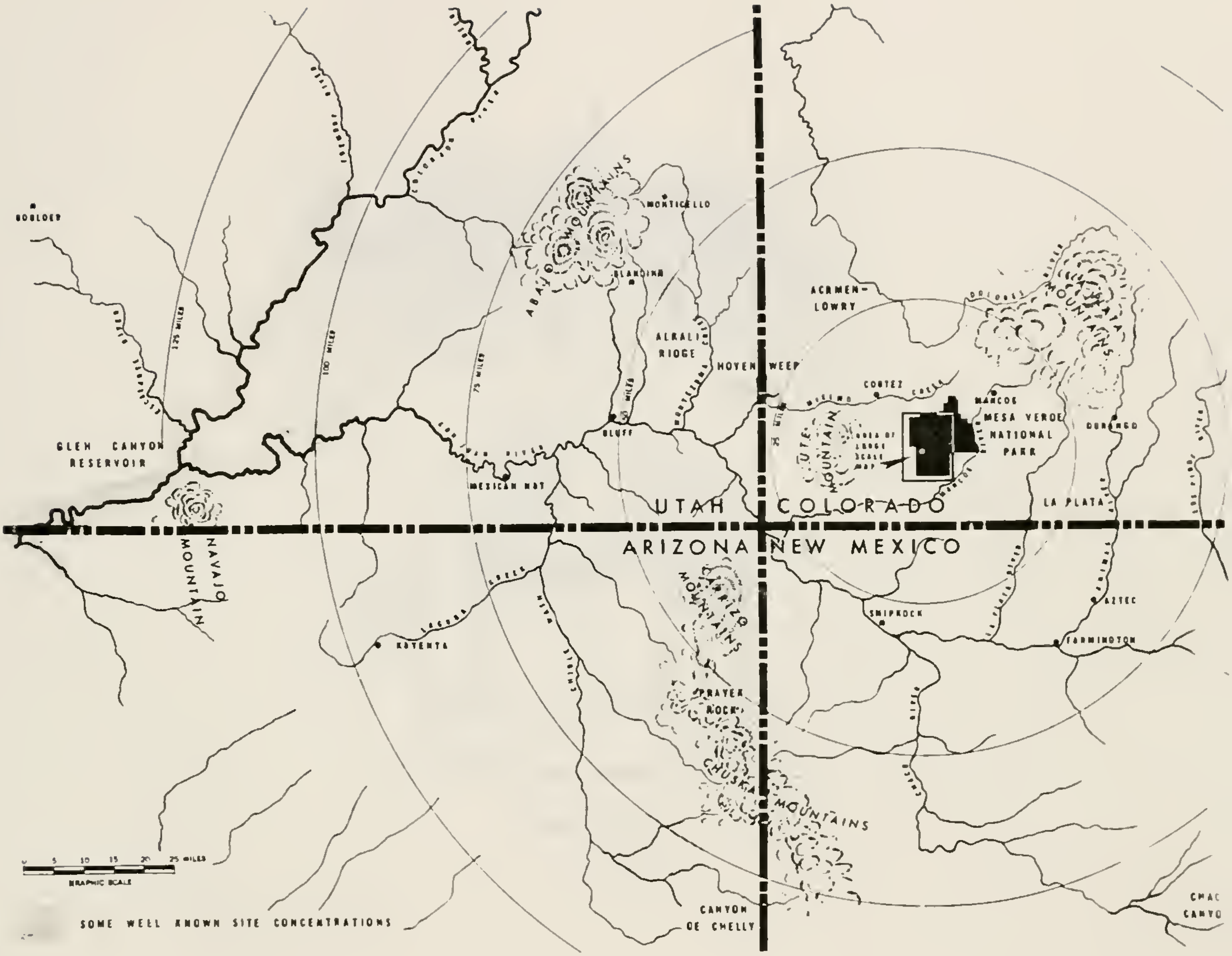
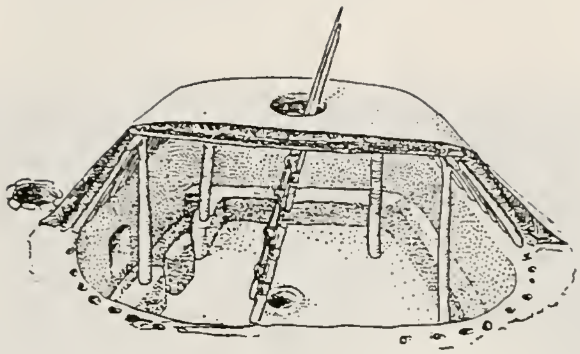
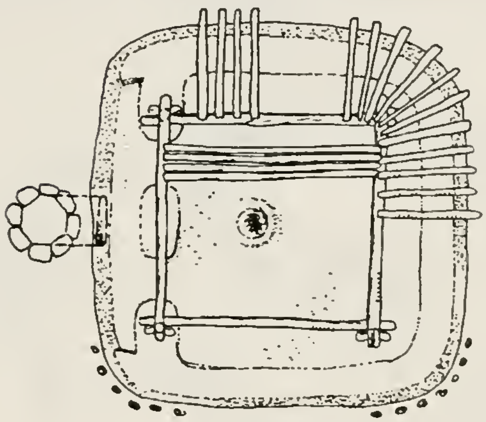


Fig. 1 Four Corners Area

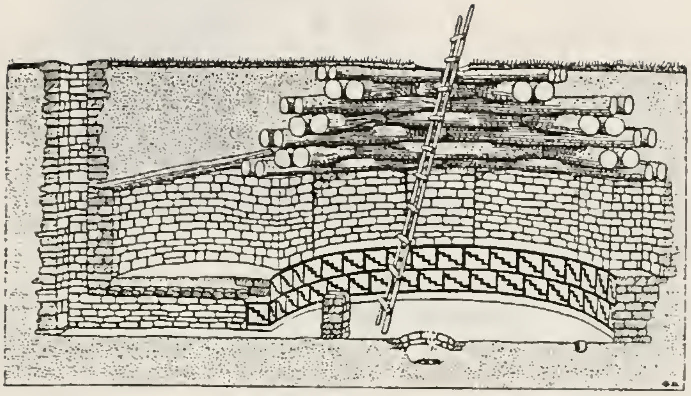


Section

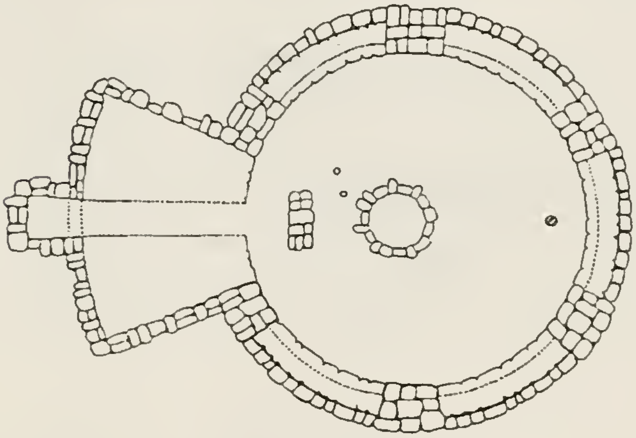


Pit house plan

Figs. 2 and 3 Pit House – Section and Plan



Section



Kiva plan

Figs. 4 and 5 Kiva — Section and Plan

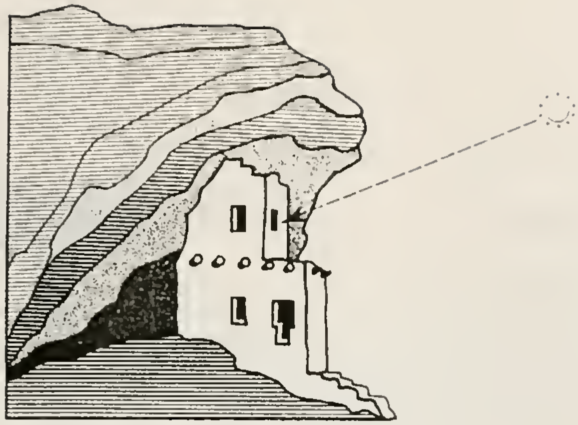


Fig. 6 Cliff Dwelling

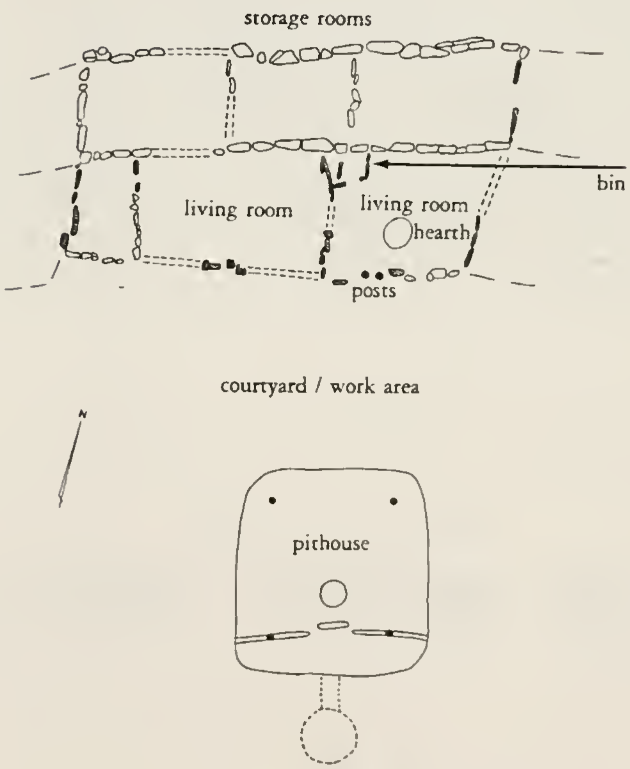


Fig. 7 Village Plan

Figs. 8 and 9

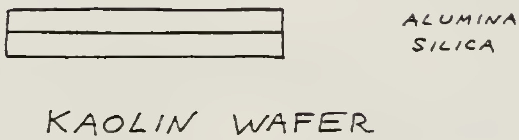


Fig. 10

Fig. 11

Fig. 12 Mug House

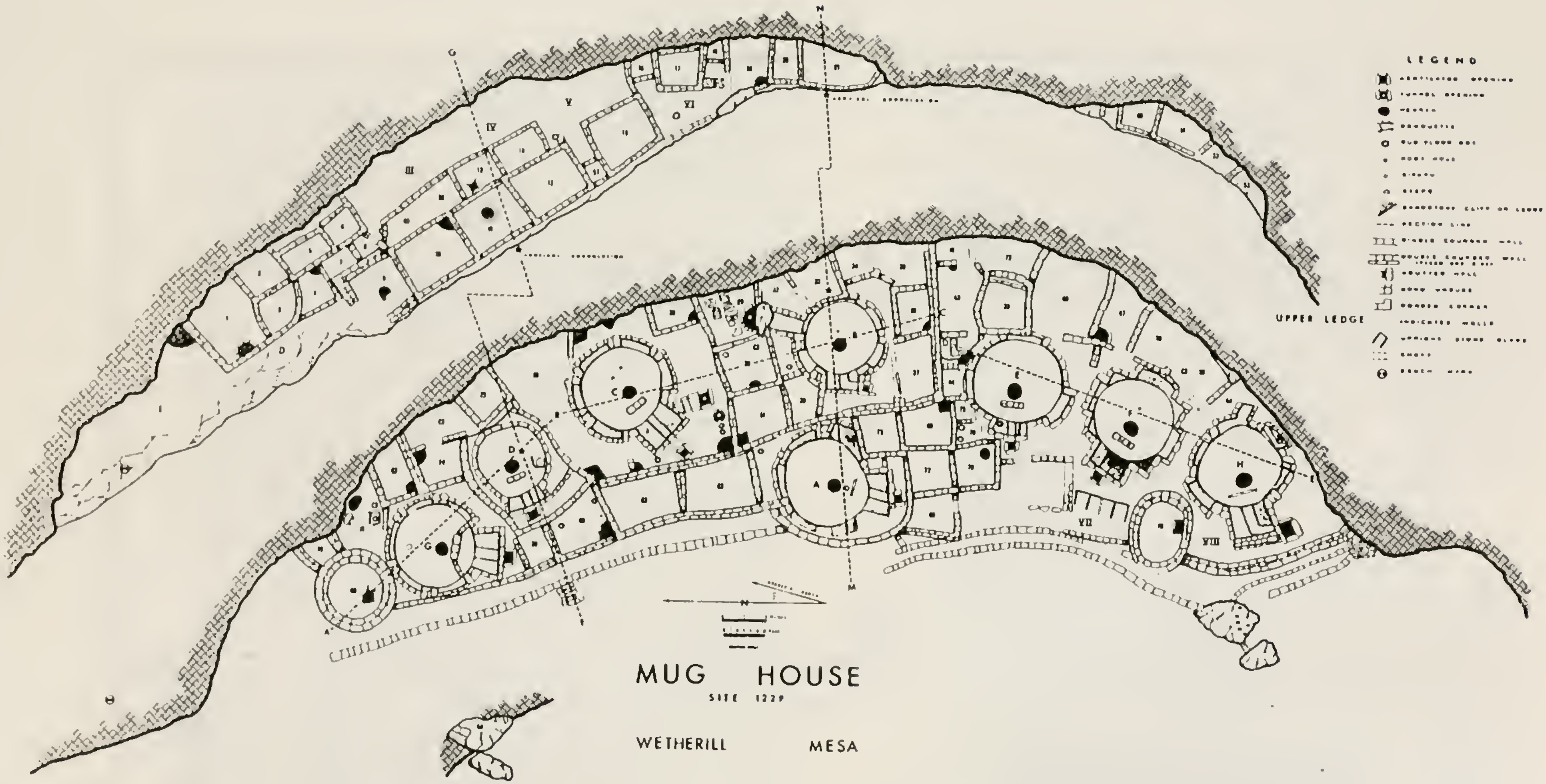


Fig. 13 Mug House Site Plan

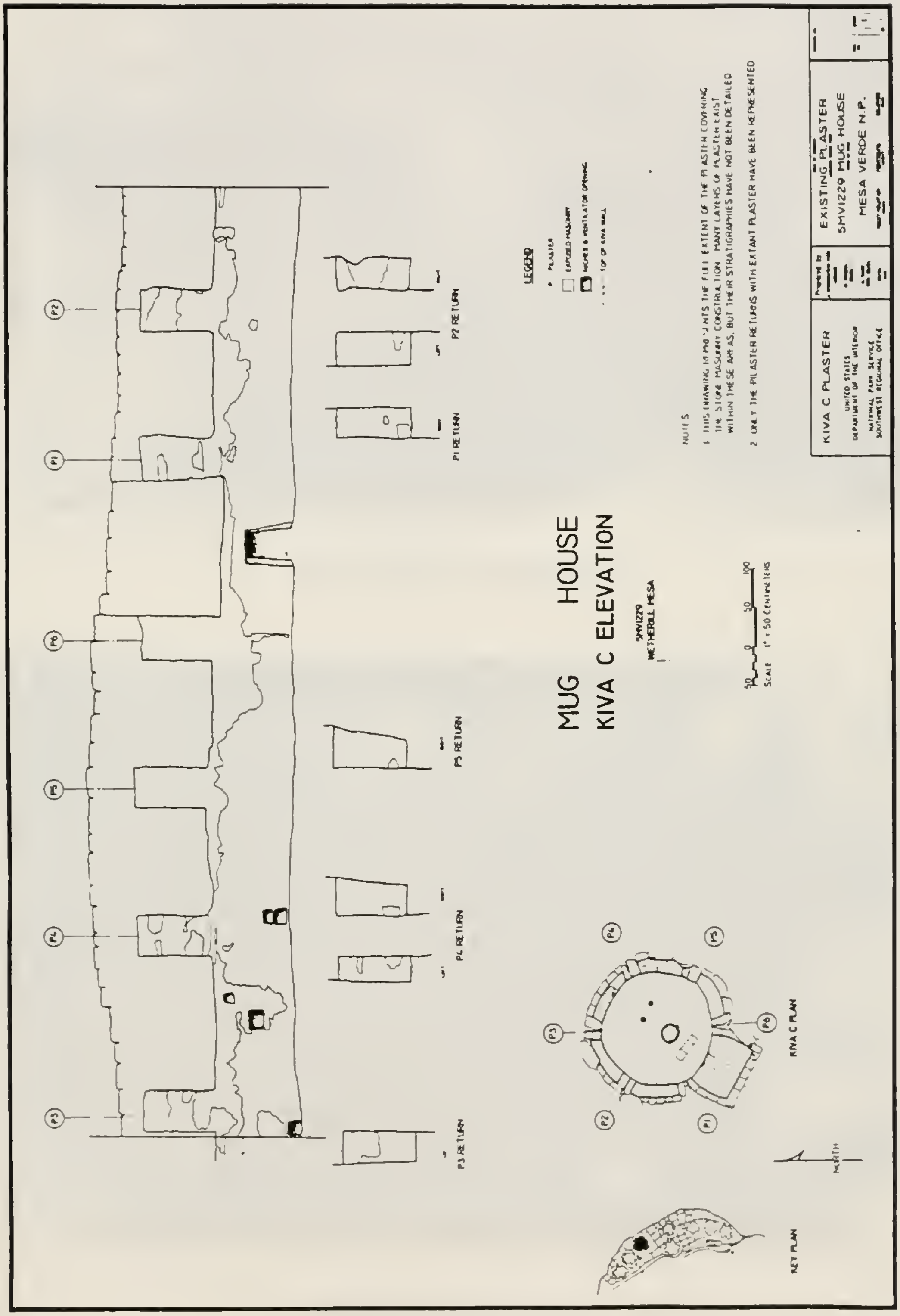


Fig. 14 Kiva C Elevation

Fig. 15 Kiva C and Room 28

Fig. 16 Adobe Cave

Fig. 17 Close-up, Kiva C

Fig. 18 Elevation of Kiva C Interior Wall

Fig. 19 Kiva C, Pilaster 3

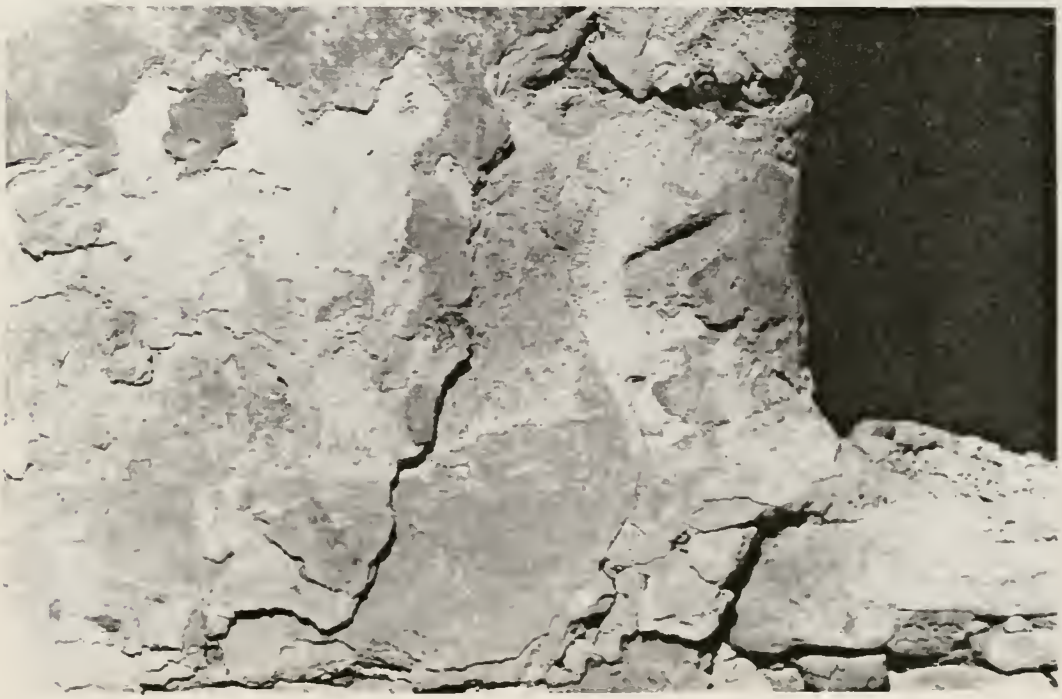


Fig. 20 Detail of Kiva C Plaster — Note Triangle Design in Center of Photograph

Fig. 21 Detail of Base Coat Plaster in Kiva C

Fig. 22 Detail of Exposed Plaster Layers in Kiva C

Fig. 23 White Band and Triangle Design in Kiva C

Fig. 24 Detail of Triangles — Note Incision Marks

Fig. 25 Elevation of Room 28

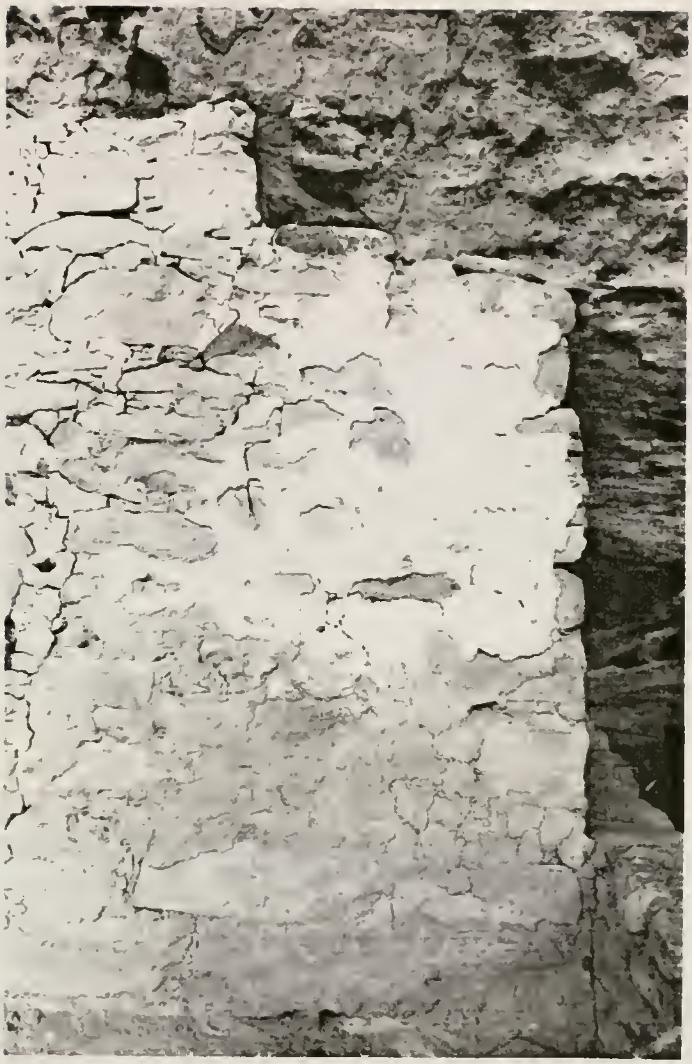


Fig. 26 Detail of Room 28 Plaster

Fig. 27 Cross Section of Kiva C Plaster from the Red Dado

Fig. 28 Thin Section of Plaster from Kiva C from the Red Dado

Fig. 29 Cross Section of Room 28 Plaster from the White Upper Field

Fig. 30 Thin Section of Room 28 Plaster from Red Lower Dado

Fig. 31 Cross Section of Mortar from Kiva C

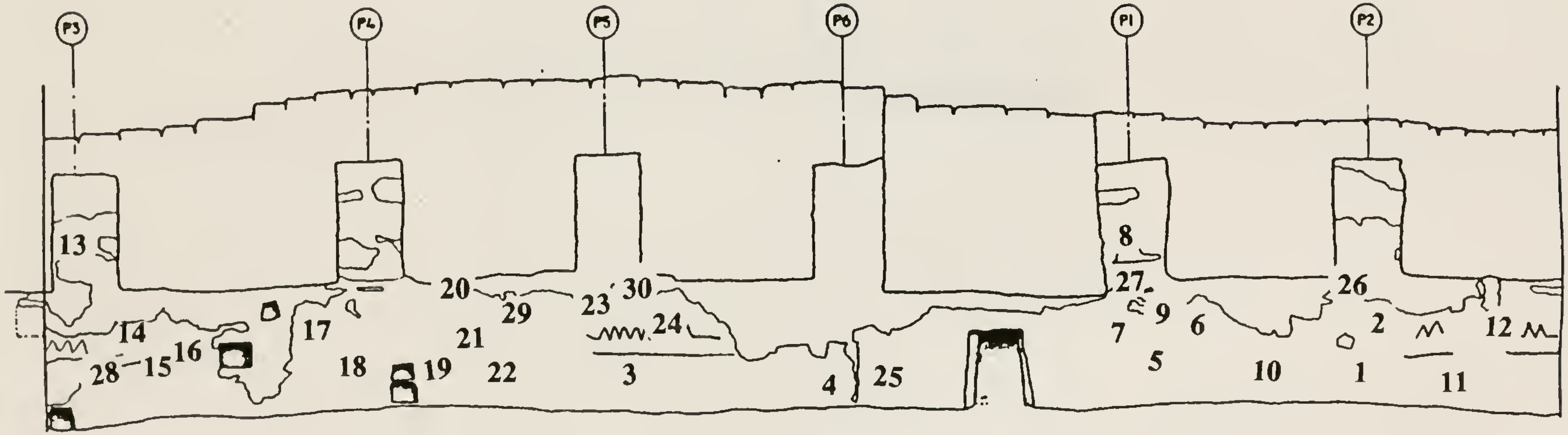
Fig. 32 Cross Section of Mortar from Room 28

Fig. 33 Cross Section of Soil from Adobe Cave

APPENDIX A

STRATRIGRAPHIES OBSERVED IN KIVA C AND ROOM 28

STRATIGRAPHY LOCATIONS



Kiva C

Layer

	1 Banquet/ Lower Dado	2 Banquet/ Upper Field
1	Tan	Tan
2	Tan	Tan
3	White	White
4	Tan	Tan
5	White	White
6	Orange	Tan
7	Tan	White
8	White	Tan
9	Orange	White
10	Tan	Tan
11	Orange	White
12	Tan	
13	Red	-

STRATIGRAPHIES OBSERVED IN KIVA C

Stratigraphy

Layer	1 Banquet/ Lower Dado	2 Banquet/ Upper Field	3 Banquet	4 Banquet/ Lower Dado	5 Banquet/ Lower Dado	6 Banquet/ Lower Dado	7 Banquet	8 Pilaster	9 Banquet	10 Banquet/ Lower Dado	11 Banquet/ Lower Dado	12 Banquet/ Upper Field	13 Pilaster	14 Banquet/ Lower Dado	15 Banquet Upper Field
1	Tan	Tan	Tan	Tan	Tan	Tan	Tan	?	Tan	Tan	Tan	Tan	Tan	Tan	Tan
2	Tan	Tan	White	Tan	White	Tan	Tan	Tan	Tan	Tan	Tan	Tan	Tan	Tan	Tan
3	White	White	Tan	White	Tan	White	White	Tan	Tan	Tan	White	Tan	Tan	White	White
4	Tan	Tan	White	Tan	White	Tan	Tan	White	Tan	White	Tan	White	White	Tan	Tan
5	White	White	Tan	White	Orange	White	White	Tan	White	Red?	White	Tan	Tan	White	White
6	Orange	Tan	White	Orange	Tan	Tan	Tan	White	Tan	Tan	Tan	White	Tan	Tan	Tan
7	Tan	White	Tan	Tan	White	White	White	Tan	White	White	White	Tan	Tan	White	White
8	White	Tan	White	White	Orange	Tan	Tan	White	Tan	Orange	Orange	White	Tan	Tan	Orange
9	Orange	White	Tan	Orange	Tan	White	White	Tan	White	Tan	Tan	Tan	Tan	White	Tan
10	Tan	Tan	White	Red	Red	Tan	Red	White	Tan	Red	White	White		Tan	White
11	Orange	White				Red	Tan	Tan	White		Orange	Tan			Tan
12	Tan								Tan		Tan				White
13	Red								White		Red				

Layer	16 Banquet/ Upper Field	17 Banquet/ Upper Field	18 Banquet/ Lower Dado	19 Banquet/ Lower Dado	20 Banquet/ Upper Field	21 Banquet/ Lower Dado	22 Banquet/ Lower Dado	23 Banquet/ Upper Field	24 Banquet	25 Banquet/ Lower Dado	26 Banquet/ Upper Field	27 Banquet/ Upper Field	28 Banquet/ Upper Field	29 Banquet/ Upper Field	30 Banquet / Upper Field
1	Tan	Tan		Tan	Tan	Tan	Tan	Tan	Tan	Tan	Tan	Tan	Tan	Tan	Tan
2	Tan	Tan		Tan	Tan	Tan	Tan	Tan	Tan	Tan	White	Tan	Tan	Tan	Tan
3	White	Tan	White	White	Tan	White	White	White	White	White	Tan	Tan	White	Tan	White
4	Tan	White	Tan	Tan	White	Tan	Tan	Tan	Tan	Tan	White	Tan	Tan	White	Tan
5	White	Tan	White	White	Tan	White	White	White	White	White	Tan	White	White	Tan	White
6	Tan	White	Orange	Tan	White	Tan	Orange	Tan	Tan	Orange	White	Tan	Tan	White	Tan
7	White	Tan	Tan	White	Tan	White	Tan	White	White	Tan	Tan	White	White	Tan	White
8	Tan	White	Red	Red	White	Tan	Tan	Orange	Orange	White	White	Tan	Tan	White	Tan
9	White	Tan			Tan	White	White	Tan	Tan	Orange	Tan	White	White	Tan	White
10	Tan	White			White	Tan	Tan	White	White	Red		Tan	Tan	White	Tan
11	Red	Tan			Tan	Red	Blue	Tan	Tan			White	White	Tan	
12		White					Tan		White			Tan		White	
13							Red								

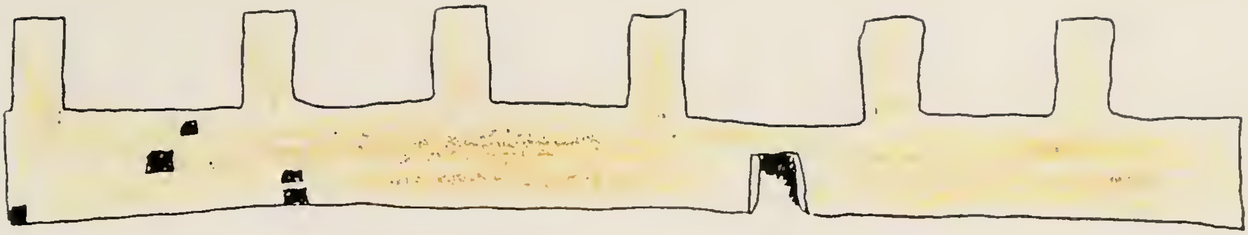
STRAIGRAPHIES OBSERVED IN ROOM 28, WEST EXTRIOR WALL

Stratigraphy

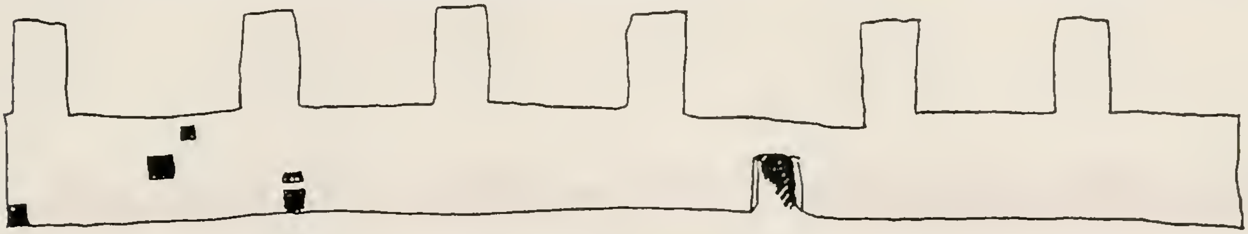
Layer	31 Upper Field	32 Lower Dado
1	Tan	Tan
2	White	Red

APPENDIX B

SPECULATIVE FINISHES SEQUENCE IN KIVA C

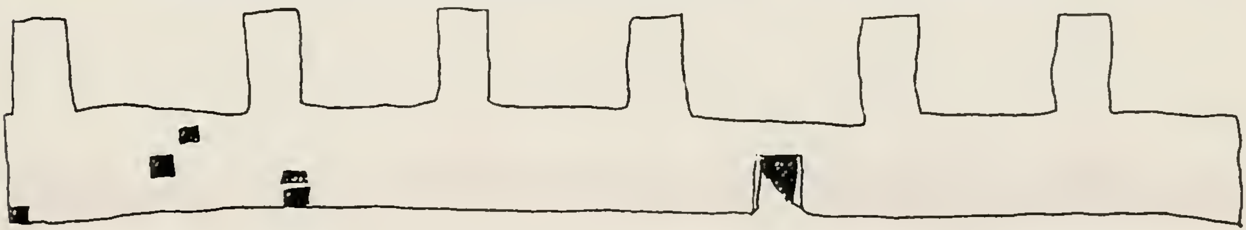


I

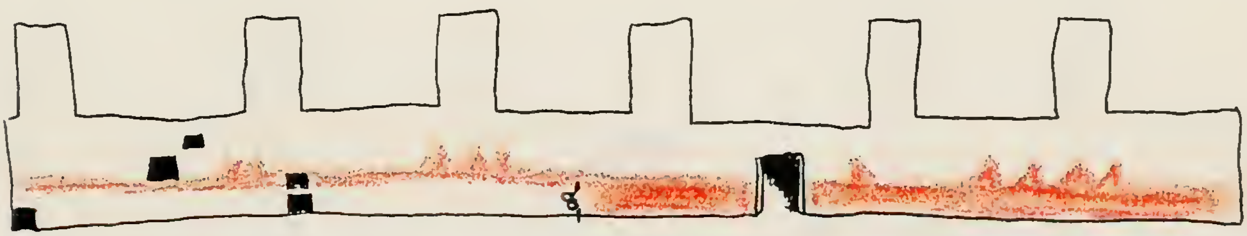


II

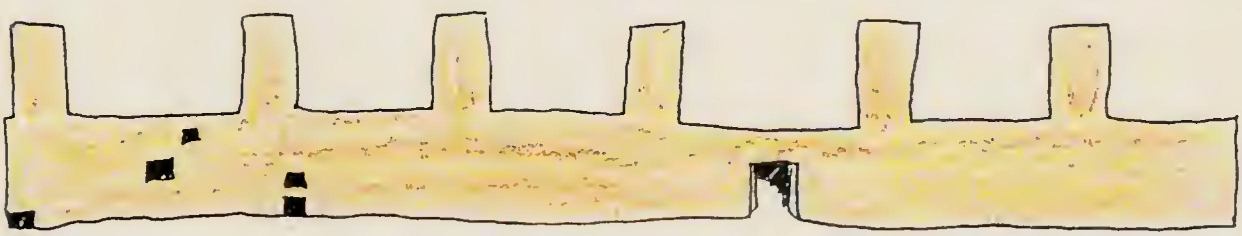
III



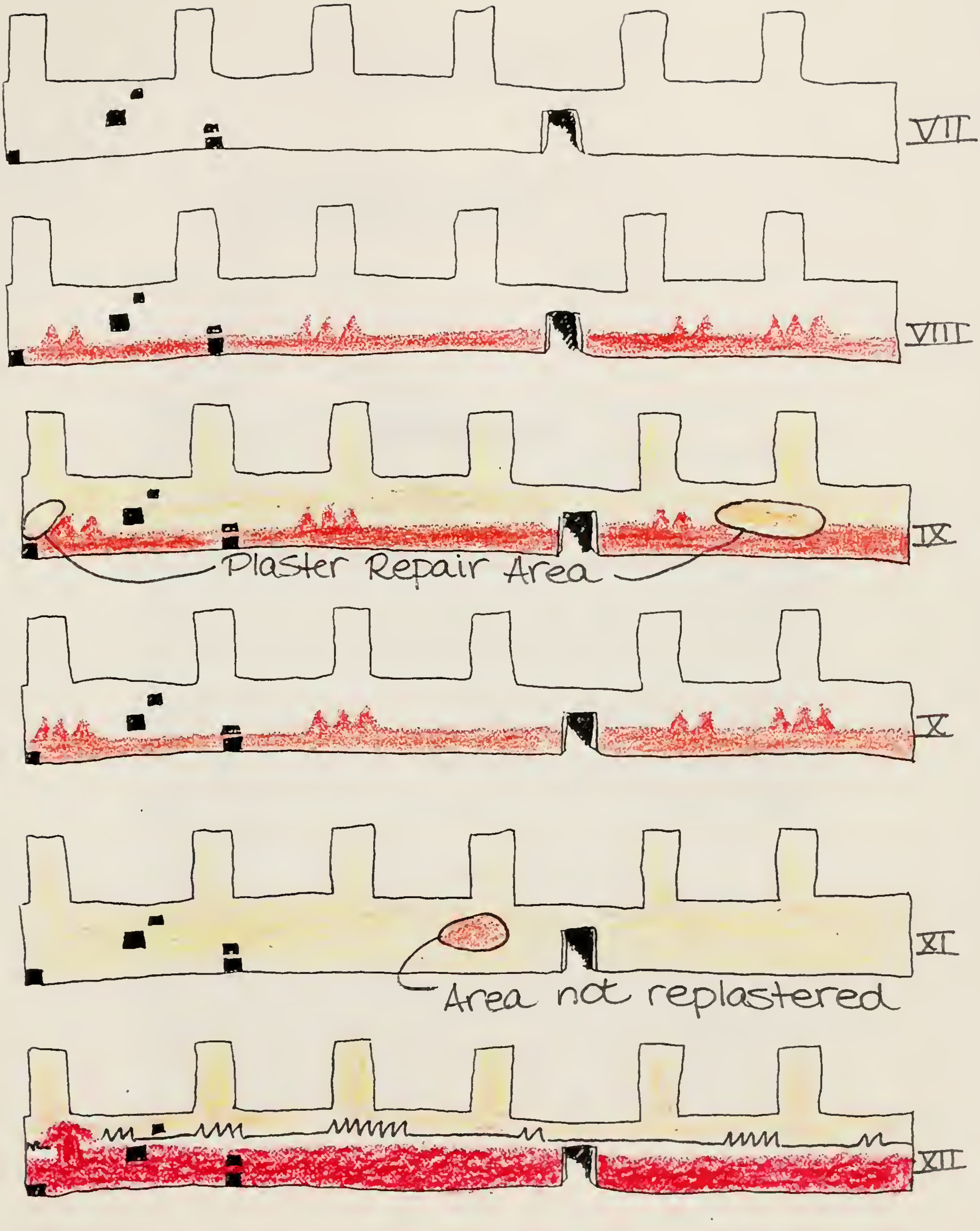
IV



V

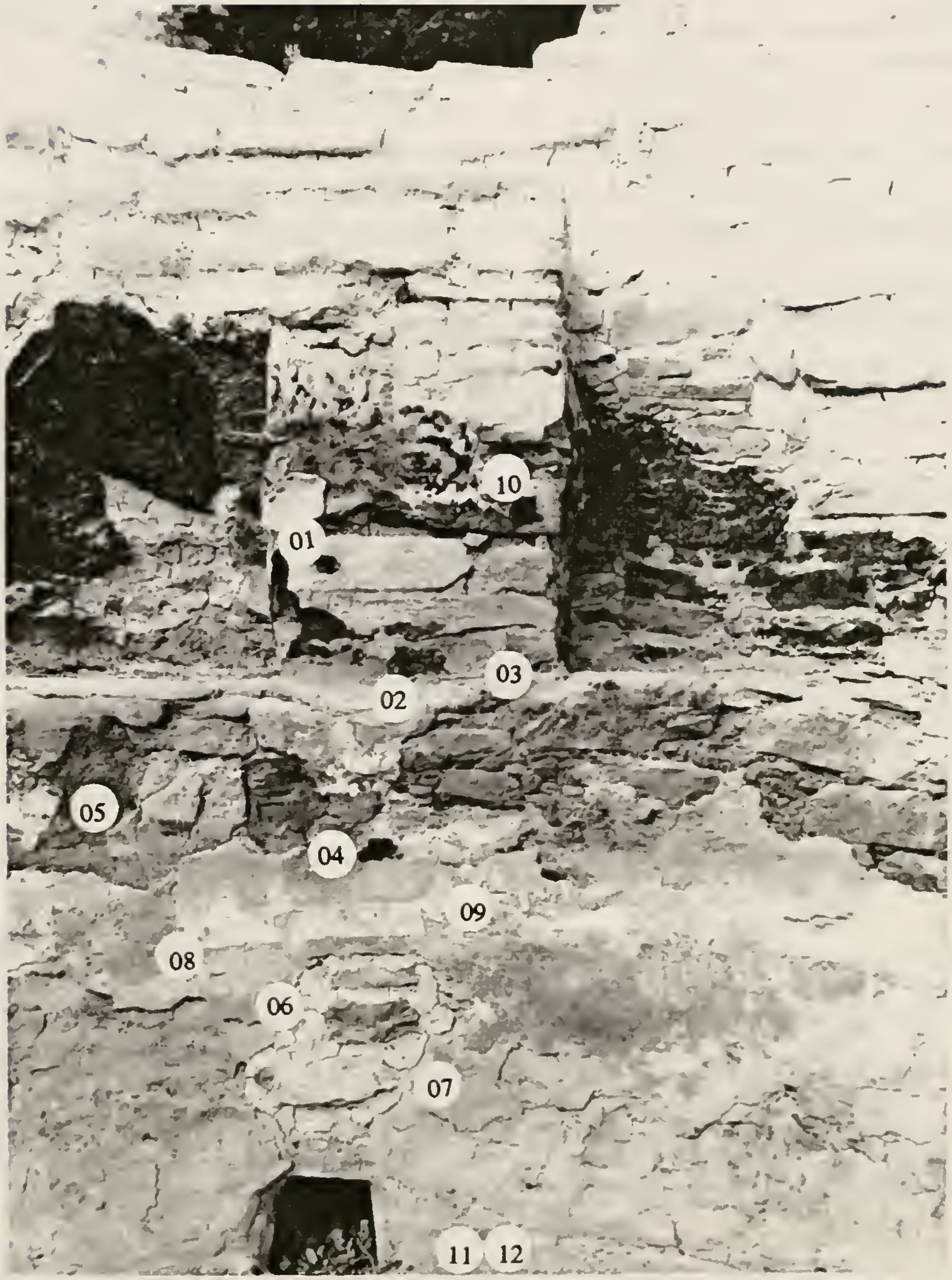


VI



VII
VIII
IX
Plaster Repair Area
X
XI
Area not replastered
XII

MAP OF SAMPLE LOCATIONS
FROM KIVA C



MUG HOUSE
SAMPLE LIST

Kiva C

Sample	Description
01	Plaster from upper portion of lintel including all layers to stone. Approximately 400 cm from floor level.
02	Plaster from junction of lintel and kiva interior wall including all layers to stone. Approximately 170 cm above floor level.
03	Bedding mortar between the 1st and 2nd course of Pilaster 3. Joint approximately 20 mm wide.
04	Plaster from kiva wall, upper field (tan finish), not to stone. Approximately 800 mm from floor level.
05	Level fill from kiva wall.
06	Plaster from kiva wall, lower dado (red finish), including all layers. Approximately 500 mm above floor level.
07	Plaster from kiva wall, lower dado (red finish), including all layers. Approximately 300 mm above floor level.
08	Plaster from kiva wall, junction of red dado and white band, not to stone.
09	Plaster at junction of white and orange finishes on dado, not to stone.
10	Base coat plaster.
11	Floor plaster.
12	Under floor.

Room 28, West Exterior Wall

Sample	Description
13	Plaster from upper field (white finish), all layers.
14	Plaster from lower dado (red finish), all layers.
15	Bedding mortar, top coarse.

Adobe Cave

Sample	Description
16	Soil sample.

APPENDIX D

THIN SECTION MICROMORPHOLOGY
Data Sheets

THIN SECTION MICROMORPHOLOGY

Sample 1: Plaster from Kiva C, Upper Pilaster

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9	Layer 10
Continuity	Continuous	Discontinus	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Thickness	Even	Even	Even	Even	Uneven	Even	Uneven	Even	Even	Uneven
Measuremnt	12.75 mm	0.25 mm	1 mm	0.25 mm	0.75 mm	0.125 mm	1 mm	0.625 mm	0.375 mm	0.5 mm
Surface	Irregular	Regular	Irregular	Regular	Irregular	Irregular	Regular	Irregular	Regular	Irregular
Misc.	Soot	Soot	-	Soot	-	Soot	Soot	Soot	Soot	-
Distinctness	Distinct	Distinct	Indistinct	Distinct	Indistinct	Distinct	Distinct	Distinct	Distinct	Indistinct
Texture	Homog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.
Color Zone	Heterog.	Homog.	Homog.	Homog.	Heterog.	Homog.	Heterog.	Homog.	Homog.	Homog.
Color	Heterog.	Heterog.	Heterog.	Homog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.
Ratio of Coarse/Fine	60:40	10:90	60:40	10:90	60:40	10:90	40:60	60:40	70:30	80:20
Anomalies	Vacuoles	-	Vacuoles	-	Lg. Blebs	-	Vacuoles	-	Blebs	-
Fine Frac. Color	Red	Pink	Orange/ Brown	Orange	Orange/ Brown	Orange	Orange/ Brown	Orange/ Brown	Grey-Brown	Tan, Orange
Coarse Frac. Color(s)	Black, White, Clear	White, Black Very Fine	Tan, Black, Clear, Red	Clear, White, Black	Clear, Red, White, Black	Tan, Red, Black	Clear, White, Black, Orange	Clear, White, Red, Black	Clear, Black, White	White, Black
Roundness	Subround	Subround	Subround	Subround	Subround	Subangular	Subround	Subangular	Subangular	Subround
Sphericity	Smooth	Undulating	Smooth	Smooth	Smooth	Smooth	Undulating	Smooth	Smooth	Smooth
Degree of Sorting	Well Sorted	Well Sorted	Well	Well Sorted	Well	Well Sorted	Well Sorted	Well Sorted	Well Sorted	Well Sorted

Sample 3 : Bedding Mortar from Kiva C

	Layer
Continuity	Continuous
Thickness	6.75 mm
Measuremnt	N/A
Surface	Irregular
Misc.	-
Distinctness	Distinct
Texture	Heterog.
Color Zone	Homog.
Color	Heterog.
Ratio of Coarse/Fine	70:30
Anomalies	Vacuoles, Blebs
Fine Frac. Color	Orange/ Brown
Coarse Frac. Color(s)	Black, Orange, Red, Clear
Roundness	Subround
Sphericity	Smooth
Degree of Sorting	Moderate

Sample 6: Plaster from Kiva C, Lower Dado

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9	Layer 10
Continuity	Discontinus	Continuous	Discontinus	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Thickness	Uneven	Uneven	Even	Even	Uneven	Uneven	Uneven	Even	Uneven	Even
Measurement	—	0.25 mm	0.25 mm	1.25 mm	0.25 mm	0.80 mm		0.20 mm	0.1 mm	0.5 mm
Surface	Irregular		Regular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Regular
Misc.	Soot	Soot	Soot	Fracture	-	-	-	Soot	-	Soot
Distinctness	Distinct	Distinct	Distinct	Indistinct	Distinct	Indistinct	Indistinct	Indistinct	Indistinct	Distinct
Texture	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.
Color Zone	Homog.	Homog.	Homog.	Heterog.	Homog.	Homog.	Homog.	Homog.	Homog.	Homog.
Color	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.
Ratio of Coarse/Fine	25:75	40:60	25:75	60:40	10:90	40:60	40:60	10:90	40:60	10:90
Anomalies	Blebs	-	Blebs	Blebs	-		Vacuoles	Blebs	-	Blebs
Fine Frac. Color	Brown	Brown	Brown	Orange/ Brown	White	Orange	Orange/ Brown	White	Orange/ Brown	White
Coarse Frac. Color(s)	Black, White, Red	Clear, Black, Red	Black, Clear, Red, Orange	Clear, White, Red, Black	Clear, White, Black, Orange	Clear, Black, Orange	Clear, White, Black, Red, Orange	Clear, White, Black, Orange	Clear, Black, Orange	White, Clear, Black, Orange, Red
Roundness	Subangular	Subangular	Subround	Subround	Subround	Subround	Subround	Subangular	Subround	Subround
Sphericity	Undulating	Undulating	Undulating	Undulating	Rough	Undulating	Undulating	Rough	Undulating	Rough
Degree of Sorting	Poor	Moderate	Moderate	Moderate	Moderate	Poor	Moderate	Well	Moderate	Well

Sample 6, Continued

	Layer 11	Layer 12	Layer 13	Layer 14
Continuity	Continuous	Continuous	Continuoua	Continuous
Thickness	Even	Even	Even	Uneven
Measuremnt	2 mm	0.25 mm	0.75 mm	0.1 mm
Surface	Irregular	Regular	Irregular	Irregular
Misc.	—	Fracture	—	Soot, Fracture
Distinctness	Indistinct	Distinct	Distinct	Distinct
Texture	Heterog.	Homog.	Heterog.	Heterog.
Color Zone	Homog.	Homog.	Heterog.	Homog.
Color	Heterog.	Heterog.	Heterog.	Heterog.
Ratio of Coarse/Fine	70:30	10:90	70:30	10:90
Anomalies		Blebs	Blebs	-
Fine Frac. Color	Orange/ Brown	White	Orange/ Brown	Red
Coarse Frac. Color(s)	Clear, White, Black, Red	Clear, Black, White, Orange	Clear, White, Black	Clear, Black, Red
Roundness	Subround	Subround	Subround	Round
Sphericity	Smooth	Rough	Undulating	Smooth
Degree of Sorting	Poor	Well	Well	Moderate

Sample 7: Plaster from Kiva C, Lower Dado

	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Layer 7	Layer 8	Layer 9	Layer 10
Continuity	Continuous	Discontinus	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Thickness	Even	Even	Even	Even		Even	Uneven	Even	Uneven	Uneven
Measurement	3 mm							0.5 mm	0.5 mm	0.25 mm
Surface	Irregular	Regular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular	Irregular
Misc.	-	Soot	-		-	-	-	-	Fracture	-
Distinctness	Indistinct		Indistinct	Indistinct	Indistinct	Indistinct	Distinct	Distinct	Indistinct	Distinct
Texture	Heterog.		Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.
Color Zone	Homog.		Homog.	Homog.	Homog.	Homog.	Homog.	Homog.	Homog.	Homog.
Color	Heterog.		Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Homog.
Ratio of Coarse/Fine	40:60		60:40		60:40	20:80	50:50	10:90	40:60	10:90
Anomalies	-		Blebs		-		Vacuoles	Vacuoles, Blebs	Vacuoles	-
Fine Frac. Color	Orange/ Brown	Pumpkin	Orange/ Brown	Pumpkin	Orange/ Brown	Pumpkin	Orange/ Brown	Red	Orange/ Brown	White
Coarse Frac. Color(s)	Clear, Yellow, Black,	Black, White	Clear, White, Black	Black	Clear, White, Black, Orange	Clear, Black,	Clear, White, Black, Orange	Clear, White, Black, Red	Clear, Black, White, Tan	White, Orange, Black
Roundness	Subround	Subangular	Subangular		Subround	Round	Subround	Subround	Subangular	Subround
Sphericity	Undulating		Undulating		Undulating	Undulating	Undulating	Rough	Smooth	Rough
Degree of Sorting	Poor		Moderate		Moderate	Moderate	Poor	Well	Moderate	Well

Sample 7, Continued

	Layer 11	Layer 12	Layer 13	Layer 14	Layer 15	Layer 16
Continuity	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Thickness		Uneven	Uneven	Even	Even	Uneven
Measurement	0.25-.4 mm	0.5-0.75 mm	0.25-.6 mm	0.25 mm	0.625 mm	0.125 mm
Surface	Irregular	Irregular	Irregular	Regular	Irregular	Irregular
Misc.	Fracture		Fracture	Soot	-	Soot
Distinctness	Distinct	Indistinct	Distinct	Distinct	Distinct	Distinct
Texture	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.	Heterog.
Color Zone	Homog.	Homog.	Homog.	Homog.	Homog.	Homog.
Color	Heterog.	Heterog.	Homog.	Heterog.	Heterog.	Heterog.
Ratio of Coarse/Fine	30:70	60:40	10:90	20:80	50:50	10:90
Anomalies	Vacuoles, Blebs	Vacuoles	-	Vacuoles, Blebs	Vacuoles, Blebs	
Fine Frac. Color	Orange*	Orange/ Brown*	White	Orange*	Orange/ Brown	Red
Coarse Frac. Color(s)	Clear, White, Black, Red	Clear, White, Black	White, Clear, Red, Black, Orange	Clear, Grey, Black, Orange, Red	Clear, White, Black, Grey	Clear, Black
Roundness	Subangular	Subangular	Subangular	Subangular	Subround	Subangular
Sphericity	Smooth	Smooth	Rough	Undulating	Smooth	Undulating
Degree of Sorting	Moderate	Poor	Poor	Moderate	Poor	Moderate

Sample 13: Plaster from Room 28, Upper Field

	Layer 1	Layer 2
Continuity	Continuous	Continuous
Thickness	Even	Even
Measurement	6.25 mm	9 mm
Surface	Irregular	Regular
Misc.	-	-
Distinctness	Indistinct	Distinct
Texture	Heterog.	Homog.
Color Zone	Homog.	Homog.
Color	Heterog.	Heterog.
Ratio of Coarse/Fine	60:40	10:90
Anomalies	Vacuoles, Blebs	-
Fine Frac. Color	Orange/ Brown	White
Coarse Frac. Color(s)	Clear, White, Black, Orange	White, Black, Red
Roundness	Subround	Subangular
Sphericity	Smooth	Undulating
Degree of Sorting	Moderate	Well

Sample 14: Plaster from Room 28, Lower Dsdo

	Layer 1	Layer 2
Continuity	Continuous	Continuous
Thickness	Even	Uneven
Measurment	9.5 mm	0.25 mm
Surface	Irregular	Regular
Misc.	-	-
Distinctness	Indistinct	Indistinct
Texture	Heterog.	Heterog.
Color Zone	Heterog.	Homog.
Color	Heterog.	Heterog.
Ratio of Coarse/Fine	60:40	40:60
Anomalies	Vacuoles, Blebs	
Fine Frac. Color	Orange/ Brown	Red
Coarse Frac. Color(s)	Clear, White, Black, Red Orange	Clear, Red, Orange
Roundedness	Subround	Subround
Sphericity	Smooth	Undulating
Degree of Sorting	Moderate	Moderate

Sample 15: Bedding Mortar from Room 28

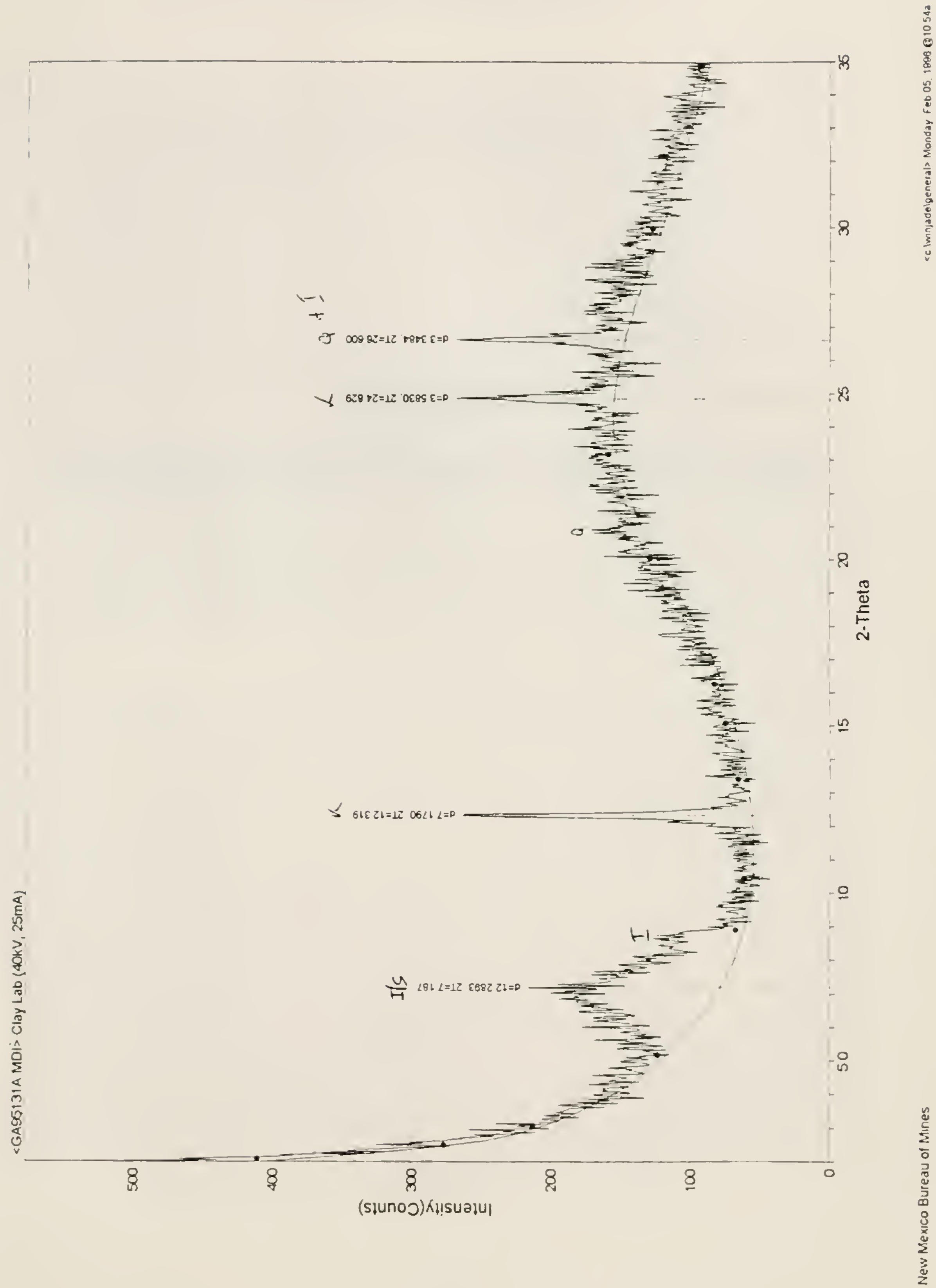
	Plaster
Continuity	N/A
Thickness	N/A
Measurment	N/A
Surface	N/A
Misc.	N/A
Distinctness	N/A
Texture	Heterog.
Color Zone	Homog.
Color	Heterog.
Ratio of Coarse/Fine	60:40
Anomalies	Vacuoles, Blebs
Fine Frac. Color	Orange/ Brown
Coarse Frac. Color(s)	Clear, Black, White
Roundedness	Rounded
Sphericity	Undulating
Degree of Sorting	Poor

APPENDIX E

X-RAY DIFFRACTION ANALYSIS

KIVA C PLASTER

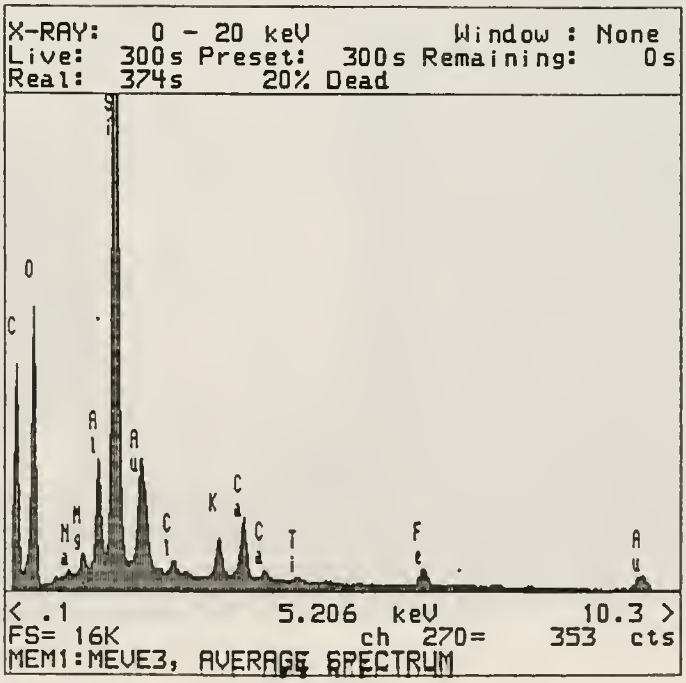
ROOM 28 MORTAR

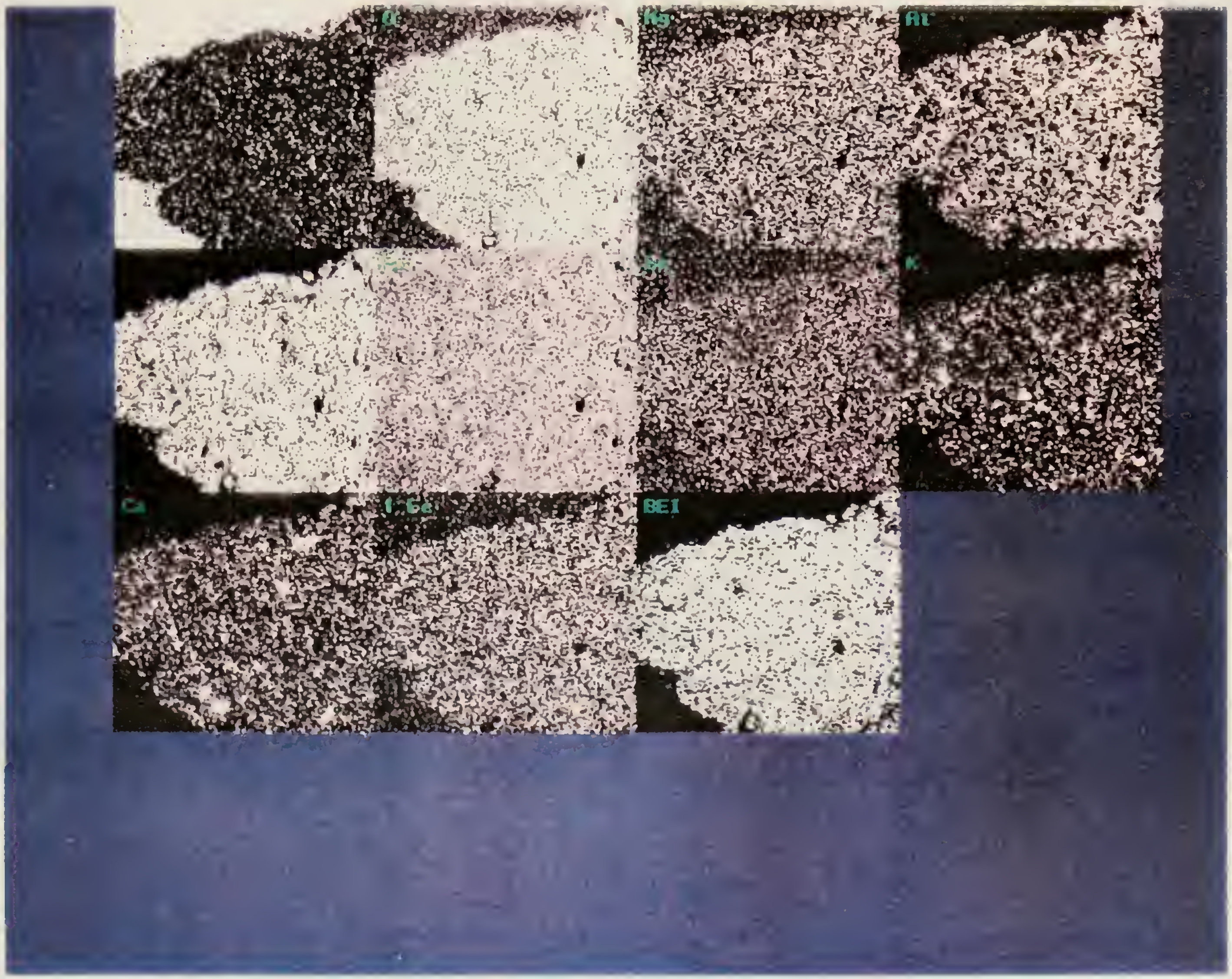


APPENDIX F

SCANNING ELECTRON MICROSCOPY WITH X-RAY ANALYSIS

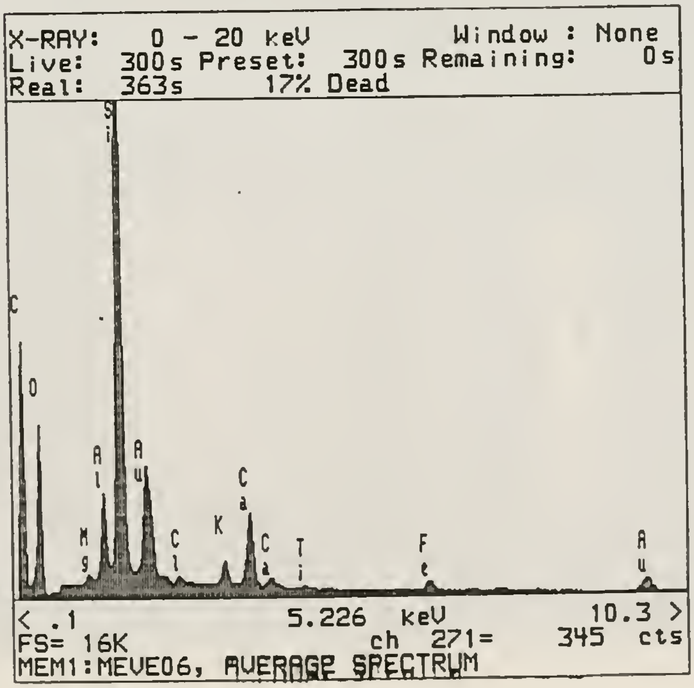
SAMPLE 03: BEDDING MORTAR FROM KIVA C

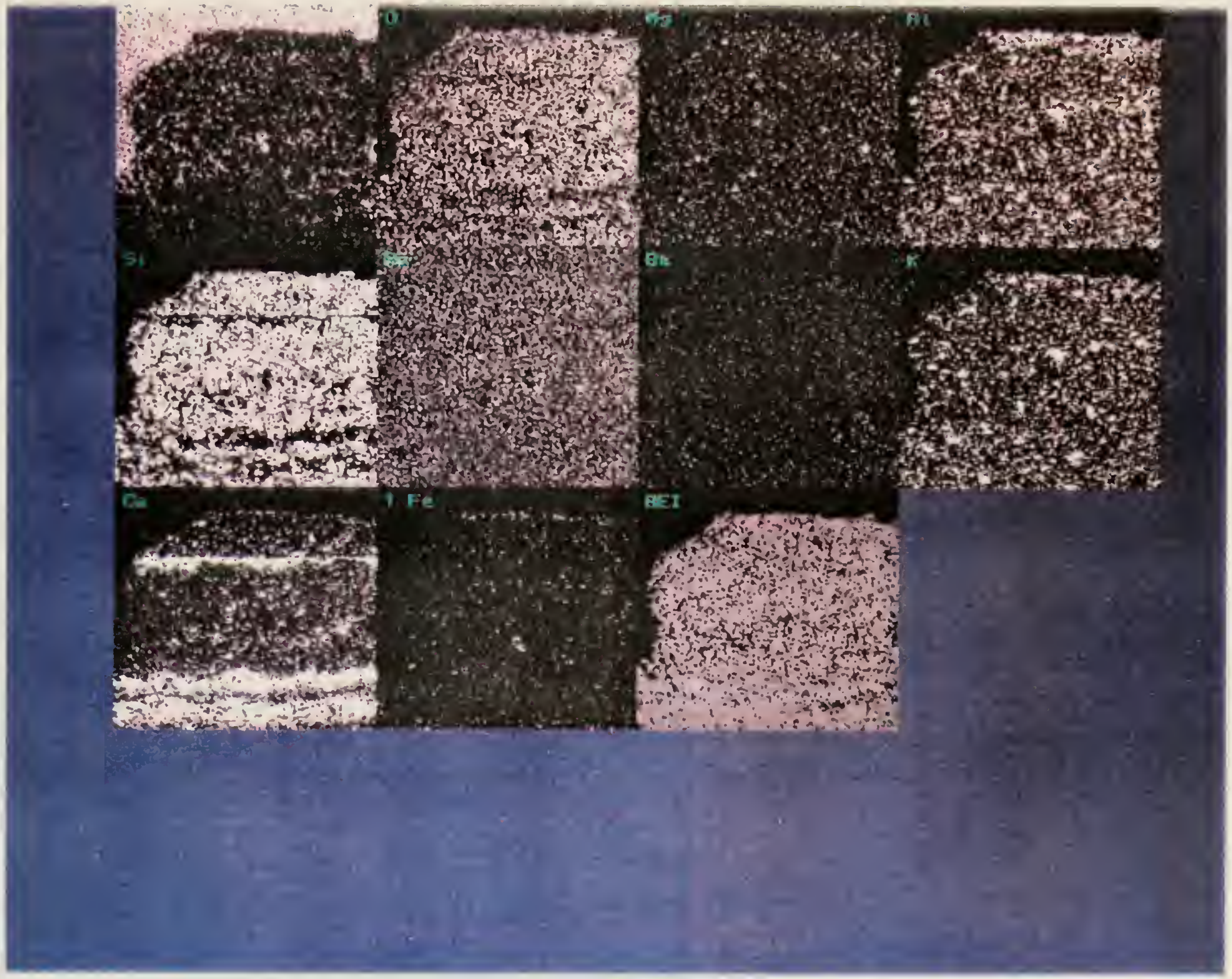




Sample 03: Electron Dot Map

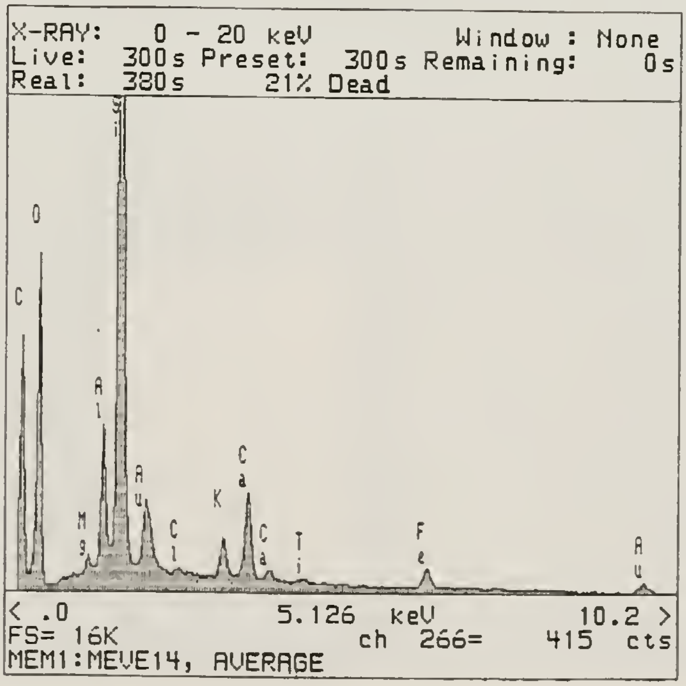
SAMPLE 06: PLASTER FROM KIVA C

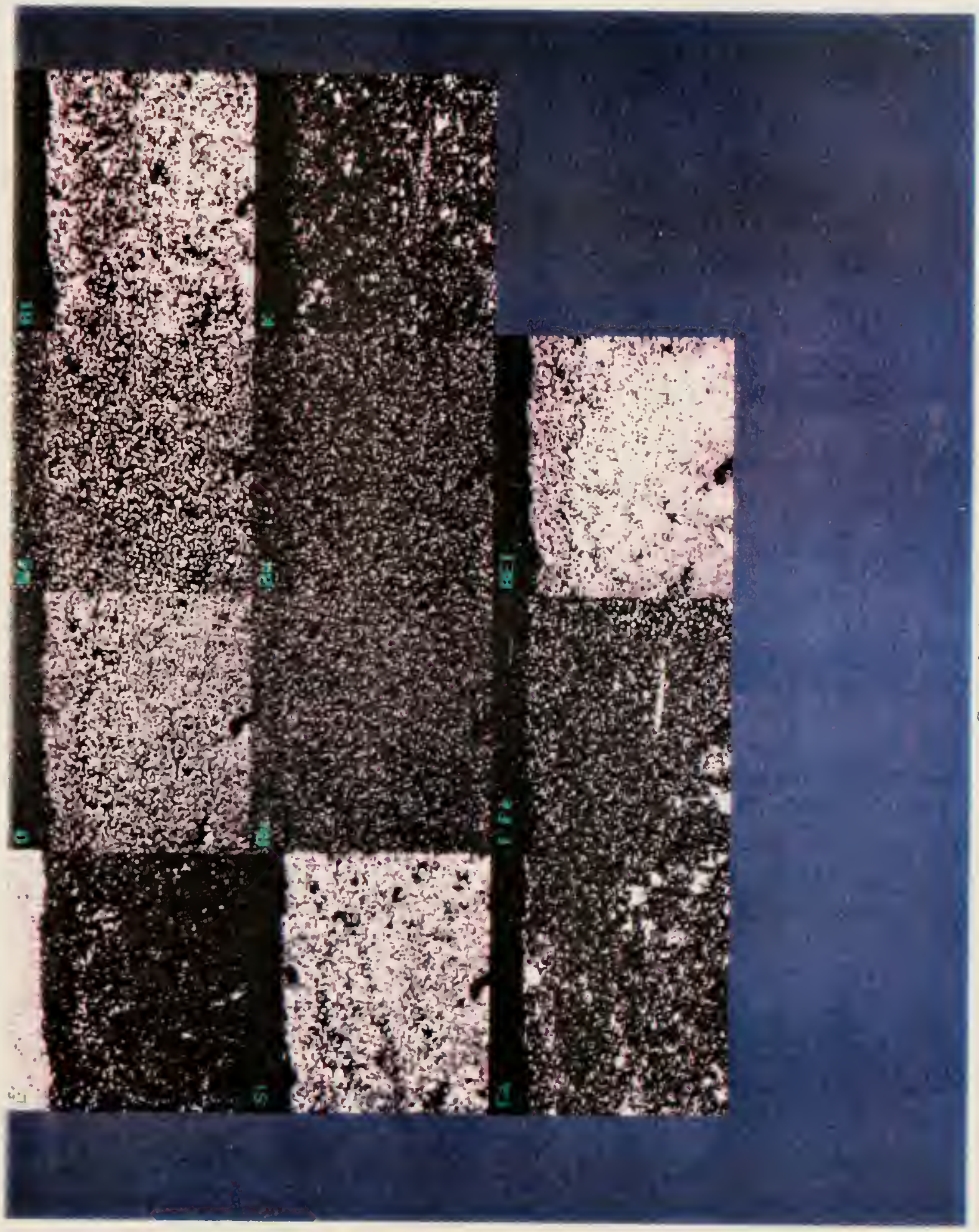




Sample 06: Electron Dot Map

SAMPLE 14: PLASTER FROM ROOM 28





Sample 14: Electron Dot Map

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