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historic structure report

TUMACACORI

NATIONAL MONUMENT / ARIZONA

HISTORIC STRUCTURE REPORT

TUMACACORI NATIONAL MONUMENT
Arizona

by
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PREFACE

This *Historic Structure Report* is the final completion report of a preservation project that basically began when a group of architects, historians, archeologists, and managers from the National Park Service gathered at Tumacacori National Monument, Arizona, in January 1975. The impetus for the meeting was the closing of the church to visitors one month before for fear that falling plaster would cause a serious injury. Decisions had to be made that would comprehensively address what appeared to be critical preservation problems. How severe were the problems and how should they be resolved? More importantly, what steps would the Park Service take in determining the severity of the problems and in undertaking the necessary resolutions? The first step--actual planning--was initiated at the January 1975 meeting.

It was a year before comprehensive on-site analysis began, but the first actual research was undertaken by the Western Archeological Center in the analysis of past archeological projects in order to synthesize the data and analyze the potential for future archeology. An important result of this report, in addition to fulfilling the goals of the research design, was the information related to the archeological and architectural preservation, which was an aid in specific decisions for preservation treatments (NPS, USDI 1975).

The other two principal disciplines that would be most directly involved in the project, architecture and history, would be represented by a historical architect and a historian from the Denver Service Center's Division of Historic Preservation. I was the historical architect and Berle Clemensen was the historian who would look at the history of Tumacacori since it was abandoned in 1848. This part of the history was extremely important since the project was intended and designed to be directed to preservation problems and not to a further understanding of the mission community, including its architecture, which would certainly have been valuable for interpretive purposes. This history was meant to identify what had been done at Tumacacori since 1919 when Frank Pinkley first assigned A.S. Noon to clean out the nave of the church. In order to design solutions to preservation problems, it was critical to know what preservation and restoration work had been done in the past, which methods had been successful, and which ones had not been successful. This history research began in the fall of 1975.

I moved to Tucson in December 1975, and for the next 18 months worked primarily on-site at Tumacacori, but was provided office space and a great deal of assistance at the Western Archeological Center. During this period most of the initial problems were identified. However, data were continually gathered on structural conditions and the source of the moisture and its extent which had led to most of those problems.

In addition, $210,000 for basic material research was contracted to the National Bureau of Standards. Much of this work has proved to be extremely valuable for all people working in the preservation of adobe. Several other much smaller contracts were let, primarily to Arizona State University, for additional information on alternative preservation procedures.

The architectural investigation, in conjunction with associated research, indicated that the major problems that moisture was causing were being accelerated by hard cement stuccos, which had been applied on most all of the exterior surfaces. These relatively impervious surfaces prevented moisture in the masonry from evaporating naturally, often resulting in moisture contents that approached the plastic limit of the material. In other cases the moisture content surpassed the plastic limit and even approached the liquid limit.

The resolution of the problems, the actual preservation procedures, were undertaken almost exclusively with day labor crews, working primarily during the summers of 1978 and 1979 and part of the spring and summer 1980. The vast majority of this work was supervised by George Chambers of the Western Archeological Center. By 1980 the preservation work was essentially completed and only the conservation of the painted plaster remained.

The entire preservation project was oriented to doing the least amount of work necessary to preserve the buildings and the site of Tumacacori. Minimal intervention was the overriding philosophy. The goal was to bring Tumacacori to a point so that it could be maintained. And, maintenance of the structures at Tumacacori is now not only a way to preserve them but is, in fact, the preferable method. Maintenance preserves the character as well as the material itself. This actual preservation procedure is best characterized by D.H. Lawrence in Mornings in Mexico: "That they don't crumble is the mystery. That those little squarish mud heaps endure for centuries after centuries while Greek marble tumbles assunder and cathedrals totter is the wonder. But a single human hand with a bit of new soft mud is quicker than time and defies the centuries."

The Historic Structure Report is basically an edited version of two previous architectural reports, which were the basis for the work at Tumacacori. In addition, it summarizes the preservation project and makes a few recommendations for the future. The actual detail and extent of discussions vary from subject to subject. For example, the analysis and the resulting conservation of the painted plaster of the dome is more technical in nature than much of the other preservation work and is therefore described in much more detail. This difference is generally consistent throughout the document.

ACKNOWLEDGEMENTS

In any project such as this, where so many different people are involved, there are many whose contribution I would like to acknowledge. The majority of these people are from the National Park Service. In particular, several of my colleagues at the Denver Service Center were directly involved in the project--Paul Cloyd, Henry Apodaca, Norma Camarena, David Ates, and Elizabeth Santos. Chief Historical Architect Hank Judd, and then Hugh Miller of the Division of Historic Architecture, Park Historic Preservation, offered their support as was appropriate. Gordon Chappel, Western Regional Historian, was involved from the outset as he attended the planning meeting in January 1975. Tom Mulhern, Chief of Cultural Resources, Southwest Region, and John Clay, Southern Arizona Group, were also involved from the beginning and supported the project from their positions.

The list of people who were involved outside the Park Service is also extensive. Many of these, such as Bunny Fontana and Charlie Polser, knew Tumacacori long before I did and will know it long afterwards.

The Tumacacori project was also supported on an international level as the Rome Center provided the services--at no salary costs to the Park Service--of three mural painting conservators over the duration of the 1982 painting conservation project. Also involved in this particular project were NPS architects and conservators from places as far away and diverse as Mesa Verde National Park, Harpers Ferry Center, and the North Atlantic Regional Office.

Throughout the project the people who were most directly involved in addition to the park staff were from the Western Archeological and Conservation Center. Chief Carla Martin, George Cattanack, George Chambers, Brigid Sullivan and, earlier, Dennis Fenn, particularly come to mind.

Lastly, I wish to acknowledge the involvement and support of the entire staff at Tumacacori. Superintendent Joe Sewell was involved throughout the project as he came to Tumacacori in the spring of 1975. Other faces changed, but people like Manny, Grace, Lulu, Doug, Oscar, and Erin made my job much more enjoyable. And, in addition to the adobe bricks and wood that compose the structures, Tumacacori, in my mind, is also people--people who shared the excitement, the disappointments, and the joys throughout the project. One person stands above the rest in his concern, involvement, and excitement over Tumacacori. This involvement goes far beyond this preservation project; it extends to the total community of Tumacacori today and to the Tumacacori mission community historically. Nick Bleser, you and Birdie are, in the final analysis, what I will remember most about Tumacacori.

ADMINISTRATIVE DATA

This Historic Structure Report is the last in a series of reports dealing with the preservation of the buildings at Tumacacori National Monument that was initiated in 1976. It is a compilation of information from those previous reports plus new information not previously available. This document covers the investigation and actual preservation work on the site up to the present time.

Tumacacori National Monument is listed on the National Register of Historic Places. Therefore, all actions must be proposed and undertaken in accordance with the procedures of the Advisory Council on Historic Preservation. The historic mission period buildings are all recorded on the National Park Service's List of Classified Structures as first order of significance.

Close coordination with the Arizona State Historic Preservation Officer was established at the outset of the project and continued throughout its duration. This coordination was very beneficial to the entire preservation project. Appendix H contains the documentation of a no adverse effect finding.

CHAPTER I: HISTORY OF TUMACACORI

EARLY PERIOD, 1691-1848

The history of the Jesuit and new Franciscan occupation at Tumacacori was from 1691 to 1848.

In the latter part of the 17th century Spanish influence began to have an effect on the people of the Pimeria Alta. This area included present-day Arizona south of the Gila and west of the San Pedro rivers and extended into the northern portion of the present state of Sonora Mexico to the Rio Altan and Magoalena valleys.

Jesuit missionaries, particularly Padre Ensebio Francisco Kino, began missionary activities in this area, and by 1691, Kino entered the Santa Cruz Valley to visit the Pima village of Tumacacori. Many dedicated Jesuits were to follow, and they subsequently were followed by missionaries of the Franciscan order. For the next 150 years, the history of the church, the people, and the land were woven inseparably into a complicated tapestry of human change and suffering and potential and philosophical conflicts in an often harsh climate. After that first contact in 1691, the church and Kino lacked the resources to administer the area, and it was not until 1701, 10 years later, that a Jesuit father was assigned to Santa Cruz. But it was the village of Guevavi, located approximately 14 miles south of Tumacacori, that was designated as the cabacera, or central mission for the area. Tumacacori was a visita, or a place of periodic visitation by the padre at Guevavi. The basic function of these frontier outposts was structured by the church into organized communities. To this end an Indian mayor was elected to assist the padres with matters involving the native population. The Indians were required to attend a daily service in the mission church and to give some of their time in the fields or in and around the mission buildings for cultivating crops, raising livestock, and maintaining whatever buildings there may have been. After only three years, again because of the lack of human and financial resources, Guevavi and Tumacacori were without a church representative. This lasted until 1731, 27 years later. From 1731 to 1736 a priest was available, but then another five years passed (1741) without a representative before Guevavi finally began receiving constant attention from the church. In 1751 a Pima uprising brought a military post or presidio to Tubac, located near the site of Tumacacori. Before 1751 the village of Tumacacori was apparently located on the east side of the Santa Cruz River, probably a little to the north of the location chosen for the presidio. However, it was at this time that the village was moved to its present location on the west side of the river (the same side as the presidio) and approximately 2 miles south. By 1757 a church existed on this site, as the burial register for July 7, 1757, recorded the burial of the Tumacacori Indian mayor there. San Cayatano was the patron saint of Tumacacori in its original location and may have remained at the new site as well for a time.

In 1767 all Jesuits were expelled from new Spain, and the Franciscan order assumed the responsibilities of administering the mission established by the Jesuits and of christianizing the native population and turning them into functioning Spanish citizens. The Franciscan missionaries were supplied by the college of Queretaro, and the first arrived at Guevavi in 1768. In addition to Tumacacori, there were also visitas at Sonita and Calabasas, which were attached to Guevavi at that time. In 1770 or 1771, Guevavi was abandoned and Tumacacori effectively became the cabacera. A visita at Calabasas still existed, but it too was abandoned in the late 1780s.

The presidio at Tubac was moved to Tucson in 1775, again leaving the upper Santa Cruz with inadequate protection from Apaches whose raiding activities increased during these years. In December 1776 they attacked Tumacacori and drove off some cattle, in June 1777 they burned the visita at Calabasas, and a few months later they stole the last livestock at Tubac. Rather than continue a policy of pursuit and punishment, which had obviously been ineffective, the Spanish turned instead to a policy of pacification. This encouraged the Indians to settle as farmers, and they were supplied with food, drink, and trinkets at government expense. This policy proved basically effective from 1790 to the 1830s.

In 1795 the church at Tumacacori was described as being cramped and flimsy. The next year Padre Meriano Bordoy wrote, "As to the church structure, I say: that it is now split open into two parts and consequently there is some need that a new one be built." Whether these descriptions refer to what is identified at Tumacacori as the early Jesuit church or to a part of the present church that was subsequently rebuilt cannot be determined. The documentary evidence is very limited during these years, but there is no doubt that a major building or rebuilding began between 1798 and 1802 under the direction of Padre Narciso Gutierrez. The work was not completed when Gutierrez died in December 1820. Construction continued under Padre Juan Bautista Estelric until 1822 and then under his successor, Fray Ramon Liberos. Apparently by December 1822 the church had been completed to the degree that mass was celebrated. The church was never totally completed, and while some changes may well have taken place in later years, the church and supporting structures probably remained essentially unchanged after 1822.

There is physical evidence that substantial changes in the basic concepts and design as well as in some of the decorative features did occur, however. Some of these changes were so extensive that it seems unlikely that they would have occurred over a relatively short building program of 20 years. The most significant change was from a cruciform church plan to that of a single nave. Finish plaster on both the interior and exterior of the remaining lower walls and foundations of the transepts was discovered during excavations. It seems unlikely that the transepts would have been completed and then have deteriorated to such a degree that the openings were closed off in only a 20-year period. Either they were removed consciously, or more likely, deteriorated over a longer period of time. After the transepts were closed, the sidewalls were plastered and painted and probably remained for some time prior to the addition of the side altars that exist now.

Another significant change occurred when the apse or sanctuary area was altered by the relocation of some walls and by the later addition of the dome. Most of the evidence for this change is in subsurface foundations, but a portion of painted plaster extending behind the existing pilasters also indicates they were added later. These later additions would have probably corresponded with the construction of the dome. The dome itself also changed as it was repainted at least once.

Still another important change took place when the coro, or choir, was altered. Evidence shows that the original concept was a vaulted choir that extended slightly farther to the north than does the present remains. Whether or not the choir was completed as a vaulted feature is not known, but the final structure was of wooden beams supported on the north by a transverse arch. This arch existed until ca. 1900 and can be seen in several late 19th century photographs. There also seems to be a direct symmetrical relationship between the foundations of the earlier conceived coro and that of the doorway into the baptistry. The doorway on the coro level from the second floor above the baptistry is not centered on the baptistry door but instead is symmetrical to the second coro.

There are many other less significant changes but important ones nonetheless. A series of subtle changes are seen in the portion of the corridor above grade. Many of these changes probably occurred during the late 19th century. However, upon close inspection of the intersections of finished wall surfaces below the existing grade, it was evident that a number of changes occurred quite early. Because of the lack of necessary physical information, the exact configuration during the late 18th century will be difficult if not impossible to determine in the future.

During the removal of the cement stucco from the campo santo walls in 1979, historic repairs to the walls were evident. Specifically, a portion of the wall extending north from the granary, and a portion of the west wall had been constructed, had weathered significantly, and had then been repaired and finished. The extent of the deterioration was more extensive than would have probably occurred in less than 10 years of normal weathering. The completed height of the wall prior to the erosion was not determined so the wall could have stood for much more than 10 years prior to the repairs.

During the excavations necessary for the setting of the columns to support the convento protective shelter, other unanticipated structural features were discovered that also could relate directly to construction periods and changes from earlier buildings and structures.

The number of these few examples can probably be multiplied several times over by other changes and other evidence of the specific sequence of building and use if the changes that exist only below grade were included. These indications of the building sequence at Tumacacori are all examples of physical evidence extant in the structures themselves. There are many more that were not mentioned, and there is also much information that could probably provide a more definitive explanation of when various components of the building complex were constructed and under what influence. However, these cited examples are enough to bring into serious question the accepted theory that the present church was commenced and executed in its entirety between ca. 1800 and 1822.

After Mexico gained independence from Spain in 1821, a prejudice against anything Spanish was evident. This resulted in another blow to the missions of the Pimeria Alta as all Spanish-born missionaries were expelled from Mexico in 1827. Only the Mexican priests remained to administer all of the churches. Secularization soon followed in 1834. The church did not desert the mission at Tumacacori although its assistance and influence were very limited. In 1841, Friar Antonia Gonzales had Tumacacori in his charge.

An inventory of Pimeria Alta missions in 1942 provides a description of the interior of the church with the names and numbers of santos and vestments still at Tumacacori. One interesting aspect of this inventory was that the patron saint given for Tumacacori was La Purisima Concepción and not San José. In the description of the interior, it appears that La Purisima Concepcion was also located above the main altar in the sanctuary. It is also interesting to look at this description in light of the iconography of the painted pendentives in the sanctuary. The well, the gateway, the palm, and the cypress are all attributes of the La Purisima Concepción and not of San José. The exact meaning of all this is certainly open to conjecture, but it does point out that there is still so much about Tumacacori's history that remains a mystery.

As the 1840s progressed, life for the people at Tumacacori became even more difficult. The Mexican government did not continue the pacification program initiated by Spain, and as a result, Apache raids became more and more frequent. People still lived at Tumacacori in October 1848 as evident from an entry in the diary of Cave J. Couts: "At Tumacacori is a very large and fine church standing in the midst of a few common conical Indian huts, made of bushes, thatched with grass, but of most common and primitive kind . . . all its images, pictures, figures, etc., remain unmolested and in good keeping." However, two months later, after another Apache attack, the people at Tumacacori joined the Papago at San Xavier del Bac near Tucson. The period of Tumacacori as a mission was over.

ABANDONMENT PERIOD, 1848-1918

The Santa Cruz Valley was on one of the routes to the west coast and the California gold fields from the east. During 1849 and the 1850s many people heading west made mention of Tumacacori in their diaries. One of the most descriptive was penned by John Robert Forsyth in October 1849:

> A few miles after leaving camp I was astonished to hear the clear loud ring of two bells which chimed harmoniously on the pure morning air and on looking across the valley and stream I spied a handsome white church. On passing over I found as usual all desolation. . . . The church and all surrounding

> buildings were in a fine state of preservation. The paintings, guildings, cement floor, walls and everything was in perfect order with the exception of the names most shamelessly scratched on the walls by some of the gold seekers. The whole place had a monastic appearance, rows of cells, confessional stalls, etc. The garden was well filled with full grown fruit trees and they had been heavily laden with peaches, pomegranates, quinces, etc., but very few were left for us, however we gleaned a few peaches. There was something oriental in the appearance of this secluded and deserted town. The white domes of the church, the deep green trees, the peaked and rocky mountains immediately in the rear all combined to give it an asiatic effect in our eyes.

H.M.T. Powell, who in addition to sketching the church, provided in October 1849:

> The church is built chiefly of brick, plastered over. The square tower looks as if it had never been finished. The houses, extending east, are adobe. The church inside is about 90x18, painted and gilded with some pretensions to taste. The altar place under the dome was, of course, more carved, gilded, and painted than anywhere else. Behind the church, north side, there is a large burying ground enclosed by a neat adobe wall plastered and having niches in it at intervals. There was a circular oratory at the south end of it near the church. East of the church there was a large square yard, on the west side of which, passing under some solid arches, we came to a flight of steps leading to a granary, three large bells, and there was one lying inside the church, dedicated to Senor San Antonio, dated 1809. (Watson 1931)

The 1850s began to see other changes as settlers began to slowly move into the Santa Cruz Valley. American troops moved into the area and established Camp Moore at Calabasas, but five months later they moved approximately 25 miles east of Tubac and constructed Fort Buchanan. This protection was the principal reason people began to enter the area (NPS 1977a).

According to the March 1859 issue of The Weekly Arizonian, the Santa Rita Mining Company apparently "purchased the old ranch and mission building of Tomacacori [sic] and . . . will make the extensive repairs." Another description of the mission was included in a report of the mining company's property by William Wrightson in 1860:

"The roof of the church was flat and covered with cement and tiles. The timbers have now fallen and decayed. The chancel was surmounted with a dome, which is still in good preservation."

Wrighttson went on to describe other parts of the mission complex mentioning the orchard and the campo santo specifically. Based on this and other descriptions of Tumacacori, it is obvious that the buildings were beginning to deteriorate at an accelerated rate.

The beginning of the Civil War in 1861 resulted in the withdrawal of the troops at Fort Buchanan, again leaving the Tumacacori area unprotected. The Apaches quickly took advantage of the situation by attacking Tubac and then individual ranchers and farmers in the valley. Tubac was abandoned (NPS 1977a).

In 1864, J. Ross Browne sketched the church at Tumacacori and provided yet another description. But this time Browne specifically refers to the defacement of "the dome, bell towers, and adjacent outhouses" (Browne 1871, 150). The vandalism that he was apparently referring to continued into the 20th century and was probably one of the most significant problems that caused extensive deterioration of the Tumacacori mission church. The earliest initials scratched into the church plaster were accompanied by a date of 1852, and while this activity mainly ceased by 1920, there are those people who on rare occasions still have the need to make their marks as well.

Some resettlement began to occur in the late 1860s, but life in the valley was difficult at best. A February 1869 issue of The Weekly Arizonian described the situation as "the Santa Cruz valley is in great part lying waste as it is situated in a portion of Arizona which may justly be called the home of the Apache." Tubac was again abandoned in 1871 for a period of five years, but peace finally came to the valley when the United States Army confined the Apaches to an area east of the Santa Cruz (NPS 1977a).

Joseph King and Henry William Lowe homesteaded near Tumacacori mission during the 1870s and 1880s, and both used the Tumacacori buildings to some degree. King apparently lived for a time prior to his establishment of a homestead in the sacristry while using the corridor as a kitchen (NPS 1977a).

Between 1876 and 1879 there again appeared various accounts of travelers passing through the area. Most all of these descriptions indicated that Tumacacori was a ruin by that time. An article in the New York Times on March 1, 1891, gave another important description and also an interesting comparison with San Javier del Bac:

> While Tumacacori did not approach San Xavier in Architectural beauty and grandeur, the outer and communicating buildings were more extensive and agricultural and mineral expectations greater. Even at the present time the ruin is not so complete but that the passer-by may see a good deal to reward him. . . . The main building was 100 by 45 feet, and its shape was that of a Greek cross. . . . The dome above the chancel is still in a fair state of preservation. But the timbers are all "knocked whichway," the tile roof is "topsy-turvy" on the ground, the residences are gone to grass.

In the mid-1880s Tom Bourgeois lived at and near the mission, and in addition to prospecting the area, he occasionally assisted a priest with performing a wedding or baptism. Pedro Calistro served as a self-appointed caretaker from the mid-nineties, living in the corridor east of the sacristy. Although he apparently undertook some repair, Calistro was not entirely successful in keeping treasure hunters from inflicting still more damage. He moved to a house approximately 1 mile north of Tumacacori in 1905, but still remained closely associated with the mission until his death in 1928. Also during the time Calistro was living on the site, two Mexican families lived in the granary.

The structures continued to deteriorate as the semicircular pediment fell in the 1890s, and the choir arch fell between 1901 and 1907. The convento and other structures continued to erode, but the natural erosion processes were certainly exacerbated by use to some degree, but primarily through vandalism.

Tumacacori became a national monument on September 8, 1908, by presidential proclamation, and was administered by the U.S. Forest Service.

Deterioration continued and by 1913 it was thought to be serious enough to warrant the expenditure of funds. A fence was constructed around the mission site in the fall of that year, but vandalism continued to take its toll (NPS 1977a).

The Forest Service effectively ceased any actions that might have slowed the continuing deterioration, and in 1918 Tumacacori officially passed into the hands of the two-year-old National Park Service, and a new portion of Tumacacori's history began.

National Park Service Period, 1918-1975

Frank Pinkley visited the site in 1918, and while he found it in better condition that expected, he set about immediately to begin work. In the spring of 1919, A.S. Noon was hired to begin the actual work, and he immediately proceeded to stabilize a portion of the bell tower and the east sacristy wall.

Two years later in 1921 Pinkley began the actual reconstruction of the nave roof. After the nave roof was completed, the facade pediment was reconstructed. The next year the campo santo was restored and holes and voids filled in the interior and on the exterior of the church. By 1924 Pinkley had reconstructed the double front doors. Minor repair, which primarily consisted of filling more holes, continued for the next few years.

In 1934 the Civil Works Administration began an extensive project at Tumacacori, which consisted primarily of filling voids in the adobe walls and constructing a new boundary wall of adobe. After the Civil Works Administration was dissolved, federal relief continued as the Federal

Emergency Relief Administration provided funding for the completion of the boundary wall.

In early 1935, an experimental vinyl resin called NPSX was applied to portions of the exterior facade and in the interior of the nave. Voids were also repaired periodically, and along with a continual problem with a leaking roof, until it was finally replaced in 1947, this apparently constituted much of the work during this period.

Decay of both plaster and adobe continued to cause concern during the 1940s. Charlie Steen inspected the mission in 1946 and identified several problems. In 1947 Steen returned with Al Lancaster to begin a stabilization program that consisted primarily of lower wall or basal repair and the filling and repair of cracks.

Superintendent Earl Jackson, attentive to the surface erosion, plastered most of the remaining unplastered upper walls that Pinkley had constructed, as well as some of the original adobe surfaces.

An important event took place in 1949 when Rutherford J. Gettens of the Fogg Museum at Harvard University inspected Tumacacori and made recommendations for the treatment of the painted plaster surfaces. The actual treatment of cleaning, plaster edge stabilization, and consolidating the paint film with a polyvinyl acetate was carried out by Charlie Steen. This work remained as an important benchmark for the paint conservation project which began in 1982.

Superintendent Jackson continued his project of plastering unprotected surfaces, and in 1950 he removed the remaining original plaster from the exterior west nave wall (NPS 1977a).

Chemical consolidants were first used in 1935 and were used fairly extensively in the 1950s and 1960s. A silicone material, "Daracone," was used by Gordon Vivian in the mid-1950s and Roland Richert began to experiment with "Daraweld" in 1960. Daraweld was apparently used periodically during the 1960s and perhaps into 1970-71.

A major stabilization effort recommended by Roland Richert to combat the capillary moisture began in 1970 under the direction of Martin Mayer. The work basically consisted of excavating along the exterior of the nave walls, coating the foundation masonry with an elastomeric membrane, and applying a 20-millimeter-thick polychloride vinyl to the foundation. The polychloride vinyl extended out from the walls approximately 6 inches to 1 foot deep. However, moisture continued to exist in the walls.

In 1971 Daniel Evans, a soils physicist from the Hydrology Department at the University of Arizona, was hired by the National Park Service to collect data to determine the extent of the wall moisture problem. Extensive testing of adobe samples from the church walls and soil samples in the church did not provide sufficient evidence to determine the extent and source of the problem. Evans did present some general possibilities which proved to be essentially correct; i.e., there was an intermittent water source, or water had entered the walls in the past and was drying up. In reality, both of these situations were influencing the actual wall moisture content in certain areas. Evans also attempted to dry the walls by pumping hot air into a series of holes excavated on the south end of the east nave wall. The experiment did not produce enough positive results to justify continuation, although Evans did feel that the wall had slowly dried to some degree (Evans 1972, 2-5).

The major general preservation approach undertaken at Tumacacori, other than the continual treatment of wall surfaces with plaster coatings, fill material, and waterproofing agents, was the attempt to preserve the structure with protective shelters. The church itself had a roof over the nave after 1921, and the sacristy and sanctuary were protected by masonry vaults. The corridor extending east of the sacristy, the granary, and the portion of the convento that still existed above grade were eventually provided with shelters.

A metal roof was constructed over the corridor in 1953, and in 1957 an enclosed structure was constructed over the convento remains. After a major stabilization project in 1970 and 1971, a metal roof was constructed over the granary. The metal roofs were eventually removed in 1979, and the structure over the convento was altered drastically a year later. It too was to be removed, but during the removal process the condition of the south wall was more fragile than anticipated.

The Tumacacori preservation project began with a meeting at Tumacacori in January 1975, and was attended by local, regional, washington, and DSC personnel. The purpose was to develop a plan for a comprehensive preservation project. A general approach was formulated, and in the summer of that year an archeological synthesis was developed. Multiyear funding began in fiscal year 1976, and the project was fully moving by January 1976.

CHAPTER II: ARCHITECTURAL INVESTIGATIONS AND PRESERVATION PROCEDURES FOR THE CHURCH

The general criteria established for the selection of a method and/or material were quite simple. The method and/or material must do the job for which it is intended and must have minimal, if any, adverse effect on the original material. A material placed in an adobe wall that remains sound but causes previously unaffected original material to deteriorate is not acceptable. A related criterion is that an action should be reversible.

The criterion of reversibility is relative because no action can be undertaken and later reversed without some effect on the original fabric and, correspondingly, practically any action can be reversed. The one exception to the reversibility of any action would be the chemical or physical change of one material to another. An example is the total consolidation of an adobe wall or some part of the wall by replacing or supplementing the natural cementing material with another cementing material, such as a thermoplastic. The placement of 3,000 pounds of concrete in a void in an adobe wall would be reversible since the concrete could be removed. However, its removal would cause much more damage to the surrounding original material than would be incurred by removing a clay material that had been used to fill the same void. In this example the concrete is considered to be basically irreversible.

The approach followed was based on the scientific evaluation of the original materials and any new materials that were considered for use and on a practical application of both in the field. This evaluation gave insight into the relative performance of the original and the nonoriginal materials and to their compatibility. Because all problems are directly related to water intrusion, the properties of the materials that have an effect or are affected by water are considered to be the most important criteria--chiefly, capillary potential and permeability.

Structural Voids in the Adobe, Plaster, and Fired Brick

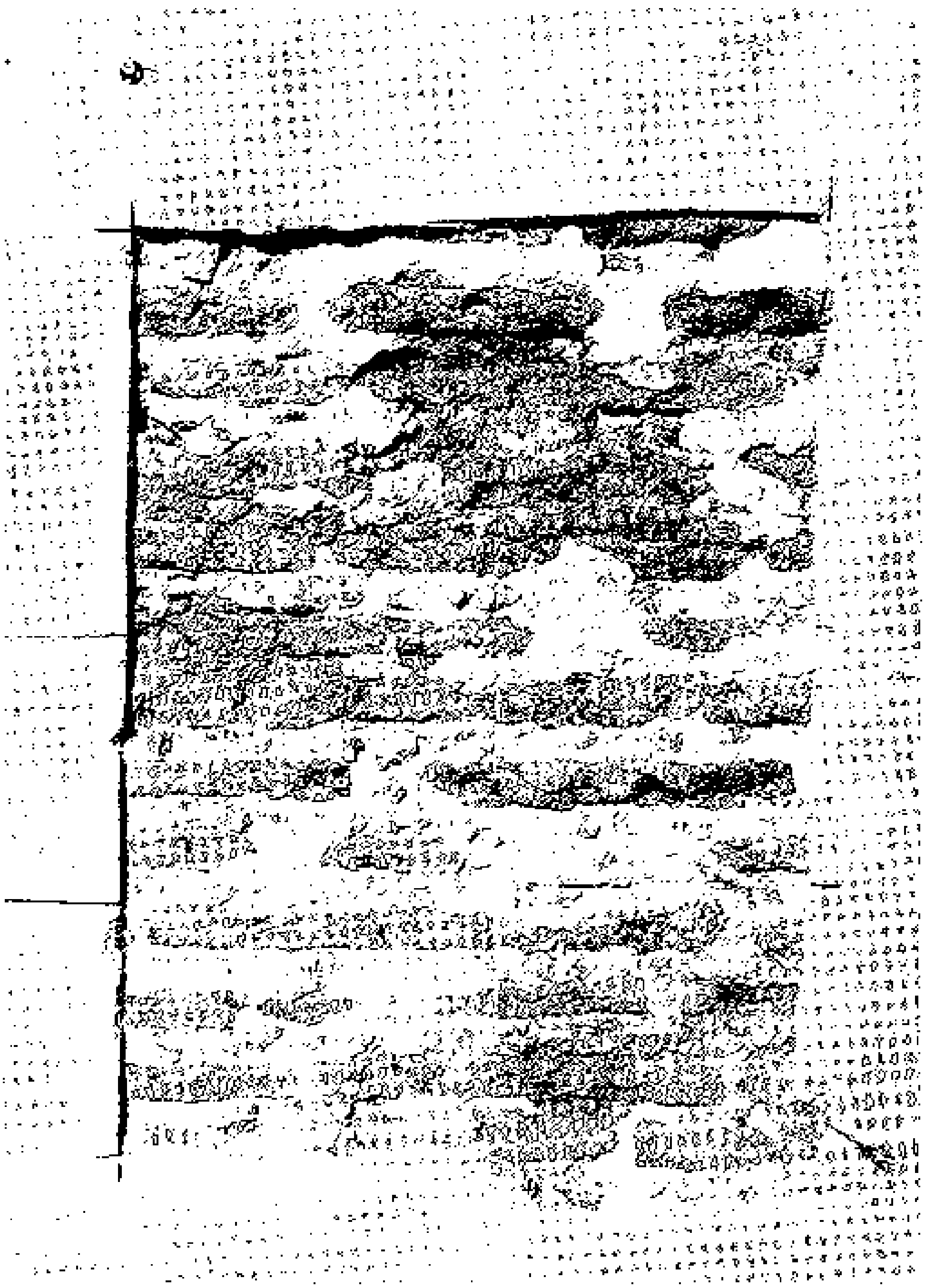
Many voids were discovered when the cement stucco was removed. While some of these voids were rather large and required up to 1 cubic foot of fill material, most voids were only a few inches deep (illustrations 1 and 2).

The methods for filling the voids were tested extensively beginning in 1977 with the construction of the test walls. The basic requirements for adobe fill were materials that had an equal or greater water transmission property and materials that would not shrink significantly. A separation of the new material from the original would restrict the desired movement of moisture through the materials to the surrounding air. Soil with a similar particle size distribution and similar clay fractions as the original, compacted to a similar density, would fall within an acceptable range for the critical properties. If other properties are kept constant, a higher clay content would result in a smaller capillary pore size and a greater capillary potential; a lower clay content would result in a lesser capillary potential. The greater capillary potential of the new material would tend to draw moisture from the original material if moisture was traveling through the original material in horizontal capillaries and if there was no interface between the two materials.

The initial testing consisted of filling several voids in the test walls in October 1977. In each case, a slightly different mixture of soil was used, the variable being the amount of clay. Also at this time the west side of the east wall of the corridor was filled because of a real possibility of the total collapse of the wall.

The voids that were filled in the test wall contained various amounts of clay ranging from 8 percent to 15 percent. The material with 8 percent and 11 percent clay was used to fill voids up to 8 inches thick, and material containing more clay was used to fill thinner voids. After several years of primarily natural weathering and some artificial weathering, there was little difference in the overall effectiveness of the material or method used to fill the voids. The surface of the materials with the smaller

1. West church wall during the filling of voids.



2. A view of the west exterior sanctuary wall during the removal of cement stucco.

amounts of clay apparently weathered slightly more, the difference not varying dimensionally but rather reflected in a slightly coarser appearing surface texture. None of the test areas showed a significant separation of the new material from the old or any accelerated weathering of the old.

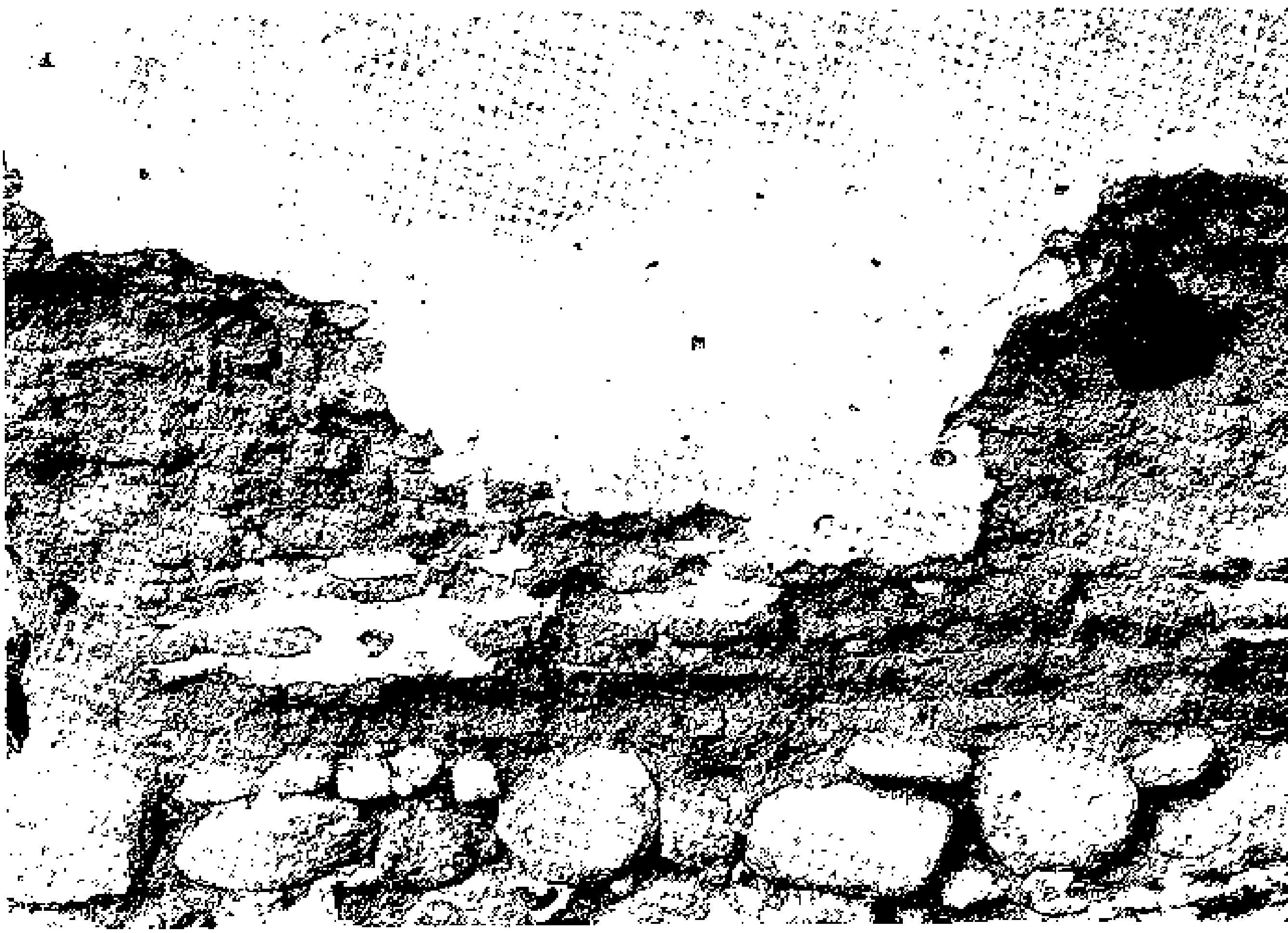
In actual practice, larger voids were filled with full size adobes or adobe batts, or pieces, laid up in regular courses (illustration 3). The smaller voids, which in some cases were merely surface undulations, were filled with smaller adobe and brick batts and mud, or with just mud alone. It was necessary to compact the mud as it was packed rather than simply daubed or troweled on.

Excessively loose material was brushed from the surfaces of the voids and then dampened slightly to ensure an adequate bond between the old and the new material.

Interestingly, this particular method for dealing with large voids in adobe material was used historically at many similar sites. The treatment at Tumacacori was basically the same, but in some areas a lime mortar was used along with fired brickbatts for the fill material. Also, the initial stabilization work undertaken at Tumacacori by Frank Pinkley consisted of the use of this method. The most obvious area where the Pinkley work can be seen is in the interior of the church in the baptistry, in the sanctuary, and at the south end of the nave near the west wall. After over 60 years there has been no distinguishable change. In areas of larger voids, Mr. Pinkley used whole natural adobes.

The mud used to fill the void in the corridor contained the same approximate percentage of clay as the adobes in this portion of the wall, the primary difference being that the clay in the original material was predominantly montmorillonite, an expansive clay, and the clay in the fill material was predominantly illite, a nonexpansive clay.

One assumption made in regard to the selection of any soil for use at Tumacacori was that it not contain predominant amounts of expansive



3. The north side of the bell tower after the removal of the hard cement stucco.

clays such as montmorillonite. Being less expansive, there would be less initial cracking or drying and less suffering from wetting-drying cycles during natural weathering. However, in actual practice no difference could be seen as both the expansive and nonexpansive clays performed equally well.

Initially some holes, in the original lime plaster were filled with mud. Water could run into these holes and eventually cause the loss of large segments of plaster. However, this practice was discontinued because of excessive staining and inadequate protection. The holes have been filled with lime from the beginning and, in fact, were as the project progressed. This lime plaster matched the original as closely as possible (or as was practical).

The original lime plaster contained approximately 25 percent lime by weight. The particle gradation varied, but there was normally less than 10 percent silt and clay. Some clay was either added to the original lime plaster or appeared accidentally in the unwashed sand.

The clay, if well dispersed, will actually add to weathering characteristics of the lime plaster and might have been consciously added, particularly in areas subject to more contact with water. It is also quite possible that an organic material such as the liquid from an agave plant was used historically at Tumacacori. Similar plant products are used in many parts of the world to increase the weathering ability of plaster and was used also in Colonial Mexico (Celorio, pers. com. 1972).

For repair purposes the holes in the original plaster were first cleaned and then filled with lime plaster slightly below the existing plaster surface. The new plaster was rubbed out after it set up slightly. This produced a rough texture similar to the existing condition of the original plaster.

The primary areas of voids in fired brick were the restored brick cornice along the exterior nave walls and the original brick cornice that remains around the exterior of three sides of the sanctuary.

The original bricks were repaired by repointing and filling the voids with lime mortar. The lime plaster and mortar used for this purpose was similar to the original plaster and contained a small amount of clay to give it better water-resistant characteristics and workability. Also, lime mortar used to fill voids in bricks was tinted slightly with brick dust.

PROTECTIVE PLASTER COATINGS

Surface erosion is a far less important part of the deterioration processes of adobe than basal erosion by floodwater and capillary moisture, or upper wall erosion by penetrating rainwater. If surface erosion was the only reason for applying a protective surface treatment on the exterior walls of the church, it would not have been done. However, in the case of Tumacacori, coatings on exposed adobes were necessary to keep rainwater from penetrating behind original lime plaster and to provide a material that erodes in place of the original material when affected by the deleterious effects of recrystallizing soluble salts and wetting-drying cycles.

Since the actual surface erosion is the least significant, any simple treatment of the original material by a chemical consolidant or water repellent was not considered. Even if such treatment had been desirable, none could be found that could be used at Tumacacori without having an adverse effect on the original material.

On this basis, two types of surface coatings were considered--an amended plaster and an unamended plaster. Within these parameters the choices were either a lime plaster or a natural soil or mud plaster.

Existing Plaster

The application of two coats of lime plaster was the treatment on all the interior and exterior wall surfaces at Tumacacori originally. The total thickness of the two coats varies, but the average would be approximately

1½ inches. The base and finish coats were consistent with the exception of the crushed brick and rock fragments, which were placed in the wet finish coat on the exterior of the campo santo wall and the lower portions of the church walls. An extensive amount of plaster remains on the upper portions of the interior surfaces of the nave walls, the interior of the sanctuary and the sacristy, the exterior of the north church wall, the exterior of the south facade, and the campo santo wall. A lesser amount can be found on the exterior of the mortuary chapel, on the bell tower, and on the exterior of the east nave wall. There is no remaining original plaster surfaces on the exterior of the west nave wall although fragments do exist in mortar joints.

The original plaster that is exposed to the surface has functioned well through the years and the loss of the original has been because of the lack of any maintenance. When maintenance was undertaken, such as in the interior of the church, it has been successful in preserving the remaining plaster.

Mud Plaster

The lower portions of the walls of the church have been most affected by moisture-related degradation and will continue to suffer to some extent throughout the life of the structure. Capillary action will continue to be drawn up into the walls as long as a source is available. However, the preservation approach was that if affected areas were maintained and certain corrective measures taken, there will never be any major loss of material. With this movement through the walls, moisture will eventually surface, causing some basal erosion. This capillary moisture will have no appreciable effect on the structures if (1) the moisture content never reaches the structurally critical level, and (2) the surface erosion at the base of the walls takes place in a nonoriginal material.

Because of the importance of reducing the source of the capillary moisture and allowing the moisture that finds its way into the walls to eventually evaporate, the surface treatment chosen had characteristics that were conducive for both to occur. Of the two specific choices available, the mud plaster was seen to best meet the desired characteristics initially.

After the cement stucco was removed, the lower portions of the exterior of the east nave wall were plastered with the mud plaster. It remained in place for two years and then was replaced with lime plaster. This initial period required the mud plaster to enable the damper walls to dry faster.

Several materials appear to perform quite well as additives to mud plaster in certain situations (NPS 1977a, 1977b). However, these seem much more suited to a use when moisture migrating from the interior to the exterior of the wall is not a problem. The admixture serves as an additional cementing agent, but in so doing lowers the capillary potential of the material if not the permeability. Consequently, it was not appropriate for use in mud at Tumacacori.

The initial patch of mud plaster used on one of the test walls was applied in October 1977. It consisted of the "red mesa" soil selected specifically for mud and adobe needs by Dr. Fenn and his staff at the Western Archeological Center. The selection was based on a good particle size distribution and the absence of significant expansive clays. The soil was cut by the addition of sand, which resulted in a material with a good particle size gradation and a clay content of approximately 12 percent. The patch was applied ½ inch thick by hand on a slightly concave portion at the base of the wall where a large deposit of soluble salts had formed as efflorescence. After drying, the surface cracks were rubbed out with a wet sheepskin.

Subsequent patches of the same basic material were applied to the test walls in January and February 1978. The primary variables in this testing were related to (1) the amount of sand added to the red mesa soil, (2) the number of coats, (3) the wall preparation, and (4) whether or not grass was added.

The resulting mixes varied from a clay content as low as 8 percent to as high as 32 percent. The optimum, based on minimal large cracks and durability, seemed to be a mix with approximately 10 to 15 percent clay.

The only wall preparation was to brush the surface free of any loose material and to dampen it slightly a few minutes before plastering. (A small amount of loose material did not seem to affect the ability of the plaster to stick on the wall, but large amounts did.) Prewetting the surface had no lasting relationship on the bonding of the plaster to the wall, but it certainly aided in the initial application of the plaster.

Local grasses were added to some of the mixes and proved to be beneficial in reducing cracking. This was particularly true of the base coat. The finish coat seemed to function quite well without the added grass if it was applied over a good base. The addition of the grass seemed most beneficial when the plaster was continually soaked by rainfall and dried. A spongy feel still characterized the thoroughly wet plaster, but once dry, the plaster returned to its original hardness. Normally only the surface of the mud plaster becomes wet after a rain shower.

The primary problem with the red mesa soil was that it was significantly redder than the adobe material used at Tumacacori. The actual colors vary, but the red soil was similar to 7.5 yr $\frac{4\ 5}{6}$ and the Tumacacori material was similar to 10 yr $\frac{6}{3}$ on the Munsel soil color chart. All the locally available soil was the same color as the Tumacacori material, but all those tested contained significant amounts of montmorillonite.

Without prior testing, some local material was used as mud plaster both with and without grass added. The results were rather surprising. The plaster set up initially and continued to function with very little cracking--less cracking than the red mesa material used under similar circumstances. A particle size analysis shows a reasonably good gradation except that more than the desired amount of fine sand and silt was present. Also, X-ray defraction analysis indicated montmorillonite clay. The clay content of 17 percent appeared to be near the optimum. This local material was what was actually used on the east nave wall.

Lime Plaster

Some testing was carried out on the test walls constructed on the monument grounds to determine an appropriate lime plaster mix and method of application. The initial mixes were derived from the analysis of the lime plaster used historically at Tumacacori and other historical references. Of approximately 12 plaster samples analyzed, all were from a finish coat. The particle size distribution for these samples varied somewhat, but all had clay contents considerably less than 10 percent of the total. The lime content varied between 20 percent and 24 percent, probably indicating a desired mix of approximately three parts of sand to one part of slaked lime. This mix is certainly not unusual since the normal called for in historical accounts in European and American publications was 3:1 or 4:1. Plaster from the late 18th and early 19th century Spanish Colonial *Mission Rosario near Goliad,* Texas, *also* contained approximately the same percentages of lime. The base or brown coat of plaster was analyzed and indicated that a similar amount of lime was used.

Slaked lime, calcium hydroxide, which was used during the testing program, was slaked on the site. Some of the first plaster tried was with lime that had slaked for only 24 hours. Later a hole was dug in a pile of soil brought to the site for testing purposes; the hole was filled with quicklime, water was added, and then it was covered over. The length of time required for complete slaking to take place is difficult to calculate accurately, but several weeks is probably a minimum. Complete slaking is desirable but not completely necessary. Under certain conditions small pockets of the unslaked lime will expand in volume and literally explode off the plaster so some care must be taken. This phenomenon is exemplified by the many small craters on the plaster surface of the sanctuary's northwest pendentive. However, in most cases there appears to be no significant effects. Consequently, the popping action was not considered to be overly important when used for replastering purposes.

The various mixes were prepared and then applied to the wall with a regular mason's trowel. In some cases the test wall was prepared by cleaning all loose material from the surface, and in other cases it was not. The plaster was also applied in some cases after mortar joints were raked so that the lime plaster going into these raked joints would form effective plaster keys. Another wall preparation included wetting the surface slightly before the plaster was applied. Again, this action, as with the others, was carried out in some cases and in others it was not.

The actual thickness of the plaster was not varied intentionally but did vary somewhat as different conditions were encountered on the wall. The average thickness was perhaps 1/2 to 3/4 inches, but in many situations, plaster was forced into small, naturally occurring holes up to 2 inches in depth.

A 3:1 sand to lime mix was applied first because of the historic use of this approximate mix. Subsequent mixes continued to decrease in the sand to lime ratio until a pure lime slurry was used. Next, mixes with an increasing ratio of 4:1 and then 5:1 were used.

The richer mixes cracked dramatically on drying, making them undesirable. Included in these was the original 3:1 mix, which actually resulted in marginal cracking but did not work as well as a slightly leaner mix. The 4:1 mix worked well, but the 5:1 mix worked even better. There were a few small cracks in the richer of the two, but it appeared to be acceptable, especially as a finish coat. The 5:1 mix did not crack at all, and its strength and toughness appeared good.

All of the mixes adhered well to the adobe wall initially. The many holes and natural undulations in the wall, when filled with plaster, provided the desired keying. The edges of the richer mixes began to pull away from the wall after a few hours of drying but still seemed to remain adequately secured. There had also been some loss of contact with the adobe surface in the center of these patches. The 4:1 and 5:1 mixes remained in contact with the wall with no noticeable loss, although when dry they all sounded somewhat hollow.

As mentioned previously, the unamended lime plaster was used at approximately a 5:1 sand to lime mix with a small amount of fines added. This plaster was used on all exposed exterior surfaces eventually. The final plastering was completed in 1979, and except for one area on the east sacristy wall, it has weathered and performed well.

The use of unamended mud plaster along the lower portions of the walls and unamended lime plaster on the upper portions of the walls is the logical approach. The exact amounts of materials and time required can only be estimated at this point. The full extent will be apparent after the stucco is removed.

PLASTER REATTACHMENT

The reattachment of original plaster that had pulled away from the walls was discussed at length in the preliminary report on the Tumacacori project (NPS 1976). At that time the reattachment with epoxy resin pins was considered to be necessary because of the existence of the friable material on the surface of the wall onto which the plaster would be attached. However, further investigation reversed that opinion, and it was later recommended that the reattachment be accomplished with a lime grout. The most important area was on the north end of the sanctuary where the only portion of original decorative exterior plaster exists. This plaster had pulled away from the wall by as much as 3 inches in places. This same area is described in more detail in "Chapter V: Paint Conservation." The other important area was on the interior surface of the west nave wall--the remains of the retablo above the south altar. However, before any action was taken the plaster fell. Since that loss in 1981, the remains have been stored at Tumacacori.

IMPERVIOUS FOUNDATION MEMBRANES

With the major moisture problem being capillary moisture in the nave walls, one of the primary concerns, which hopefully material and method of research would solve, was the practicality of effectively eliminating the vertical movement of moisture up into the walls. This can only be accomplished by cutting off the capillaries by one continuous impervious membrane located from one side of the wall to another along its entire length, or by actually filling the capillary pores themselves.

Continuous Sawn-in Membranes

Continuous membranes have been used before in extant structures (Gratwick 1974, 90). These structures have all been either brick or stone masonry, and no attempt has ever been made to place a horizontal membrane in or near the foundations of an adobe structure.

Even after a cursory evaluation, it is obvious that many other problems exist. The nearly 6-foot-thick walls would have made it extremely difficult, if not impossible, to accomplish the goal. In addition to the thick walls, the inconsistency of the mud mortar would also make the placement of a membrane difficult. The most important reason why this type of moisture barrier is not desirable is the effect on the adobe structure if it could be installed. Moisture would continue to move up into the wall until the membrane was reached. The moisture content of the adobe in this area could conceivably increase to such a level that the adobe material would deform under the weight of the wall.

Chemical Membranes

The principle of this particular approach seemed much more valid for use at Tumacacori than that of the sawn-in membrane. However, the problem was the inability of a chemical-method approach to fill enough voids to form a horizontal impervious layer in the adobe itself. Even those chemicals that offered the most potential, such as the monomers, have not been effective.

One end of a test wall at Tumacacori was treated by Dr. William Burke of Arizona State University in October 1978. He had used a methlmethacrylate monomer for in situ polymerization of sandstone and also of soil in a prehistoric pithouse. Some success was claimed on the stone consolidation, but apparently the pithouse wall project was not successful.

Immediately after the test wall was treated, large cracks began to develop on the top of the wall; also, the cracked material appeared to swell noticeably. Within two months the surface acquired a mottled appearance typical of silicone treated walls. This appearance is a result of part of the surface having a coating of the chemical on it, while other portions have already lost the coating. This mottled appearance becomes even more noticeable as time passes. Aside from this surface alteration, the wall does not seem to absorb much water during a rainstorm, and there has been less coving immediately below the cap than on some other sections of the wall. The actual amount of chemical penetration is not known, but it is obvious that the top cap was not consolidated, and consequently, it is doubtful if much of the wall interior was affected.

Dr. Charles O'Bannon had also been experimenting with adobe and earth consolidation, using a method based on the principles of electro-osmosis to pull a chemical through a wall (O'Bannon 1977). The method certainly has proved to have application in the stabilization of roadways, but the experiments by Dr. O'Bannon at Casa Grande National Monument were not successful (Fenn, pers. com. 1978).

PRESERVATION MONITORING SYSTEM

A monitoring system was designed for the specific problems at this site, and the system was incorporated into the preservation project. The primary purpose of the monitoring system was to record the conditions of the structures and the changes in the microenvironment so that the two can be related. The monitoring program itself consisted of two basic components: (1) the recordation of the effects of deterioration; i.e., the permanent deformation of building material and the chemical processes that result in fabric degradation; and (2) the recordation of the causes of deterioration.

In addition to monitoring the actual changes in the buildings, particularly the church, the existing conditions of both the structures and the site were established. This complete system was reported on in depth in the APT Journal (Crosby 1979).

Existing Conditions

The size, shape, and position of individual elements, as well as the combination of these elements in the complete structures, were recorded photographically and graphically.

Scale drawings of the church were completed by the Experimental Engineering Station at Ohio State University from stereophotogrammetric fieldwork by Perry Borchers. These drawings consist of plans, elevations, and sections of the church at a scale of 1/4" = 1' - 0" and an interior plan of the sanctuary dome at a scale of 1" = 1' - 0" with 1" contours of the interior dome surface. Some architectural details have been recorded on color and infrared film. This recording is principally oriented to areas where color changes could have an adverse effect on the overall integrity of the structures.

The moisture content within the church walls was determined at a particular point in time by drilling holes on an established grid and taking material samples. A knowledge of the absolute moisture content in the walls of the church nave was important for two reasons. First, the location and extent of wall moisture provided information that was helpful in determining the sources of the moisture. Secondly, the knowledge of the extent of wall moisture was related to the strength of the adobe material at different moisture contents (see "Chapter VI, Moisture Conditions and Their Effects).")

Topographic conditions were determined by studying existing contour maps of the area and through the preparation of a 10 centimeter contour map, which recorded more specific data. The primary purpose for the assimiliation of this data was so that the existing specific drainage patterns and their resulting impact on the structures could be determined.

The subsurface investigation provided such information as the depth of the water table, the moisture content of the soils, and the physical and chemical properties of the ground upon which the complex rests. Based on the results of the subsurface investigation, locations for the continued monitoring of soil moisture were selected.

Results of Deterioration

As indicated at the beginning of this section, the first component of the monitoring system is the recordation of the actual results of deterioration of the structures at Tumacacori. The elements monitored and the methods of monitoring are discussed below.

Elements Monitored. These include (1) cracks in sanctuary dome (2) cracks in nave walls, (3) plaster for erosion or spalling, (4) exposed adobe for erosion or spalling, (5) color change in any materials, and (6) nonvisible structural fabric.

Mechanics of Monitoring. Since June 1977, the cracks were monitored by linear variable differential transformers (LVDTs), mechanical points, and leveling equipment. The LVDTs are capable of recording movement across a crack as little as 5/10,000 of an inch. The mechanical points were measured with calipers and were accurate to 1/1,000 of an inch.

The erosion of both the plaster and the adobe material was monitored visually and photographically. The discoloration was also recorded photographically.

The nonvisible structural fabric was monitored indirectly by comparing the potential causes of deterioration, i.e., moisture content, wetting-drying cycles, and earth movement, with the actual existing conditions. For example, if it is known through controlled tests that a moisture content of 10 percent results in a loss of compressive strength of 50 percent, then, if a portion of an actual wall contains 10 percent moisture, it can be assumed that the wall has been weakened to the same degree. No direct material testing for compressive strength is necessary.

Causes of Deterioration

Many of the changes in the environment were monitored, which apparently had little specific relationship to the causes of deterioration. However, other factors could be related to the deterioration of the structure.

Elements Monitored. These include (1) ambient temperature and relative humidity inside structures and on monument grounds, (2) moisture and temperature conditions within structural fabric, (3) moisture and temperature conditions on wall surfaces, (4) subsurface moisture content, (5) force of wind, (6) ultraviolet radiation, and (7) total precipitation

Mechanics of Monitoring. The ambient temperature and relative humidity was recorded in the structures by hygrothermographs and periodically with a sling psychrometer. One hygrothermograph was located in the sanctuary at floor level, one was located for a period of time at the level of the dome, one was located along the nave wall next to the east nave wall, and one was located in the extant convento.

The ambient temperature, relative humidity, total wind and direction, and precipitation were recorded for a time by a battery-powered weather station on the monument grounds. The total precipitation is also recorded by an official weather recording station on the grounds.

The total solar radiation was being recorded by a pyranograph located on top of the visitor center and later by nonrelating pyranographs in the dome. The ultraviolet radiation is a constant percentage of the total.

Moisture and temperature conditions within the structural fabric were monitored primarily by small resistivity sensors placed in the church in 29 different locations and depths until recently. The interior wall temperature reading was often supplemented with a long-stem dial thermometer initially, but this did not prove to be very effective.

The wall surface temperature is taken periodically by reading small surface thermometers placed in critical areas. The surface moisture is determined relatively by a surface resistivity survey and determined absolutely from material samples.

The subsurface moisture conditions were monitored for the first two years of the project by taking material samples and checking the water table monthly. Two soil moisture sensors were placed in the vicinity of one of the subsurface ruins.

CHAPTER III: ARCHITECTURAL INVESTIGATIONS AND PRESERVATION PROCEDURES FOR ADDITIONAL STRUCTURES

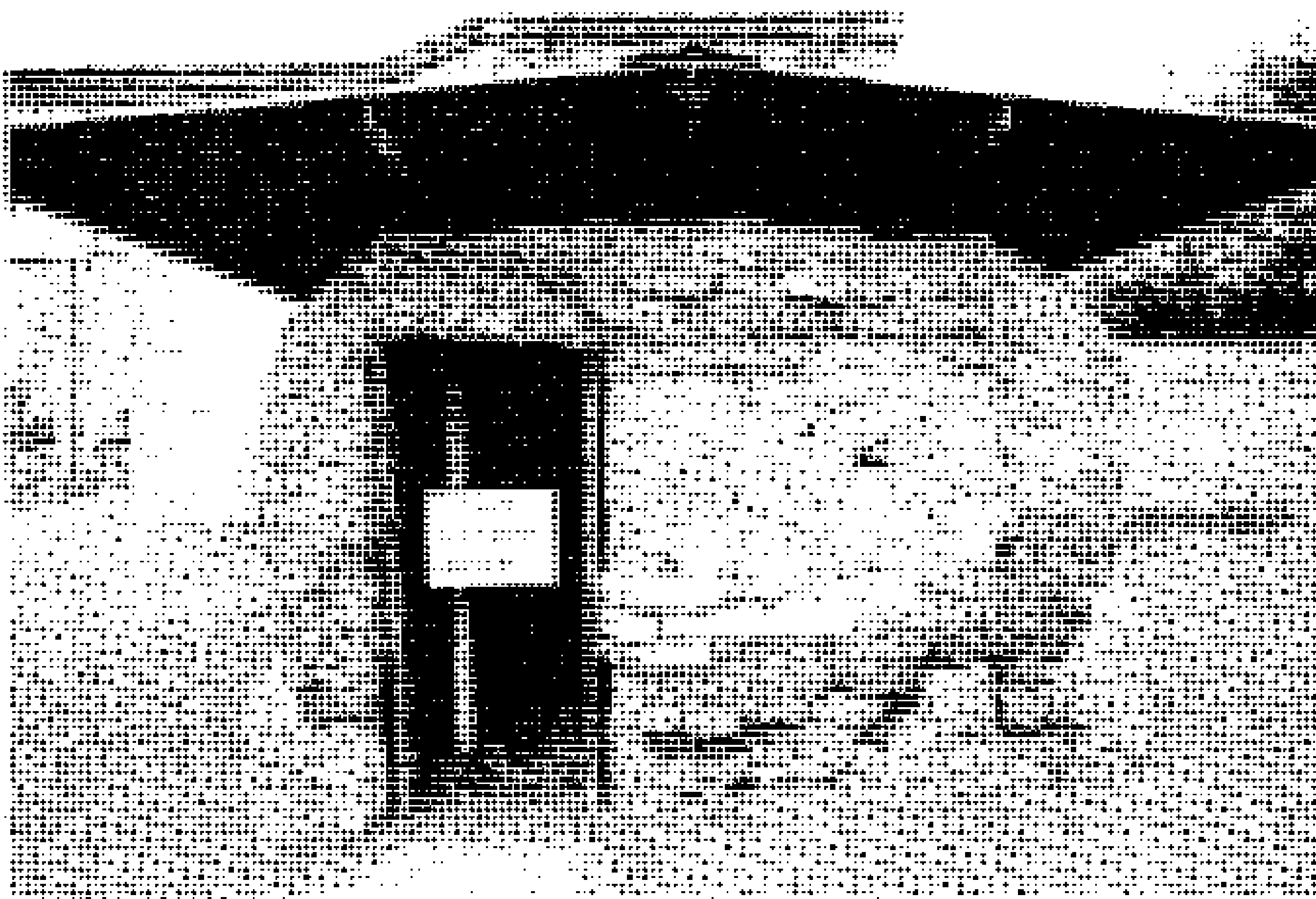
CORRIDOR

The corridor, located east of the sacristy, is made up of late 19th century as well as historic period materials. The only original construction is the base of the west end of the south wall and a small portion of the intersecting north wall. However, the east end of the south wall and the entire north wall was probably constructed during the historic period. The late 19th century work included a portion of the south wall, the east wall, and a roof that has since disappeared. This work was apparently done by Pedro Calistro, who lived there from the 1890s until 1905 (NPS 1977c).

A protective metal structure was built over the corridor in 1953 (NPS 1977c). It kept direct rainfall from eroding the upper portions of the walls, but other stabilization efforts aggravated the problem. The cement stucco used along the base of the exterior wall surfaces forced capillary moisture higher in the walls and caused much more deterioration above the stucco (illustration 4).

This structure is representative of a preservation philosophy that too often leads to exaggerated deterioration. The most appropriate method for preserving extant, abovegrade, ruined walls is the incorporation into the preservation plan of a cyclic maintenance program. However, once such a dramatic step as a separate protective roof is installed, it is assumed to be permanent, and any maintenance would appear to be unnecessary. But, in fact, if the roof had not been erected in 1953 and instead the structure had simply been maintained using compatible materials, it would certainly be in better condition today.

Deterioration from capillary moisture was initially and continues to be most prevalent at the northeast corner and the east wall. The conditions were



4. A view of the corridor prior to the removal of the protective roof. Photograph taken in August 1979.

so critical that repair was undertaken in the fall of 1977. The actual method was simply to fill the major void on the interior, or west side, with mud, fired brick and adobe batts, and rocks. The area was first cleaned of all loose friable material, the surface kept damp, and the fill brought up in successive layers in the deepest concave areas to facilitate drying. The mud, which had a content of approximately 15 percent of nonexpansive clay, was packed in so that it would have more capillary potential than the adobe wall. If properly executed, moisture which will continue to rise in the wall will move, if not be drawn, through the new fill material causing this new material to deteriorate rather than the old. Only the most critical area was repaired at that time, but a similar approach was carried out later on remaining areas.

In addition to the deterioration caused by capillary moisture, an extensive amount of material loss could be attributed to insects and rodents. Ants occupied a large portion of the north wall, and voids of several cubic inches were seen in several places. The actual damage was probably much greater than evident on the surface. In 1979 a large mound of earth of approximately 1 cubic foot appeared at the base of the north wall. An amount of material this large could be critical, particularly if the entire amount came from the wall or immediately below.

In 1979 the protective shelter was removed from over the corridor. At the same time, the cement stucco along the base of both walls was removed, and some of the lower wall voids were filled with natural adobes and mud. The tops of the walls were capped with unamended mud and have been maintained continually since.

GRANARY

The building known as the granary is located along the east side of a portion of the campo santo wall at the northwest corner of the convento. It was excavated in 1934 by Paul Baubien and in 1970 by Marty Mayer. Results of the archeological investigation indicate that the structure was used for storage purposes, although it remains a distinct possibility that it could have served other functions also. The archeological investigations provided some evidence for the establishment of the construction sequence of the granary, the convento, and the campo santo wall.

Very little stabilization work took place on the granary before 1970. Earlier work consisted primarily of capping the walls with a cement stucco. The thrust of the 1970 project was directed to the stabilization of the building, but a substantial amount of restoration also took place.

Stabilization work consisted of replacing deteriorated adobes with soil cement ones, recapping some of the adobe walls, and spraying the upper portions of the walls with what was probably some type of acrylic resin.

Restoration work consisted of restoring the original entrance, restoring portions of some interior piers and the stairs to the second floor, and placing some new timbers where there was evidence of historic period timbers. A metal roof was also constructed over the building to give some protection from rainwater.

Historic period adobes continued to deteriorate on their exposed surfaces in some areas. The deterioration appears to be greater in areas where the original adobes are next to stabilized adobe replacements (illustration 5).

One phenomenon that apparently contributed to the accelerated deterioration results from the difference in the rate of absorption of the two different types of adobes. Rainwater running down the wall surface was not absorbed into the stabilized adobes; consequently, water ran over the face of the original adobes at unnaturally high concentration levels, causing abnormal surface erosion.

Many of the stabilized adobes that were added to the structure changed colors over the years, possibly as a result of ultraviolet radiation.

5. Northeast corner of granary showing effects of dissimilar materials.

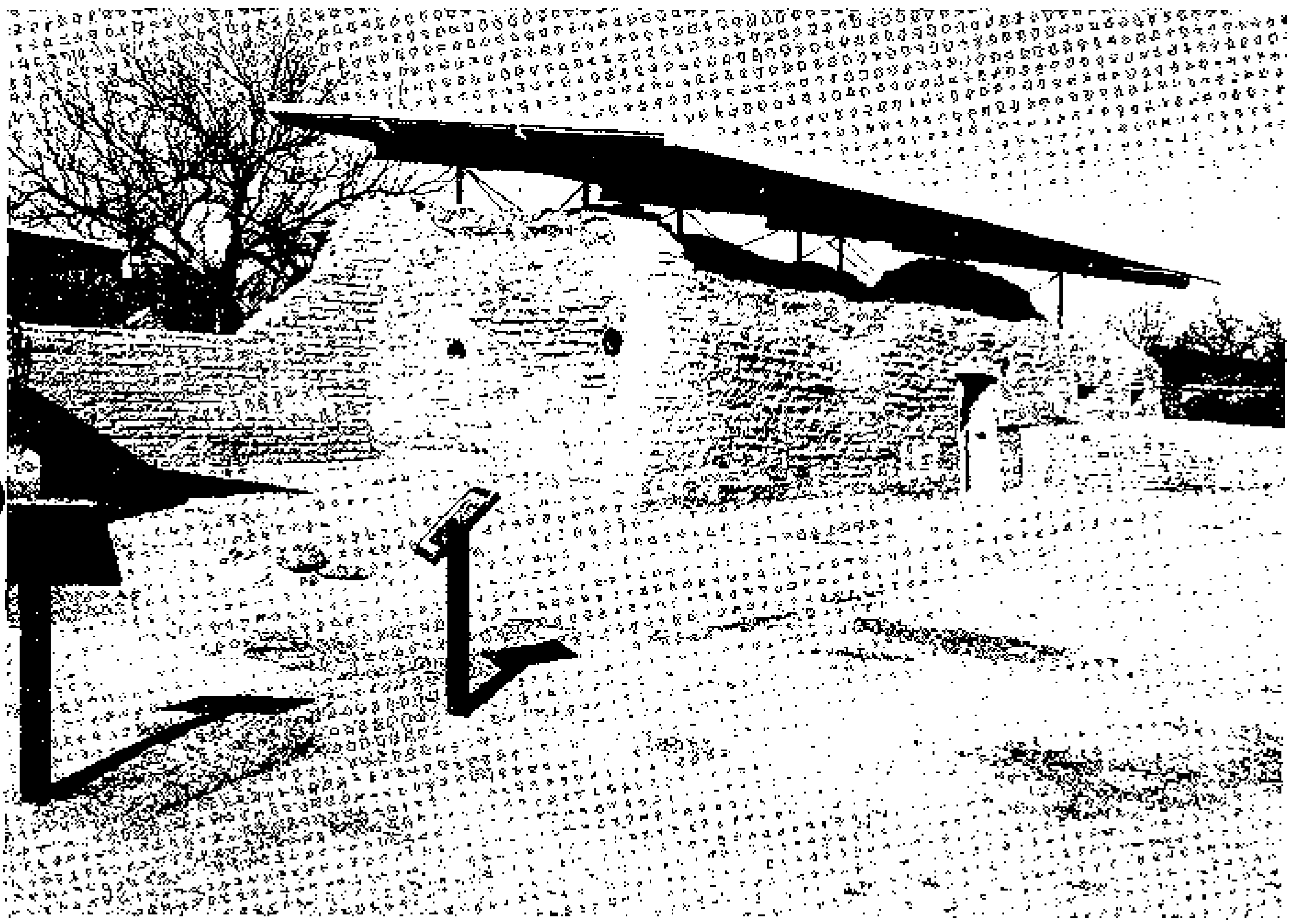
However, some of the color change reportedly occurred during or immediately after the manufacturing of the individual adobes. Some of this stabilized material still remains.

The metal roof over the building afforded some protection from the rains, which predominantly came from the southeast. However, the overhang of approximately 6 inches on the west side is totally inadequate for rains coming from that direction. Contributing to the impact on the building by the inadequate roof was a cracked cement cap on this west wall. The cracks in the cap allowed water deposited on top of the wall to percolate down into the wall or to run down the face of the adobe wall beneath the original lime plaster. This condition caused the loss of some of the upper portions of original plaster.

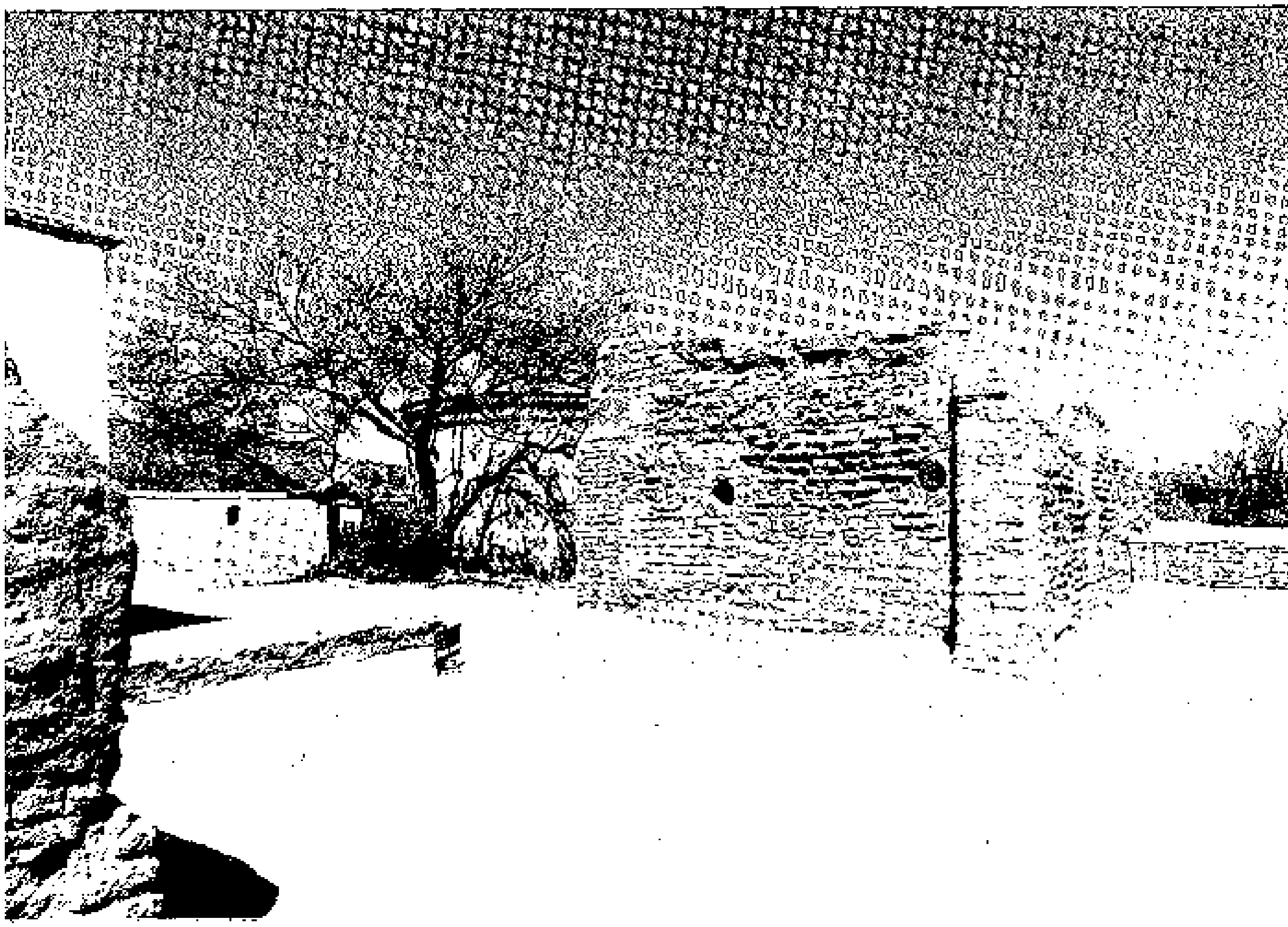
Probably even more important, the roof was a significant visual intrusion on the entire site as well as on the granary itself (illustration 6). As with the corridor, it was decided to remove the shelter and preserve the granary by continual maintenance (illustration 7). Additional maintenance was required to properly drain the interior once the roof was removed.

The problem of proper drainage of unroofed structures in general has been addressed in various ways many times. In the case of the corridor, a natural slope from the sacristy to the east allows main water to simply run out the east doorway. In most all other cases when an adequate natural drainage situation does not exist, excavations, sometimes extensive, are required for the installation of some type of lateral subsurface drain. A lateral drain would have required extensive removal of both above- and below-grade structural remains. Consequently, a typical lateral drain was not considered further.

Initially, two dry wells were considered with one to be located in the south granary room and one in the north granary room. Both of these dry wells would have consisted of a vertical shaft approximately 1 meter, or 3 to 4 feet in diameter, extending through at least two or three layers



6. The granary from the southeast before the removal of the protective roof.



7. The granary from the southeast after the removal of the protective roof.

of cobbles, which occur naturally every three 3 to 4 feet. The shafts themselves would then have been filled with cobbles. Rainwater falling in either of the rooms would have drained into the shafts and then from the shafts into the subsoil through the cobble layers, which provide excellent percolation. If over a period of years the voids between the cobbles in the shafts became filled, the shafts could have been reexcavated and the silt removed.

However, another system, which would have less immediate impact because it would have required a minimum amount of excavation, was designed by a Denver Service Center civil engineer. This system, instead of a large shaft, used well casing. A well point was attached to the end of the casing and driven to the water table or a depth of approximately 22 feet. Once installed with an offset flow drain, the casing shafts were tested by running water down into them. The rate of flow was approximately 5 gallons per minute. Neither holes could be filled during a test duration of 45 to 60 minutes.

The first few rainfalls of the subsequent rainy season did not tax the system as all water quickly drained away. However, with each additional rainfall, more and more water began to stand before finally draining. At one stage the original contractor using compressed air blew out what was apparently accumulated silt and coloidal material and the casing drained well again for one or two more rains. Then, the same thing began to happen and the rooms began to fill up again before finally draining. There was at least one additional attempt to clean out the casings of the fines by the park staff. This did not prove successful. Eventually the park staff resorted to sweeping and finally pumping the accumulated water out the east doorway after each rain. This situation continues at the present time.

The reason the well points and casings have not been successful is really quite simple. The original theory was that instead of using the perforated well points to pump water from an underground water supply up to the surface, the rainwater would drain back into the surface soil by gravity. However, just as the small perforations in the head of the well point keep some of the larger fines from being pumped up, these same holes became plugged by the fine particles which were draining down into the holes. The suction of a pump would normally keep these holes clear when used as a well. The force of the water's gravitational pull was minimal and not enough to keep the holes clean.

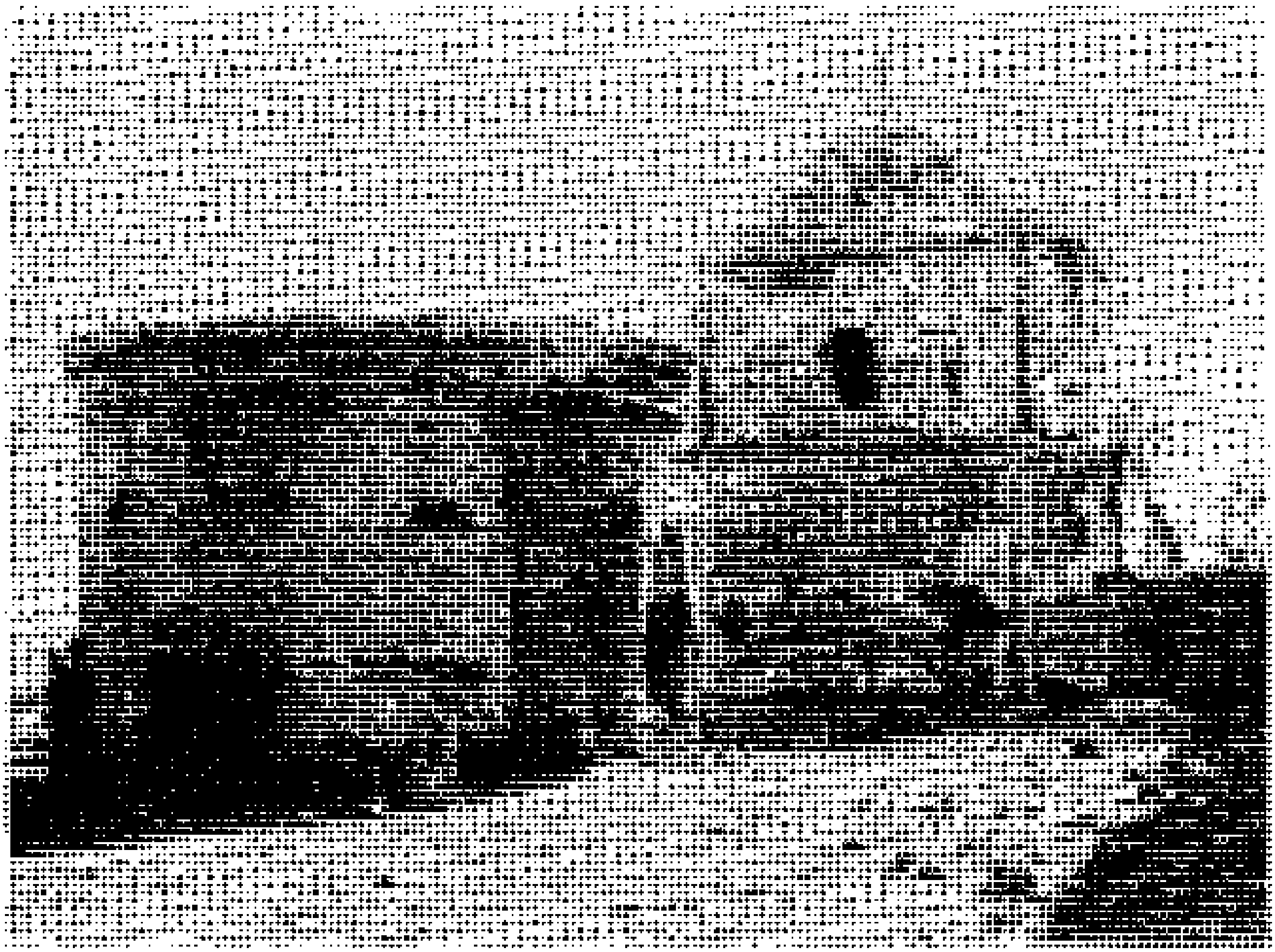
In retrospect, the dry well would have probably been the best solution. And, in fact, it is probably the solution that should be employed in the future. A recommendation for the development of a solution of this problem is included in "Chapter VIII: General Conclusions and Recommendations."

MORTUARY CHAPEL

The mortuary chapel is located in the campo santo, approximately 20 feet north of the north end of the church. Apparently, it was never finished because no evidence of any roofing material was found in the interior of the structure during Frank Pinkley's initial investigations. A relatively large number of photographs of the mortuary chapel were taken during the late 19th and early 20th centuries, and some of the earliest ones indicate that the building was in good condition. Much of the original plaster finish coat remained intact, and the general character had not yet been compromised (illustration 8).

The preservation efforts undertaken primarily concentrated on the plaster surfaces. Much of the original plaster remains, but extensive replastering had completely altered the character exhibited in the earliest visual records.

The interior surfaces had been completely replastered with a tinted cement plaster. Much of the exterior surface had also been replastered with the same tinted plaster, but some of the surface of the exterior had been replastered with a cement plaster that attempts to duplicate the



8. A view of the mortuary chapel from the northwest. 1892 International Boundary Resurvey photograph, No. JM-22/3275, Arizona Historic Foundation, Arizona State University Library, Tempe, Arizona.

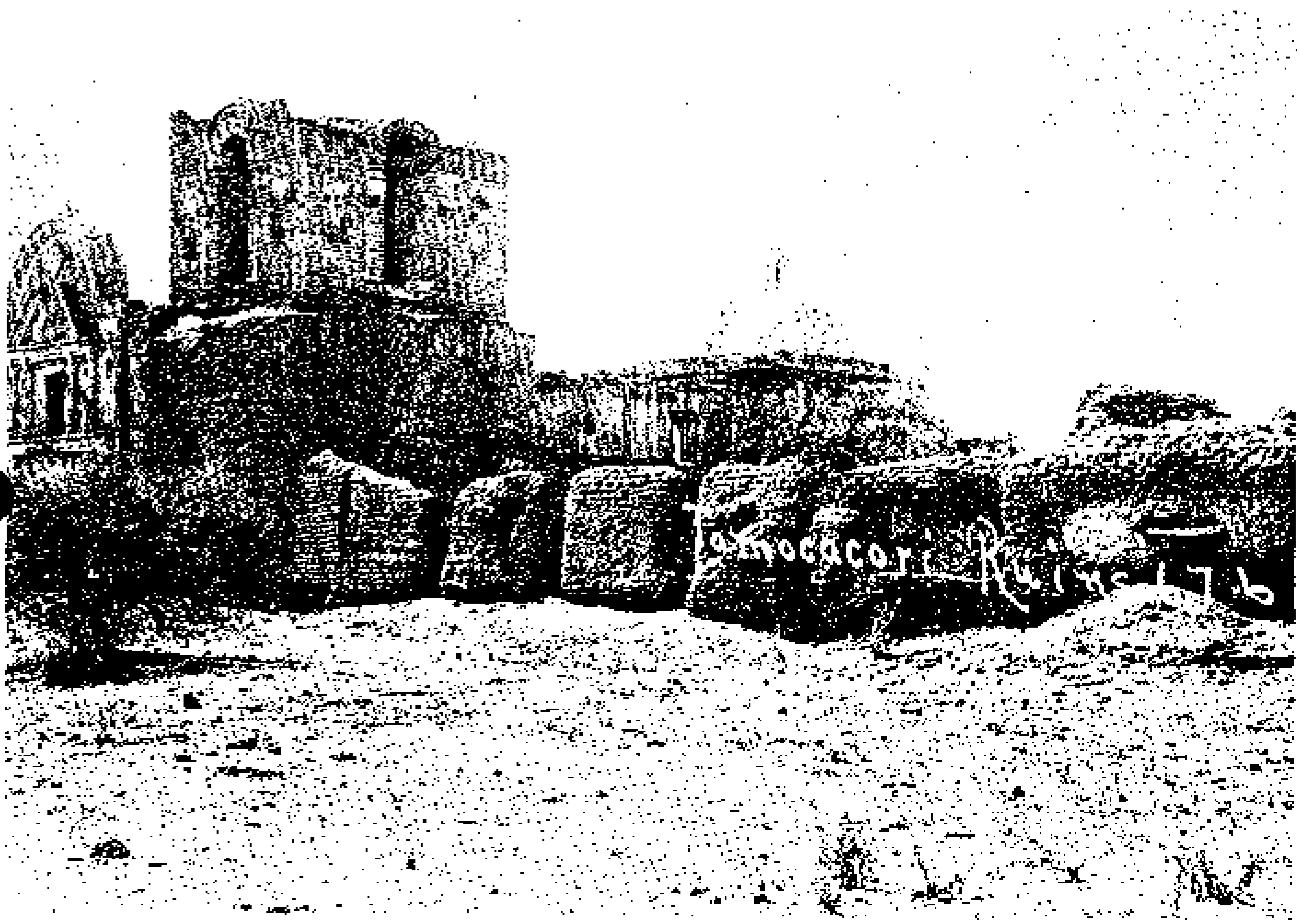
original finish coat. The original finish coat had small pieces of crushed brick set into the plaster in a random fashion. The physical technique was certainly much the same as was used on the exterior of the camp santo wall and the lower portions of the church, but the result was completely different. It probably reflects a somewhat hurried approach by a less skilled craftsman to a method that had been used previously.

The decision to rebuild the upper portions of the walls was made to protect the upper walls from continual erosion and to remove the visually intrusive stuccos that had been added over the past few years. After the restoration was completed, the new adobes were plastered with a lime-and-plaster and tinted with mud washes. Some of the new bricks that form the torus molding have weathered over the past four years and added to the overall weathered appearance of the chapel.

CONVENTO REMAINS ABOVEGROUND

The only portion of the convento that still remains above the surface in any form is located directly east of the church's bell tower. Even as early as 1843 the convento was described as being in ruins, and by the time the first photographs were taken in the 1880s, it appeared to have been in extremely poor condition (illustration 9). However, it does seem that portions of the convento must have been purposely destroyed during the next few years because by 1900 only the small portion that exists today remained.

Whether or not portions of the convento were purposely destroyed, the remains have undergone many changes, probably during the latter years of the 19th century as well as the early years of the 20th century. The changes have occurred to such an extent that it is unlikely if over 50 percent of the building material is from the historic mission period. The convento building continued to be used for various functions such as an office, a schoolhouse, and a museum by the National Park Service until the present visitor center was completed in 1937.



9. View of the church and convento from the southeast.

Until recently a minimal amount of preservation work has been undertaken on the building. Two parallel walls, one of which was leaning drastically to the south, were given some support by a steel tension rod and composite wood frame compression plates by the late 1940s. In 1952, the existing building was constructed over the convento remains for protection from the weather. In addition to not providing the best protection, primarily because of the significant increase in the ambient moisture under the enclosure, the shelter effectively screened the ruin itself to all but a limited inspection. In conjunction with the removal of the protective shelters over the corridor and the granary, a determination was made to also remove this shelter and protect the ruin by preservation maintenance. However, when the exterior plasterboard was removed and the entire building could be adequately assessed, it appeared that the structure was in far worse condition than originally thought. The shelter was serving to some extent to support a portion of one of the adobe walls, but even if that problem was adequately resolved, the building could not withstand direct exposure. Therefore, it was recommended that either the existing shelter be modified to adequately protect the building or a new one should be constructed. After an evaluation of various alternatives was completed, the National Park Service decided to modify the existing shelter. The modification was approved by the Regional Director, Western Region, in a memorandum to the Assistant Manager, Denver Service Center, on July 23, 1980. The Arizona State Historic Preservation Officer was notified on August 11. The work was subsequently carried out as a day labor project during August 1980.

SUBSURFACE STRUCTURES

Although not visible and consequently not the prime resource at Tumacacori, the subsurface structures are still extremely important, and a small portion was included in the architectural investigation.

The area of concern was a small portion of the north convento wing at the juncture of the wing with the granary. A small concrete block retaining wall was constructed without mortar along the mound perpendicular and just to the north of the doorway leading into the granary. Moisture continually moved from this retaining wall, being greater during the rainy seasons. If the moisture was moving through the subsurface walls, it would no doubt have been adversely affecting them.

In addition to learning whether or not the walls were being affected by the moisture movement, it was desirable to try to determine the amount of weathering that was taking place below grade. It has been the general consensus that structural remains are best preserved in a backfilled condition. It is essential, though, to compare the deterioration of the structures below ground to their deterioration when being maintained aboveground.

The actual monitoring of the deterioration is extremely difficult to accomplish. It was hoped that good photographic coverage of this area existed so that comparisons could be made at the time of the excavation. However, the only photograph of the area found that was taken at the time of the back-filling in 1968 is in the personal collection of Don Morris of the Western Archeological and Conservation Center in Tucson. The photograph was taken looking west along the top of the convento wing from about 75 feet away. Needless to say, no diredt photographic comparisons could be made to the level of detail which would have been required.

The excavation of the small area was accomplished in approximately one and a half working days. It was discovered that the block retaining wall was located 2 feet from the southernmost part of the south wall of this room. The fill on the south side of this wall was moist, but the fill on the north side was dry.

A polyethylene sheet covered the top of the wall and extended down both sides. Its primary function was to delineate the wall to assist reexcavation of the same area. Another polyethylene sheet was used to cover the filled room and the wall about 6 to 8 inches below the top of the fill. Don Morris indicated by personal communication that the polyethylene had been perforated, but it was difficult to determine the extent since several holes were also punched in the sheeting during the reexcavation.

The exposed wall appeared to be moist. A sample for moisture determination was not taken, but it was estimated to be in the range of 10 percent moisture by weight. There seemed to be no relationship between the moisture in the wall and the moisture that was percolating through the concrete block retaining wall. Apparently the water coming through the concrete wall was rainwater that moved over the top of the backfilled room and the south wall and seeped down into the fill just north of the retaining wall. The moisture in the retaining wall was probably being drawn up from below and perhaps to some extent from the fill in the room because of the greater capillary potential of the wall material.

While examining the wall an invaluable aid was discovered which gave very specific information about the rate of deterioration this wall has suffered since it was backfilled in 1968. Small amounts of the adobe material could be seen along the vertical wall surfaces, having been deposited there during the rains that fell on the wall while it was exposed between 1964 and 1968. The very distinct lines made by water that had run down the wall appear just as they would have looked if they had been rained on only a few days before the examination. Even though the walls were wet, they have remained in a state of preservation. It is likely that the moisture content of the wall fluctuated little, if any, and the stable condition was the primary reason for no deterioration.

A moisture sensor was placed in the north side of the wall at its base, 3 feet 6 inches below the polyethylene and 5 feet 8 inches from the north end of the wall. Another sensor was placed in the fill approximately 1 foot below the polyethylene. These were used to monitor the relative increase or decrease of the moisture content of the two materials over the next two years. During this time the moisture content of the surrounding fill and the walls varied little and did not seem to be affected significantly by seasonal changes.

The wall was also photographed extensively by the project architect and by the archeologists who actually did the excavating. These photographs will serve as a basis for comparison if the wall is ever reexcavated again.

The examination of this small portion of the subsurface structures seems to indicate that they are in fact being preserved far better than they could be if exposed to the elements and neglected. However, if they were ever exposed for interpretive purposes, they would probably survive for an extensive period of time if maintained properly.

CHAPTER IV: STRUCTURAL CONDITIONS

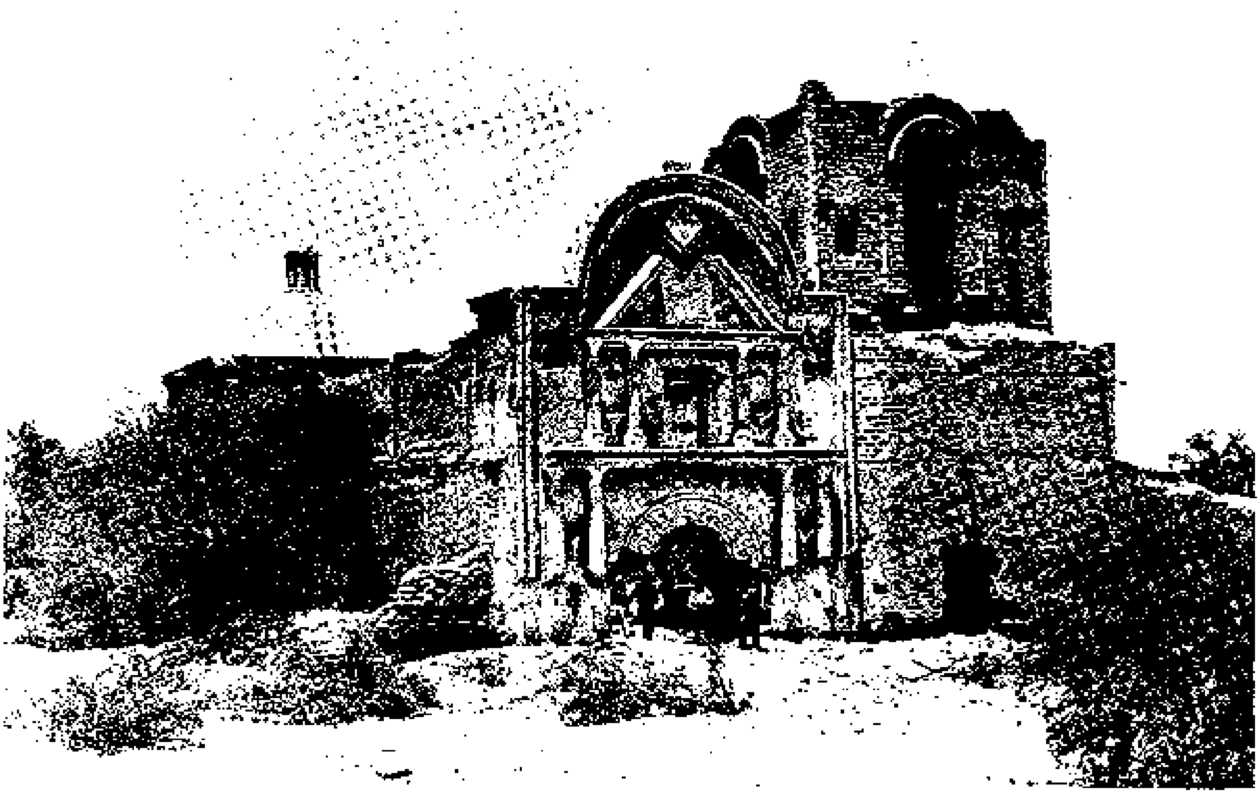
The analysis of the structural conditions of the building was based on (1) an evaluation of its structural history, (2) visual observations, (3) specific monitoring of suspected trouble areas, and (4) a comparison of the theoretical compressive strength of the material at various moisture contents and the actual loading.

STRUCTURAL HISTORY

The major structural components of the church remained intact for at least 70 years without maintenance. This represents the time between the abandonment of the complex in 1848 until the National Park Service began rehabilitation work in 1919. The actual time was probably closer to 100 years since it is doubtful if much maintenance was done on the building after 1822. During this period the building was inevitably subjected to changes in the microenvironment, which could potentially have adversely affected it. The roof, which would have provided some lateral bracing for the walls, was probably removed soon after abandonment. In 1860, William Wrighttson, who was associated with the Santa Rita Mining Company, described Tumacacori's roof as "now fallen and decayed."

Early photographs of Tumacacori clearly indicated the absence of a roof over the nave. Later photographs show the effects of erosion on the upper portion of the walls (illustration 10). The upper wall erosion suggests that rainwater also percolated down through the walls to further weaken them. Basal erosion to a depth of 12 inches into the walls certainly compromised the structural integrity of the building even more.

An earthquake of great magnitude damaged many buildings in Tucson, Tombstone, Willcox, St. David, Charleston, Fort Huachuca, and in Sonoran cities on May 3, 1887. The magnitude of the shock at Tumacacori is unknown, but it must have been appreciable, too. But



10. An 1889 George Roskruge photograph of the church from the south. Photograph is from the Tumacacori National Monument files.

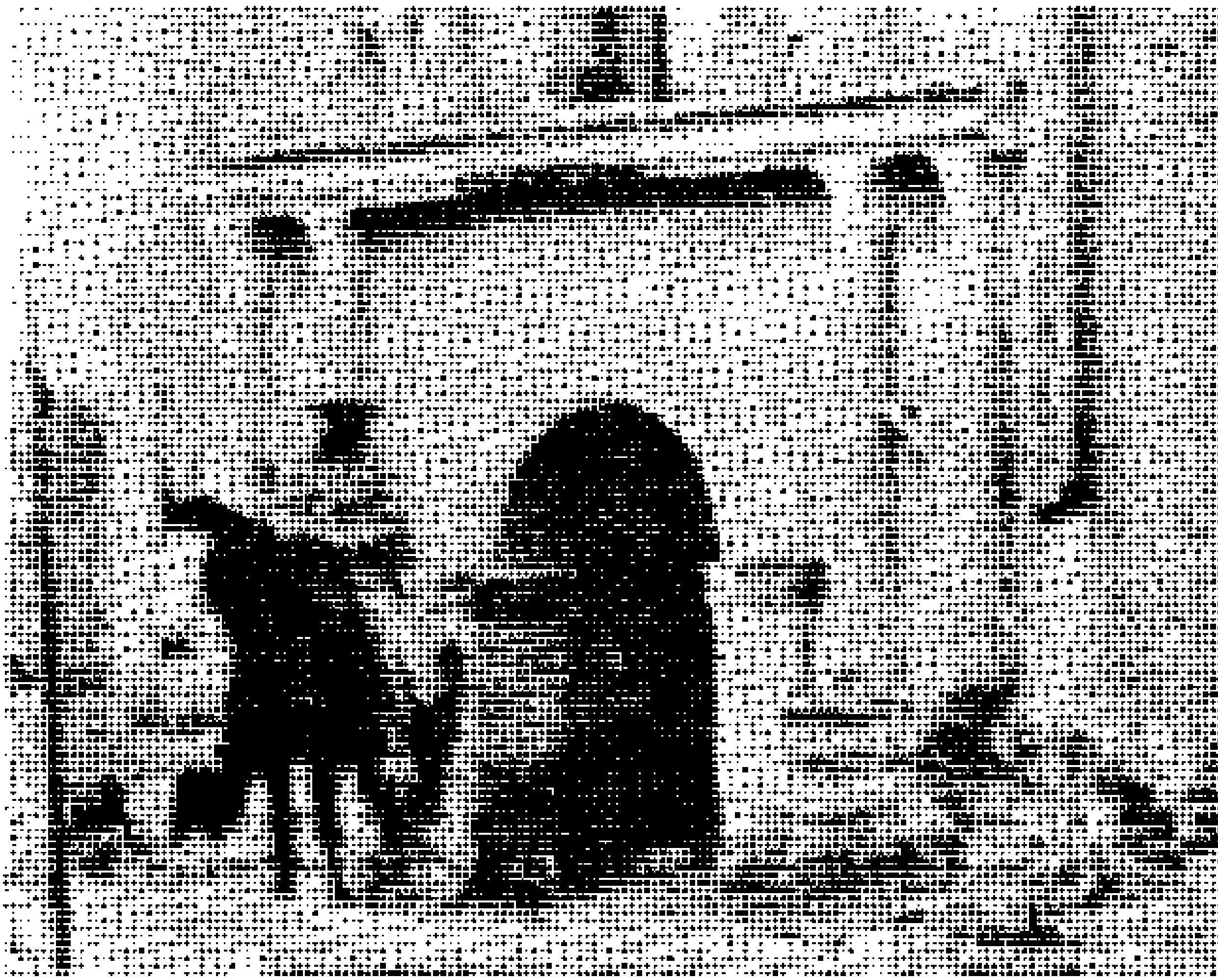
even in a less than ideal situation, the church apparently did not suffer any major loss through structural failure.

A pre-earthquake photograph, ca. 1882, shows the base and the lower portions of the engaged columns on the front facade (illustration 11). However, photographs taken in 1889, after the seismic activity, revealed that these same elements were missing. While there is no specific proof, they could have been shaken loose by the earthquake.

STRUCTURAL CRACKS

The existing cracks in the walls and the dome could have been a result of this traumatic shock. The two cracks in the west nave wall certainly appear to be the result of a sudden shock rather than the result of settlement. The settlement at the southwest corner of the building occurring over a long period of time would be expected to result in a diagonal crack. While it is not known when the cracks appeared, a photograph taken ca. 1900 shows the two cracks extended completely through the wall at that time. While these cracks are certainly significant, any stresses that produced them were not of the magnitude to cause the loss of any portion of the walls and dome.

A request was made in the spring of 1977 to the National Bureau of Standards through George Fatal, a structural engineer, to recommend and install crack monitoring gauges on five cracks in the church. Two gauges were placed in the dome, two were placed along the west nave wall, and one was placed in the southeast corner of the nave. During the week of May 23, 1977, Randy Williams, an electrical engineer, and a technician assistant installed six LVDTs on the five cracks. Gauges 1 and 2 were installed to measure displacement normal to the dome surface at the large cracks on the east and west sides. The other gauges were set up to measure displacement parallel to the wall and dome surfaces. Wires from the LVDTs led to power supplies, recorders, and readers located in the bell tower at the second floor level. A two-channel



11. Detail of the front of the church ca. 1882.

strip recorder was set up to record gauges 1 and 2 continuously. The other four gauges were read periodically. Later the National Bureau of Standards' gauges were replaced with similar gauges owned by the Western Archeological and Conservation Center.

The LVDTs actually measure a voltage change, which corresponds to a change in the distance from a plate on one side of the crack to the device itself on the other side of the crack. A Keithley brand multimeter was used to read the voltage change to the nearest 1/1,000 of a volt. The voltage change could then be multiplied by a factor unique for each LVDT, to translate the voltage change to an actual displacement.

The two cracks in the dome were monitored continuously for two months, and the other four gauges were read periodically. The voltage was read and recorded every hour initially, but after a daily fluctuation cycle was established, they were read less frequently. When it appeared that the two gauges being read continually were recording no significant movement, continuous recording, which lasted another two months, began for another gauge. After this time the automatic recording was discontinued and daily readings for all the gauges continued.

The daily fluctuation cycles seemed to result from the expansion and contraction of materials as they were heated and cooled during the day. One gauge in the dome would normally show a movement between 8:00 a.m. and 4:00 p.m. of approximately 1/1,000 of an inch, and then as the day would cool, material on either side of the crack seemed to return to near the early morning location.

There was also an obvious seasonal cycle as well. The general trend of several cracks was to become wider during certain times of the year and to return to or near their original locations at other times.

One of the gauges, which recorded movement parallel to the west nave wall at the crack near the south end, exhibited a widening of the crack during the months of July, August, September, and part of October, and then a narrowing until January when the crack began to widen again.

The movement at this crack seemed to have some relationship to the increasing and decreasing rainfall activity in the seasonal rainy seasons, but it was not determined whether the relationship was actual or merely coincidental. Increased capillary activity during this time might be the cause of the movement.

The movement exhibited at the crack at the juncture of the bell tower and the south facade wall has been the most drastic of all. A movement indicating the opening of the crack has been somewhat continuous from at least August 1977. Periodically, the movement seemed to stabilize somewhat. In January the LVDT monitoring was supplemented by mechanical measuring devices using a micrometer. Both the LVDTs and the mechanical devices have indicated a movement of 2 mm from 1977 until 1983. The last of the LVDTs was removed from the dome in August 1982, but several other LVDTs have remained at the south end of the nave.

One of the original structural concerns was the effect of sonic booms on the dome of the church. However, immediately after the equipment was installed in 1977, a loud boom occurred which shook the windows in the church. No change was recorded on the multimeter immediately afterwards, and there was only a point on the continuous recording for one of the gauges in the dome. This point would translate to considerably less than 1/1000 of an inch. Most subsequent sonic booms showed no mark at all on either of the continuously recording channels.

In a trip report written in June 1977 by George Fatal, structural engineer with the National Bureau of Standards, the question of seismic activity and the building's response was addressed. Mr. Fatal, through his report and both prior and subsequent personal conversations, responded to several areas of concern such as wall moisture, improper roof drainage, subsurface moisture conditions, in-place cement stucco and its eventual removal, structural design of a possible new roof, proper material for replastering, and possible danger from seismic activity. Of seven items mentioned specifically, the concern for any problem resulting from seismic activity was stated to be the least important.

The lack of any major loss of structural fabric during the 1887 earthquake implies that the chance for structural failure from the same level of activity is probably minimal. The monitoring of the structural cracks during the past six years has also lessened the concern.

During the repair and replastering of the dome, the cement stucco on the flat portion surrounding the dome was removed. Numerous cracks in the stucco had allowed water to penetrate down into the masonry. Beneath the cement stucco were two layers originally composed of lime mortar and brick batts, and beneath that was soil (illustrations 12 and 13). Soil had been used originally to fill the void between the dome and the brick cornice. In addition to the soil, there were also numerous fired bricks, or adobe quemados, that had been formed for use on the bell tower, but were used here instead, merely as fill material. Most of these bricks, which were set in mortar, were below the soil fill.

When the soil was removed, additional cracks in the masonry beneath the fill were found. Some of these cracks completely isolated the portion of the brick cornice on the northeast and northwest corners. The cause of these cracks was not determined. They could have occurred quite early, perhaps soon after construction. But it is also likely that at least some occurred because of excessive loading along the cornice caused by a combination of excessive moisture content and horizontal erosion of the adobe immediately below the cornice.

Because of the precarious nature of the two corners, the cornice bricks themselves were tied to the adjacent secure portion of the cornice. This was done by installing a No. 4 re-bar in epoxy resin grout into a groove which was cut into and followed the cornice line. The groove was cut approximately 2 inches deep to secure the bar with an adequate amount of epoxy. The other cracks were filled with lime grout to the extent possible, and the space previously filled with soil was filled with fired adobe bricks in dry mortar. The entire area was then covered with brick pavers and two coats of lime plaster.

12. A view of the northwest flat portion of the sanctuary adjacent to the dome after removal of the cement stucco. Photograph taken in August 1979.

13. A view of the west side of the dome and top of the sanctuary from the south after the removal of the dirt fill.

STRUCTURAL RESTORATION OF MORTUARY CHAPEL

During the initial restoration of the chapel, the upper portion of the walls were rebuilt with adobes and a soil rubble fill. A rainstorm, which occurred before the walls were completed, saturated the fill and caused the entire new work to collapse. A new extension of the adobe-arched doorway also collapsed at this time. The most important change during the subsequent restoration was stepping the original adobe so that the new material had a flat horizontal surface to rest on. In actuality, the stepped horizontal surfaces were inclined toward the interior of the wall so that the dead loads of the material were transformed back into the wall rather than to the exterior. Steel re-bars were installed at the request of the Western Archeological and Conservation Center as an additional measure to ensure against another failure. They were first painted and then set into predrilled holes that had been filled with epoxy resin. These holes extended through the new material into the original.

STRUCTURAL TIMBERS

Most of the original timbers used as window lintels are not capable of carrying the loads for which they were intended. Two timbers serving as lintels over the south nave window on the west wall fell apart when being examined in November 1977 for termites and the extent of sound wood (illustration 14). However, the adobe material above remained in place until the lintels were replaced. The original lintels over the sanctuary windows appear to be in excellent condition but in actuality are not capable of carrying the necessary loads. Some other timbers such as the ones in the bell tower have not deteriorated at all.

Generally, the nonoriginal timbers placed by Frank Pinkley and others are in good condition. A supplemental lintel that supports one of the original timbers at the main entrance on the south facade does have a slight sag at its midpoint and might eventually need some additional support. Both original and supplemental lintels over the opening from the sanctuary to the sacristy are performing adequately.

14. Deteriorated lintel in a west nave window.

The nave roof timbers appear to be in good structural condition. No water or insect damage has been observed. The extreme ends of the timbers were examined when the roof was replaced in 1978 and also were sound.

Generally, all the deterioration has resulted from both insect and fungal infestation in the past. Termites are currently active in the adobe walls of the church, but the wood is not being affected, probably because of the periodic treatment with a wood preservative that is a part of the cyclic maintenance program. The details of the cyclic treatment are included in the "Historic Structure Preservation Guide" for Tumacacori.

CONCLUSION

The primary structural concern will always be directly related to the amount of moisture in the building and the corresponding loss of mechanical properties of the adobe material. As the moisture problems were resolved, the concern for the structural stability of the church became even less important.

The significant cracks in the walls and in the dome were monitored until no structural problems were indicated. While there is no excessive movement in the southeast corner of the church that warrants drastic intervention, the actual extent of that crack is still being monitored under the direction of the Western Archeological and Conservation Center.

The lintels in the west sanctuary window are not sound. While there is no concern for the failure of the adobe above the window, the wall plaster requires a sound lintel for support. This will have to be addressed in the near future or the adjacent painted plaster could be lost.

CHAPTER V: PAINT CONSERVATION

HISTORY OF CONSERVATION

Early stabilization work in the 1920s and 1930s consisted of filling holes in the plaster with cement, rebuilding small architectural elements such as moldings, and giving support to rough plaster edges. These stabilization attempts do provide some information about the rate of deterioration since approximate dates for most of this work are known. However, the best benchmark was the extensive work done by Charles R. Steen and R.J. Gettens in 1949. Their investigation and evaluation and the work resulting from the research is accurately described in "Tumacacori Interior Decorations" and "Report on Inspection and Recommendations for Treatment of Plaster Walls and Wall Paintings" (Steen and Gettens 1962).

The investigation and material analysis was completed by Gettens. Interestingly, he only analyzed the paint pigments and wash and did not look at efflorescence on stains that may have resulted from, or have been the cause of, deterioration. In fact, the actual deterioration in the form of spalling plaster and paint was not mentioned, although the problem was known to have existed even before this time. Photographs taken by the Historic American Buildings Survey in 1937 show a clear line of deterioration that is similar to the present conditions. The material analysis of pigments found in the sanctuary of the church is as follows:

Pigments	Analysis
Orange-red	Ochreous hematite
Pale green	Copper mineral
Pale pink	Ochreous hematite
Bright red	Cinnabar, mercuric sulfide
Brown-gray	Copper-zinc metal powder
Green	Copper mineral
Blue gray	Charcoal carbon
Red	Ochreous hematite
Orange-yellow	Ochreous hematite
Black	Charcoal carbon
Green-blue	Indigo
Blue	Indigo
White finish	Gypsum

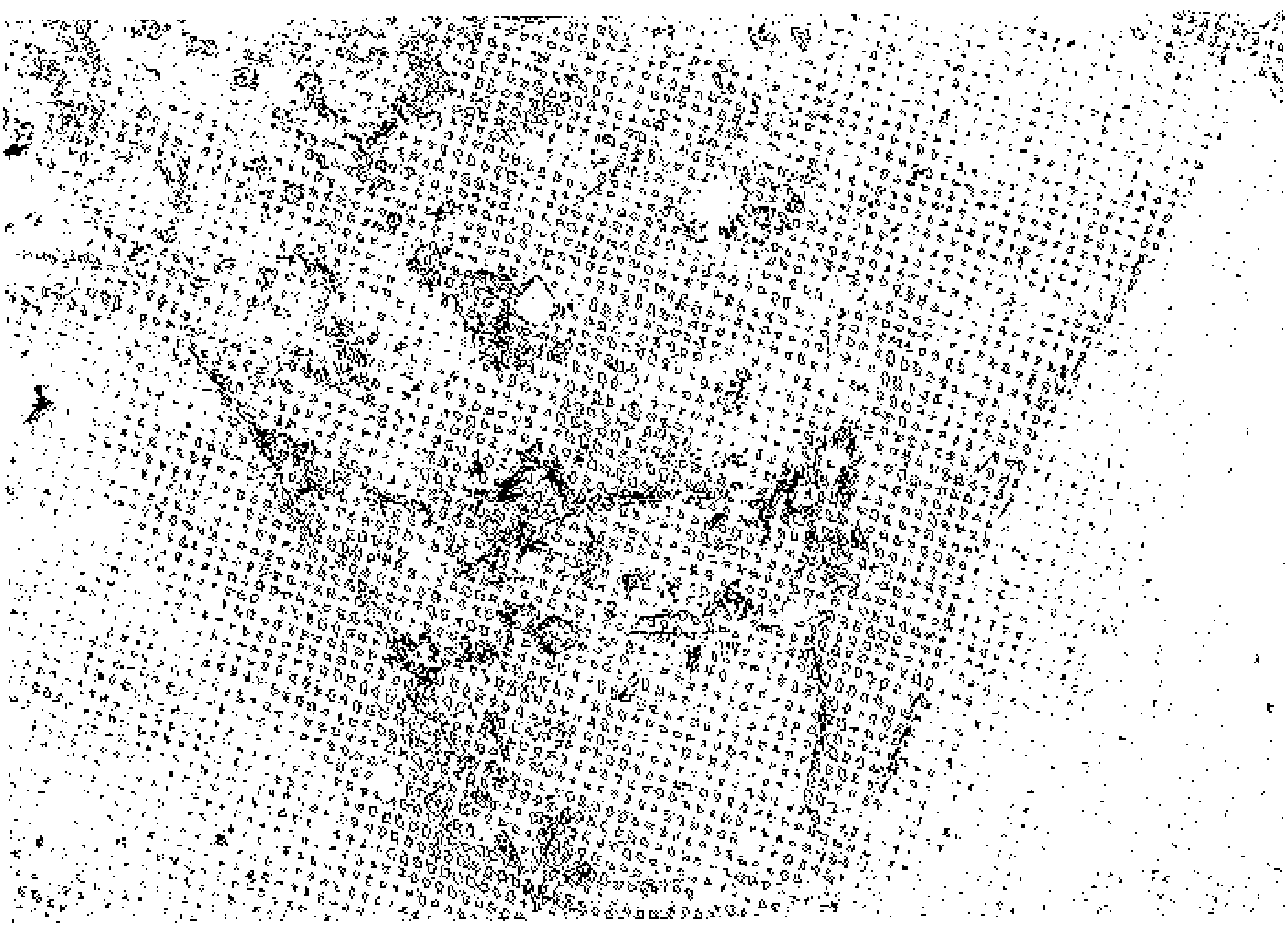
The actual treatment was undertaken by Steen and consisted of cleaning plaster surfaces and spraying a polyvinyl acetate (PVA) onto the surface. The exact formula was developed by Gettens and is as follows:

Vinylite A, medium viscosity (PVA), 50 grams
Solvent: toluene, 700 ml.
ethylene dichloride, 200 ml.
cellosolve, 40 ml.
(trade name for ethylene glycol monoethylether)
cellosolve acetate, 40 ml.
dibutylphthalate, 20 ml.

During an examination of the nave and sanctuary walls in January 1980, the effectiveness of the treatments were evaluated. The actual cleaning, which utilized small whisk brooms, was basically abrasive in nature because apparently the soiled or stained portions of the plaster were brushed away. The implication in the 1949 report was that all the surfaces were treated with PVA, but in actuality, the coverage was less than complete. Many areas, particularly in the dome, have retained a high degree of reflectance while other areas have not. In some cases the PVA remained on the surface layer of paint or gypsum wash, and in others it penetrated through the surface layer to settle on another layer of wash. In some areas the treatment was apparently not completed as only isolated drops of the PVA were found on the surfaces. In areas where there was heavy efflorescence, the PVA had often pulled away and was hanging net-like from the surface of the plaster.

More deterioration occurred after the 1949 work by Gettens and Steen, but it is not known if it began immediately after their work or sometime later. However, by the beginning of the comprehensive preservation project in the winter of 1975-76, a critical situation had developed. Excessive deterioration resulted in an accelerated loss of a section of original painted plaster in the sanctuary.

The affected area that had suffered the most was the northwest pendentive (illustration 15). Walter Nitkiewicz, painting conservator with the National Park Service's Harpers Ferry Center, evaluated the



15. View of the northwest pendentive.

conditions in March 1976. It was noted that a loss of approximately 10 percent of the paint had occurred up to that time. There was a loss of perhaps another 5 percent until January 1977 when the rate of deterioration accelerated tremendously, resulting in a loss of another 35 percent by March 1, 1977.

January 1977 was an extremely wet month at Tumacacori. Consequently, the accelerated deterioration can probably be traced to rainfall percolating down and surfacing at the affected spot. The reason for the deterioration occurring at that time after many years of similar conditions is not known. However, another significant amount of rainfall occurring at any time would have probably resulted in the loss of the remainder of the paint in this area.

The affected area was examined continually during January and February 1977 by the project architect. Another NPS architect familiar with conservation techniques of painted surfaces, and a private conservator also examined the area in February. The recommendation of each of these professionals, as well as the Harpers Ferry Center conservator who examined the painted walls in 1976, was to remove the remaining paint film from the plaster of the pendentive. It was felt that the determination of the exact causes of deterioration could not be made in time to preserve the paint in situ, and the removal of the paint film was the only possible way to save it.

In March 1976, Mr. Nitkiewicz tried to reattach a few square inches of paint in an area where the paint had lost its adhesion to the plaster. The treatment was not successful as the paint in the treated area soon became detached. This was the result of a significant amount of moisture moving through the plaster from the interior of the wall.

In April 1977 the actual removal of the paint film was carried out by a conservator, Gloria Fraser Giffords, using the strappo method (see appendix A). The friable paint film was first stabilized with a diluted solution of a polyvinyl acetate, AYAF. A facing of cheesecloth and muslin was then attached to the paint film and removed, taking the film with it. Because of the extremely friable nature of the paint, some loss occurred both during the initial preparation and the actual removal. However, the removal of the film was considered successful and the film itself is currently stored at the Western Archeological and Conservation Center.

EXISTING CONDITIONS

The overall existing conditions, which were factors in the complex deterioration process, are elaborated on in chapter II but are summarized here to emphasize the conditions that led directly to the deterioration of the paint film.

The source of the problem was moisture. Moisture migrated through the dome transporting soluble salts that recrystallized in the form of efflorescence and subflorescence. In the case of efflorescence, the salts recrystallized on the surface of the plaster, forcing the paint film away from the wall. In the case of subflorescence, the salts recrystallized in the plaster, creating pressures that fracture the plaster causing it to simply fall as it becomes friable. The recrystallized salts also acted hygroscopically, resulting in more ambient moisture being drawn to the area of salt concentration. During the time of the accelerated loss of paint from the northwest pendentive, efflorescence would reappear in a small cleaned area in only two or three days.

Another indication that moisture was moving through the dome from exterior to interior at that corner was a light yellow-green discoloration that appeared in concentric rings on the pendentive. The efflorescence always formed on the outer edges of the stain. At first it was thought that the stain could be organic, but later it was determined by proton induced X-ray emission to contain trace amounts of copper and nickel. Apparently, the minerals appeared in a spot on the pendentive and created the stain as moisture moved from within the pendentive to the surface.

The horizontal holes drilled in March 1979 were to a depth of 2 feet in the area of the northwest pendentive from the exterior. Material samples were taken and a determination of moisture content was made. At the 2-foot depth, lime plaster or mortar was encountered, which was probably the interior portion of the pendentive where it was set into the adobe wall. The moisture content was approximately 10 percent at that depth. This left little doubt that water was percolating down from above and was migrating to both the exterior surface of the adobe wall and the interior surfaces of the pendentive, dome, and wall.

Conditions inside the sanctuary were monitored to determine if there were causes of deterioration in addition to rainwater moving through the dome. The elements of the monitoring consisted of (1) recording of relative humidity and temperature at both the floor and dome levels, (2) recording of surface temperatures of the dome on the north, south, east, and west, (3) recording relative surface moisture, and (4) recording the amount of air movement at critical points. Also, the amount of total solar radiation was monitored on a vertical plane at the northwest, northeast, and southwest pendentives.

The purpose of recording the relative humidity was to determine, in combination with the recording of the surface temperatures, whether or not conditions exist that would lead to condensation of ambient moisture on the dome or wall surface. At no time was the relative humidity in the dome ever over 60 percent during the recording period, and the normal was closer to 40 percent. A maximum differential between the ambient temperature in the sanctuary and the surfaces was 5 to 6 degrees Fahrenheit. This difference occurred on the north portion of the dome surface. For condensation to form, a combination of 6 degree Fahrenheit temperature differential at approximately 90 percent relative humidity is required. At 60 percent relative humidity the temperature on the surface would have to be approximately 15 degrees cooler than the air. Obviously, the conditions do not exist for condensation to take place on surfaces unaffected by the hygroscopic salts of efflorescence.

A relationship between the relative humidity near the floor of the sanctuary and up within the dome has been established. At high relative humidities near the floor in the 60 to 80 percent range, the relative humidity at the dome will be between 30 and 45 percent. When the sanctuary floor range is 30 to 45 percent relative humidity, the dome relative humidity will be in the 15 to 30 percent range.

It is difficult to explain the relationship of the relative humidities near the dome and the sanctuary floor. A somewhat lower relative humidity was expected because of an expected higher temperature in the dome. However, the higher temperature was extremely minimal when it existed at all. But to account for the maximum relative humidity difference, there would have had to be a temperature difference in the range of 18 degrees Fahrenheit or 10 degrees Centigrade. Obviously, the air in the lower portion of the sanctuary is not being mixed well with the air in the upper portion. One reason would be that the air moves from the open sacristy in through the sanctuary, down the nave, and out the front door with little obstruction. Of course, the reverse air movement also occurs. In either case the air in the dome apparently moves very little, not being influenced either by the lower air movement.

A slight temperature difference from the sun side to the shade side on the interior surface of the dome is related directly to the exaggerated difference on the exterior surface of the dome. This temperature difference of more than 60 degrees Fahrenheit or 33 degrees Centigrade has been recorded, and a difference of 50 degrees Fahrenheit is quite common on the exterior. This difference is the reason for many of the cracks in the cement stucco that covered the dome. A temperature difference of as much as 50 degrees Fahrenheit between the cement stucco and the original dome had also contributed to the loss of bond between the two. However, the temperature difference on the interior surface of the dome from one quadrant to another is never more than 3 degrees Centigrade.

The relative amounts of surface moisture on the interior of the dome were measured several times with a surface resistivity meter. However, this aspect of the monitoring in this particular case contributed little. Those areas that exhibit the greatest amount of deterioration gave higher readings, indicating a relatively greater amount of surface moisture. These areas also have the greatest amount of recrystallized salts on the surface, which would give a higher reading with the same amount of moisture as areas that had less surface salts. The surface surveys did seem to indicate that some areas that had deteriorated greatly in the past had become somewhat stabilized with little indications of any surface moisture.

The movement of air in and just below the volume defined by the dome appears to be minimal. On several different occasions the amount of air moving near the northwest corner was measured and compared to the movement of air through the sacristy door and along the nave wall. At no time was the movement in the dome greater than 1 mile per hour, and an average over a period of several hours would be significantly less than that. Over the same period of time the air movement through the sacristy door would average 3 miles per hour, and on occasion, would be more than 4 miles per hour. The movement in the nave could average approximately 1 to 1½ miles per hour.

From the standpoint of conservation, the more stable conditions in the upper portions of the dome are preferable. It would probably be undesirable to increase the air movement in this area, and in fact, it may be desirable to decrease the movement of air through the lower portion as well. Air moving through the sanctuary had deposited a large amount of soil particles over the past 30 years and will continue to do so. Closing off the access of exterior air would certainly minimize the amount of particles deposited in the dome area, but minimal air movement may be desirable.

The area on the exterior above the northwest pendentive at the base of the dome was examined in an attempt to determine where the moisture was entering. Approximately 2 square feet of cement stucco were removed from the lower portion of the dome down to its juncture with the flat exterior. This stucco had pulled away from the original surface and was easy to remove without any damage to the original material.

When the stucco was removed at the base of the dome, a watermark was apparent approximately 3 inches above the flat surface. The material in this location also appeared to be wetter than the material above. As more material was removed, it became more obvious that water was getting in behind the cement stucco following the exterior surface of the dome down to the horizontal platform and then seeping down into the masonry base.

All the cement stucco on both the exterior of the dome and the horizontal portion of the base of the dome was removed in the summer of 1979. The exterior of the dome was in excellent condition. However, when a portion of a deteriorated plaster and brick batt covering was removed from the horizontal base, the source of the moisture problem was revealed. As seen in illustration 13, the original construction technique consisted of filling the space between the base of the dome and the upper exterior walls of the sanctuary on all four sides with loose earth and cobbles. At the time it was uncovered, the moisture content of the fill material was 20 to 25 percent by weight. There were significant cracks in the covering material, which allowed moisture penetration from above which probably kept the earth fill consistently damp throughout the year. The cement stucco material with its painted surface allowed little, if any, upward moisture loss through evaporation. Consequently, the most logical path that the moisture could follow was to the interior of the dome. The corrective procedures consisted of removing the fill, replacing it with low-fired bricks in an extremely dry lime mortar, and replastering the surface with a lime plaster. The mixture was 5 parts of lime to 1 part sand by volume with a small amount of clay added for workability. A lime whitewash was then applied over the plaster. A small amount of moisture continued to move through to the interior surface for another few months as was evidenced by the slow buildup of efflorescence in a previously cleaned spot. However, by January 1980, visible efflorescence no longer appeared in the cleaned spots. The buildup of efflorescence immediately after the repair of the exterior was most probably the result of moisture that remained in the dome bricks themselves, continuing to move to the interior.

In September 1979 a conservation evaluation of the conditions in the sanctuary was undertaken by Gloria Giffords and Martin Weaver (see Appendix B for their report). Rather than reaching conclusions and proposing specific treatments, the report basically outlined further analytical steps to determine the conditions that led to the decay.

The areas of deterioration were remapped to compare them with previous conditions. A comparison of relative surface moisture conditions indicates little real change, although only small amounts of efflorescence had reformed in areas that had been cleaned. The conclusion was that while moisture was no longer gaining access to the interior through the dome, a minimal amount of moisture in the material that had not evaporated continued to move to the interior surface. The hygroscopic nature of the salts of efflorescence were mainly responsible for the amount of surface moisture that still existed.

Samples of efflorescence were also collected at this time, and the results of the spot tests for anionic salts are listed in appendix C. The samples were collected to represent various conditions and various locations in order to gain a better understanding of the distribution and effects of the various salts. While most of the anionic salts were carbonates and sulfates, a significant amount of nitrates were also present. Chlorides were also present in a small percentage of the sample tests. The present amounts of the carbonates and sulfates were anticipated because of the basic components of the plaster and wash of lime (calcium carbonate) and gypsum (calcium sulphate). The presence of nitrates at this location in a building would normally have been somewhat unusual, but in this case, the earth fill used during the original construction contained some nitrates as well.

There did not appear to be any obvious relationship of the anionic salts to type and significance of decay, to the yellow stain, or to samples that fluoresced and samples that did not under ultraviolet light. The fluorescing and nonfluorescing salts in this case appear to be more related to the irregularities in the mass-void relationship of the salt to the plaster ground. This phenomenon has also been noted by others (de la Rie 1982).

During the course of the evaluation by Ms. Giffords and Mr. Weaver, a potential effect on the capillary movement of moisture through the adobe building material was suggested by Mr. Weaver. The suggestion was also incorporated into this report (see Appendix B). It is based on the fact that an electrical current flowing in the opposite direction of capillary moisture movement will increase the force of the capillary suction. The electrical current can be produced by an external power supply or internally in the wall by the chemical reaction of various minerals dissolved in the wall moisture. The existence of this current will be reflected in an electrical potential difference measured in volts. Consequently, if a voltage can be measured from one part of a wall to another, then a current exists.

In an attempt to verify this condition, contacts were driven into the interior surface of the west wall of the sanctuary at various elevations. Leads from a digital multimeter were attached to various combinations of these contacts with the electrical potential difference indicated in millivolts. These readings varied between 1 and 75 millivolts depending on the contacts used and the time the connections were made. The higher voltage readings, if reflecting an electrical current flowing from the upper to the lower portions of the wall, would probably cause any moisture present to rise higher in the wall.

However, a real question exists whether or not the voltage indicates an actual difference. It is extremely difficult to eliminate all the additional variables that can affect a voltage reading on the multimeter. Stray electromagnetic radiation will have some effect as will slight variations in the contacts themselves. These can easily cause a difference of several millivolts. These, of course, are completely unrelated to any actual potential differences between different parts of the wall. Also, the readings often had different signs with no apparent reason for the difference. These sign changes could result from the extraneous variables as well. If, however, the readings did reflect an actual condition, the sign differences probably represent a complex combination of electrical potentials that are distributed throughout the wall with small amounts of current flowing in all different directions. This condition is one that could be expected, and the overall effect on vertical capillary movement would be negligible. While some of the current would cause the moisture to rise, other current would cause the water to fall.

Another important consideration is that capillary moisture in the adobe walls at Tumacacori, when not affected by the presence of exterior coating, never existed higher than approximately 1 meter above grade. The amount of rise measured here is consistent with the findings of others (Torraca 1981, 97).

The rise of capillary moisture to extreme heights in adobe walls is an interesting theory but nothing more. The most important fact is that the source of the moisture migrating through the walls prior to the dome repair was obvious. Water penetrated through the cracks in the cement stucco into the earth fill and then migrated to the interior surface of the dome.

Ms. Giffords and Mr. Weaver also mapped the entire sanctuary wall for the relative integrity of the bonding between the lime plaster and the wall and dome surfaces. The technique was to tap the plaster and record a hollow sound as a lack of bonding. This is an acceptable technique. However, one should be aware that a small area of the plaster could have pulled away from the wall and sound hollow when tapped but still be effectively attached to the wall by plaster keys. Also, different thicknesses of even new plaster will sound quite different when tapped even if both are attached completely.

Solvents were also used in an attempt to remove the 1949 PVA consolidant with inconclusive results. Soluble nylon was tested as a just above the cornice on the west side of the dome, but the results or the specifics of the testing were not recorded in their report.

CONSERVATION TREATMENT ANALYSIS

The specific problems of flaking paint and gypsum wash and of stained, friable, missing, and poorly attached plaster had been identified prior to the arrival of painting conservator Paul Schwartzbaum of the International Center for the Conservation and Restoration of Cultural Properties (ICCROM) at Tumacacori. Scaffolding had been set up in the sanctuary because the most significant plaster and paint were there and because all the problems that existed elsewhere in the church were represented in the sanctuary as well. In consultation with Mr. Schwartzbaum, some conservation materials that were to be used for testing of various treatments had been purchased prior to his arrival, and he also brought other materials with him.

The various treatments were tested primarily on the west side of the interior surface of the dome. Several cleaning techniques were also tested in the sacristy, on a lower wall in the sanctuary, and on the intrados of the arch at the south entrance to the church. This section describes those treatments in detail and analyzes their effectiveness. The specific treatments tested were for (1) gypsum wash reattachment, (2) cleaning, (3) plaster consolidation, (4) reconstruction of missing plaster, and (5) the reattachment of the plaster to the structural material on to which it was originally applied.

Gypsum Wash Reattachment

The condition of the flaking gypsum wash was evaluated along the west side of the dome. As described earlier, moisture through the dome at this location has been some of the most disruptive, resulting in extensive loss. Testing began within this general area as a small 5-inch by 7-inch (12.7 cm by 17.8 cm) portion of gypsum wash was reattached to the dome surface in its original plane. The technique incorporated the use of a long fiber Japanese tissue and water.

The tissue was used primarily to protect the gypsum during the subsequent conservation work. It also served as a vehicle, as moisture was actually absorbed from a soft, natural bristle brush and the friable wash then absorbed the water from the tissue. Care had to be exercised in applying water at a rate that the wash could easily absorb; water applied too rapidly could displace the fragile wash. As the wash absorbed the water it became pliable, and a light stroking with the brush on the protective tissue would press the wash back in place on the plaster. Additional pressure was then consistently and carefully applied to the wash through the tissue to secure it back onto the wall plane.

One hour later the tissue was removed. The gypsum wash remained in direct contact with the plaster ground and the efflorescence was no longer visibly present. Previously loose flakes were secured on the plaster, and some of the yellow stain that exists had migrated to the edge of the wetted area; some of the stain was also removed with the tissue.

The following day the area was reevaluated with no apparent change from the condition immediately after the removal of the tissue. Salts had not reformed on the surface as may have been anticipated, and the wash remained intact and in place.

The next step was to expand the area to incorporate the full range of conditions associated with the deterioration of the gypsum wash. This larger area included examples of areas previously treated by Steen in 1949 with PVA. The PVA existed on the surface of the final gypsum wash in some areas, on underlaying layers in others, and hanging net-like from the plaster surface in still others. Also included were areas of heavy efflorescence, areas where the gypsum wash had not become detached, and areas where the ground plaster had eroded beneath the wash, leaving the wash freestanding and insecure. The water and tissue treatment was carried out during the next two days over this expanded area on the west side of the dome. The total area was 41 inches by 24 inches or 104 cm by 61 cm. The results were similar to that of the smaller area evaluated initially.

As the water was applied to the tissue, the efflorescing salts went into solution quickly. Most of the gypsum wash became pliable with water and was easily returned to the plane of the dome plaster. Very little of the wash remained brittle during the wetting and reforming procedure. Some small amounts of the wash that did remain brittle were removed along with the facing tissue. Some grains of sand and small plaster fragments in areas where the wash was completely missing and where the plaster ground was friable were also removed with the tissue. Upon drying, small areas of the treated wash appeared to cleave again from the plaster by the following day and additional water and tissue treatments were necessary.

The entire area was evaluated on Friday, and conditions seemed to remain the same as when the tissue was just removed. Efflorescence was still not visible on the surface, and no additional wash had become detached. An additional evaluation of the surface in October 1981 again showed no visible change.

Surface Cleaning

Surface cleaning of dust from the nave walls was undertaken in January 1980 and again in November 1980. At those times, many other stains were identified and recorded for further evaluation.

The walls and ceiling of the sacristy were significantly disfigured by smoke stain. Discoloration from unknown sources is noticeable on large portions of the nave and sacristy walls. Possibly micro-organic activity and airborne particles attracted to the surface contributed to stains visible on the south side of the dome. Graffiti, primarily graphite, covers large areas of all interior surfaces.

Both wet and dry methods of surface cleaning were investigated by Mr. Schwartzbaum. Wet cleaning with ammonium carbonate was evaluated in several different areas in the sacristy, the sanctuary, and the intrados of the main doorway.

The first area was located on the south jamb of the doorway leading from the sanctuary to the sacristy. Both smoke stain and graphite were present. Japanese tissue was applied with water, then a paper pulp poultice of ammonium carbonate and solvent mixture was applied to the lower half, and a poultice of ammonium carbonate alone was applied to the upper half of the tissue. The solvent was added to determine if it would prove beneficial in the removal of any surface grease. The tissue and both poultices were removed after 50 minutes. A saturated solution of ammonium carbonate was immediately brushed onto the area in a circular motion to thoroughly loosen all the dirt, which was then blotted with a cotton ball. Cotton balls moistened with water were gently blotted onto the surface several times until no dirt was visibly removed and the cotton remained clean. Although both poultices were effective, it was felt that the solitary ammonium carbonate poultice more completely removed the embedded soot and graphite.

A second test area on the sacristy side of this same doorway was also successfully cleaned with an ammonium carbonate poultice during the same 50 minutes. Following this, another test was undertaken using ammonium carbonate, but this time the poultice was left in place for only 15 minutes.

On evaluation it appeared that too much blotting with the cotton was necessary. To eliminate the danger of surface abrasion, it was felt that the 50-minute duration was highly preferable.

All of these tests were conducted to evaluate the effectiveness of the ammonium carbonate on a gypsum wash surface. The next step was to evaluate the effectiveness of this cleaning method on other surfaces, such as those that had been painted with an agueous solution of mineral pigments.

The same cleaning procedures as previously detailed were used on a small area approximately 2 inches by 3 inches (5 cm by 7.6 cm) along the remains of the black painted dado in the southwest corner of the sanctuary. Upon lightly blotting the area after the removal of the tissue and poultice, it became obvious that the pigment itself was being affected and the treatment was stopped.

Another test was undertaken on the intrados of the entrance doorway arch. Although the treatment did not affect the pigmented orange painted surface as much as it affected the black dado, some of the iron oxide pigment particles were displaced.

Small areas on the dome and on the main sanctuary cornice were also tested to determine the effectiveness of ammonium carbonate. The specific area on the dome was the dark brown area on the south side. The poultice cleaning easily removed the brown stain revealing the original pale blue paint beneath. A small area on the top horizontal surface of the cornice was also successfully cleaned using the ammonium carbonate poultice method.

Dry cleaning with a soft bristled brush was also tried, but the results were not as promising. The primary application to this cleaning method was to be limited areas when the paint pigment is adversely affected by the wet method.

Surface Consolidation

Closely related to the reattachment of the gypsum wash was the evaluation of three surface consolidation techniques: the use of ammonium carbonate and barium hydroxide; the use of barium hydroxide alone; and the use of Acryloid B-72, an ethyl methacrylate-methyl acrylate copolymer.

The ammonium carbonate/barium hydroxide treatment was located on a portion of the west dome surface previously reformed with water and tissue. The actual test area was 4-3/4 inches by 6 inches (12.1 cm by 15 cm). Japanese tissue was first applied to the surface with water, and then a paper pulp poultice saturated with barium hydroxide was left in place for six hours. The straight barium hydroxide treatment was done at the same time.

The treatment and the basic concepts have been described adequately by Edward Sayre (1973). Basically, the ammonium carbonate combines with calcium sulfate (gypsum) to form calcium carbonate and ammonium sulfate, a highly soluble salt. Barium hydroxide is then added, combining with the ammonium sulfate to form barium sulfate, which is extremely stable. The use of barium hydroxide has been used as a consolidant since the mid-19th century, although the details of the methods and materials of treatment continue to be investigated. This specific treatment was apparently developed by Enzo Ferroni, an Italian chemist in 1967 (Tintori 1973).

After six hours the barium hydroxide pulp was removed along with the tissue, which again was serving as a protective layer between the actual wall surface and the paper pulp. The effectiveness of the treatment could be evaluated by wetting the treated as well as the adjoining untreated surface and then noting the difference in the absorption of the moisture. The effectiveness could also be judged by visual observation of flakes of gypsum wash that had remained brittle and detached from the plaster ground prior to the consolidation treatment.

The evaluations indicated that while the treatment seemed to have had some effect, it was limited, probably being hampered by the existence of a substantial amount of the polyvinyl acetate applied by Steen.

The second treatment using barium hydroxide alone was conducted exactly as the second step of the treatment using ammonium carbonate and barium hydroxide described above. The treatment area was 3-3/4 inches by 6 inches (9.6 cm by 15 cm). The barium hydroxide pulp and tissue were also removed after six hours and the treated area evaluated. The results were similar to those of the ammonium carbonate/barium hydroxide treatment. Again, there appeared to be some consolidation, but the treatment was limited in its effectiveness.

The third treatment, using Acryloid B-72, covered an area 4-5/8 inches by 5-3/8 inches (11.8 cm by 13.7 cm). The solution used was approximately 4 percent solids, in a good grade lacquer thinner. The B-72 was applied in two thin coats, the second applied immediately after the first, directly onto the surface. The post-treatment evaluation indicated that the B-72 treatment was more effective in consolidating the surface than either of the previous two treatments.

It should be noted that one test of the effectiveness of the various consolidation treatments was to compare the water absorption of the treated with an untreated portion. In each case, moisture was not absorbed as readily on the treated surface, indicating the reduction of effective pore size and effective permeability of the material. In no case was the surface sealed completely since the moisture was absorbed, although at a slower rate than the untreated material. But even reducing the permeability slightly could be undesirable if significant amounts of moisture were still moving through the dome to evaporate on the interior surface. For a further look at the use of Acryloid B-72 on Tumacacori plaster, see appendix D.

Reconstruction of Plaster Edge

Acryloid B-72 was also used along a plaster edge in this same area to reattach some gypsum wash where the plaster ground had totally disintegrated behind it.

The first step was to give support to the extremely loose and friable wash prior to any attempt at working with it. This was done by gently facing the insecure area with Japanese tissue and attaching it with the B-72. Once this was completed, there was no danger of loosening any additional wash while working on the edge.

The next step was to reconstruct the missing plaster ground. It was necessary to first remove the old loose and crumbling plaster up to a depth of 2 cm. A fat lime putty, calcium hydroxide that had been slaked on-site for approximately two years was combined with a fine sand at a lime-sand ratio of approximately 1:4 by volume. The edge was built up only in areas necessary to support the loose wash and beveled down to the surface of the original plaster at an angle of approximately 60 degrees. In some cases it was only necessary to reconstruct the plaster to a depth of less than 1 cm. However, in one case the depth of the reconstruction was approximately 3.5 cm. This was built up in two successive layers with the final finish work completed as the very last step.

The new plaster was allowed to set approximately 24 hours, and while it was hard to the touch, it had certainly not cured. With the new support, the tissue-faced gypsum wash was then simply brought down onto the new surface plane and attached to it with Acryloid B-72. The tissue was removed at the same time with an appropriate solvent, and the final beveled plaster edge finished. In one case it was necessary to inject a PVA emulsion behind the largest piece of flaking wash in order to attach it to the new plaster.

This new plaster was evaluated during the October inspection. The gypsum wash was still well attached and there was no cracking or separation between the new plaster and the original. Also, readings from a conductivity meter indicated that no surface moisture was present. This is additional evidence that moisture is no longer moving from the exterior through the dome to the interior surface.

Plaster Reattachment

The problem of finding a solution for plaster that has become detached from an underlying plaster coat or from the supporting adobes or brick surfaces has long been a major concern.

Previous estimations of the amount of unbonded plaster have been high, primarily based on hollow sounding responses when tapped. However, this evaluation technique is not entirely satisfactory because, as has been pointed out, effective bonding keys often exist although the plaster is not attached on the face of the adobes or bricks. The actual areas in need of treatment were not extensive, but where the problem exists, it was a critical one.

One spot of bulging plaster on the south side of the dome surface was chosen for treatment evaluation. In this particular case, the final plaster coat had pulled away from an underlying coat. Also, a portion of the plaster had become friable and spalled off. Cheesecloth was first attached to the area to be treated with a PVA emulsion to secure it during the treatment. Water was injected behind the detached layer of plaster followed immediately with an injection of the PVA emulsion. Pressure was applied to the surface during and after the injection to enable the PVA adhesive to take effect. Presses were placed on the area and held there for approximately 20 hours. The presses were then removed, and the portion of the plaster that had been held in contact with the underlying plaster appeared to be attached firmly. However, the portion that had not been held in contact was still detached. In this latter case, a sufficient amount of the underlying plaster was missing prior to the treatment, and it would have been necessary to rebuild the plaster up to its original surface plan to allow an adequate bonding surface or support. In this case it will probably be necessary to remove the bulging layer eventually, rebuild the underlying plaster, and then reattach the removed plaster layer.

The cheesecloth that was applied as the first step in the reattachment attempt was left in place to remain until the underlying plaster can be rebuilt.

A proposal for the actual treatment was based on the preliminary testing and the success of the treatments after several months of continued observation. Several ways to undertake and complete the work were investigated, all based primarily on the direct involvement of ICCROM.

1982 CONSERVATION WORK

In addition to this author the conservation work was undertaken by a team of six NPS employees and three mural painting conservators:

Paul Schwartzbaum, Chief Painting Restorer, ICCROM
Carlo Giantomassi, Painting Conservator, ICCROM
Donatella Zari, Painting Conservator, ICCROM
Greg Byrne, Conservator, Harpers Ferry Center
Toby Raphael, Conservator, Harpers Ferry Center
Allen Bohnart, Curator, Mesa Verde National Park
Carole Perrault, Architectural Conservator, North Atlantic Regional Office
Elizabeth Santos, Historical Architect, Denver Service Center
Brigid Sullivan, Conservator, Western Archeological Center

The goal for the project was to fill voids, reattach loose paint, reattach plaster, and clean the wall surfaces of the sanctuary. It was also hoped that plaster in the nave and the north exterior sanctuary wall could also be reattached and consolidated as necessary and that the nave plaster could be cleaned. The work outside the sanctuary was not completed.

The work in the sanctuary was completed to a point immediately below the window sills except for treatment of the wooden lintels of the west window. The poor condition of this lintel was not known until treatment was undertaken on the adjacent painted plaster. Work began on the painted plaster attached to the intrados of the main entrance arch. The adobe onto which the plaster was attached was first consolidated with PVA, and then the plaster was attached to the adobe and small voids filled with the same PVA. There was a very hard insoluble putty-like material along the edges of the plaster, and not only was it visually intrusive, but the material was also much stronger than the plaster, and in some cases, was causing fractures in it. Some of this material was removed, but some remains.

A portion of one of the original canales on the exterior of the north sanctuary wall was temporarily stabilized with a lime mortar. This was not a permanent solution and was undertaken simply to prevent water from running behind the plaster during rainstorms. Some of the remaining original north wall plaster was also in need of conservation work, probably reattachment, but a temporary solution, which was to be completed by the Tumacacori maintenance staff, was not undertaken before the plaster fell.

The specific items of conservation work in the sanctuary varied somewhat from that which was proposed and anticipated. The main difference was that the overall cleaning of the surface was not necessary. Specific areas were cleaned with ammonium carbonate, primarily on the south portion of the dome. The dark stain in this area was extremely difficult to remove, and it required approximately eight days to complete.

PVA was used more extensively than anticipated. Several larger areas of hollow sounding plaster north of the west sanctuary window were reattached with about 150 cubic centimeters of PVA. More PVA was also used on the north sanctuary wall immediately above the retablo niche.

Although some acrylic resins were used in addition to the polyvinyl resins as consolidants and adhesives, the majority of the work was completed using unamended lime plaster, plain water, and tissue. This basically conservative approach to resolving the conservation problems was the principal consideration throughout the project.

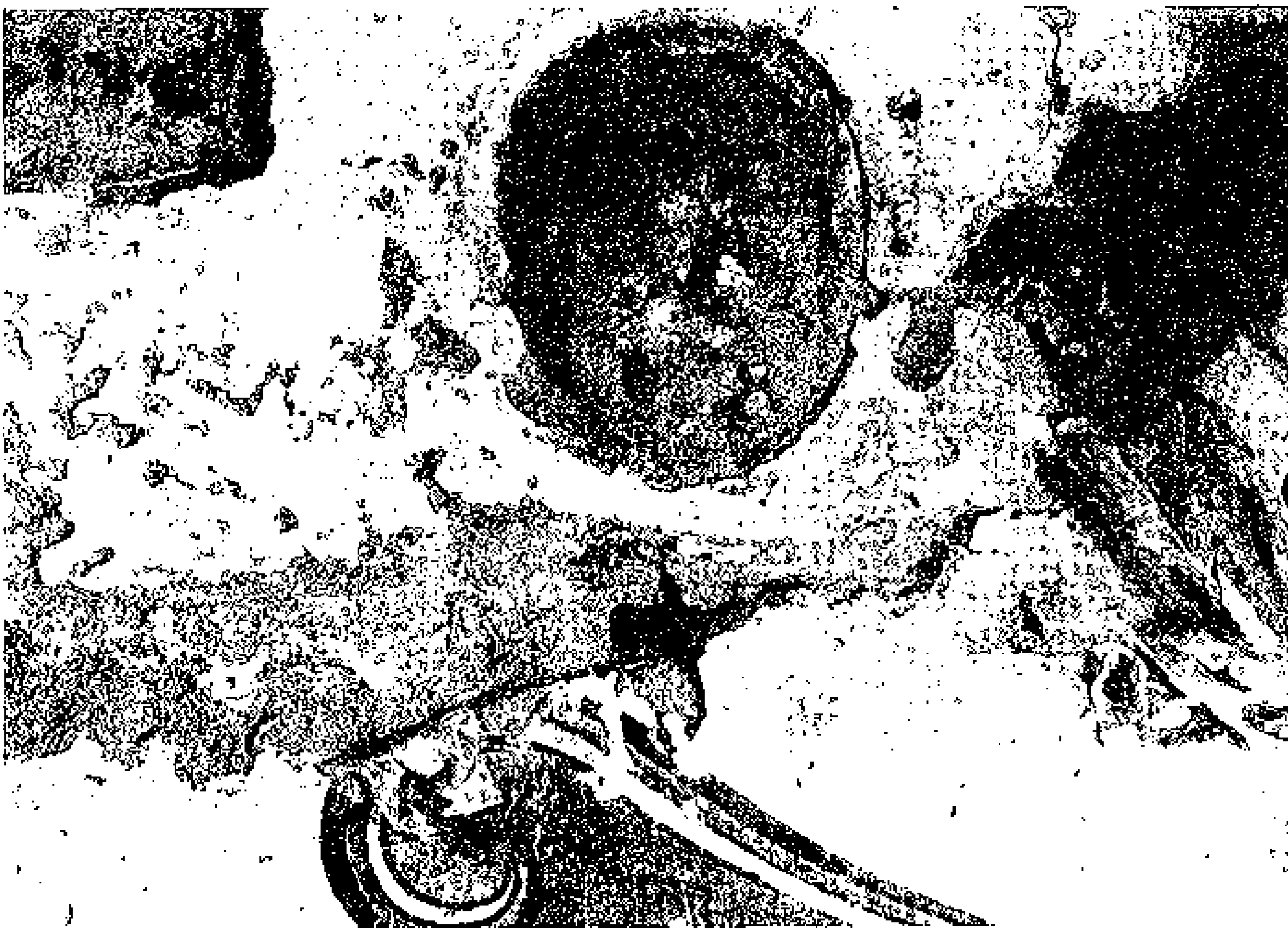
Visual comparisons provide the best information about the extent of the work and its overall effect. Illustrations 16 and 17 show a before and after treatment comparison of the lower portion of the west surface of the dome. Illustrations 18 and 19 show the condition of the painted volute on the upper portion of the painted retablo on the north wall in 1976, in 1982 prior to treatment, and after treatment. The last comparison (illustrations 20 and 21) shows the entire dome area before and after treatment.

The stabilization of friable plaster edges, the infilling of large cracks and holes, and the reattachment of a loose friable paint film resulted in two beneficial effects. One effect is a visual consistency that allows for a greater appreciation of the remaining original paint and plaster. The other effect is a material soundness that will ensure the continued existence of the original fabric into the future.

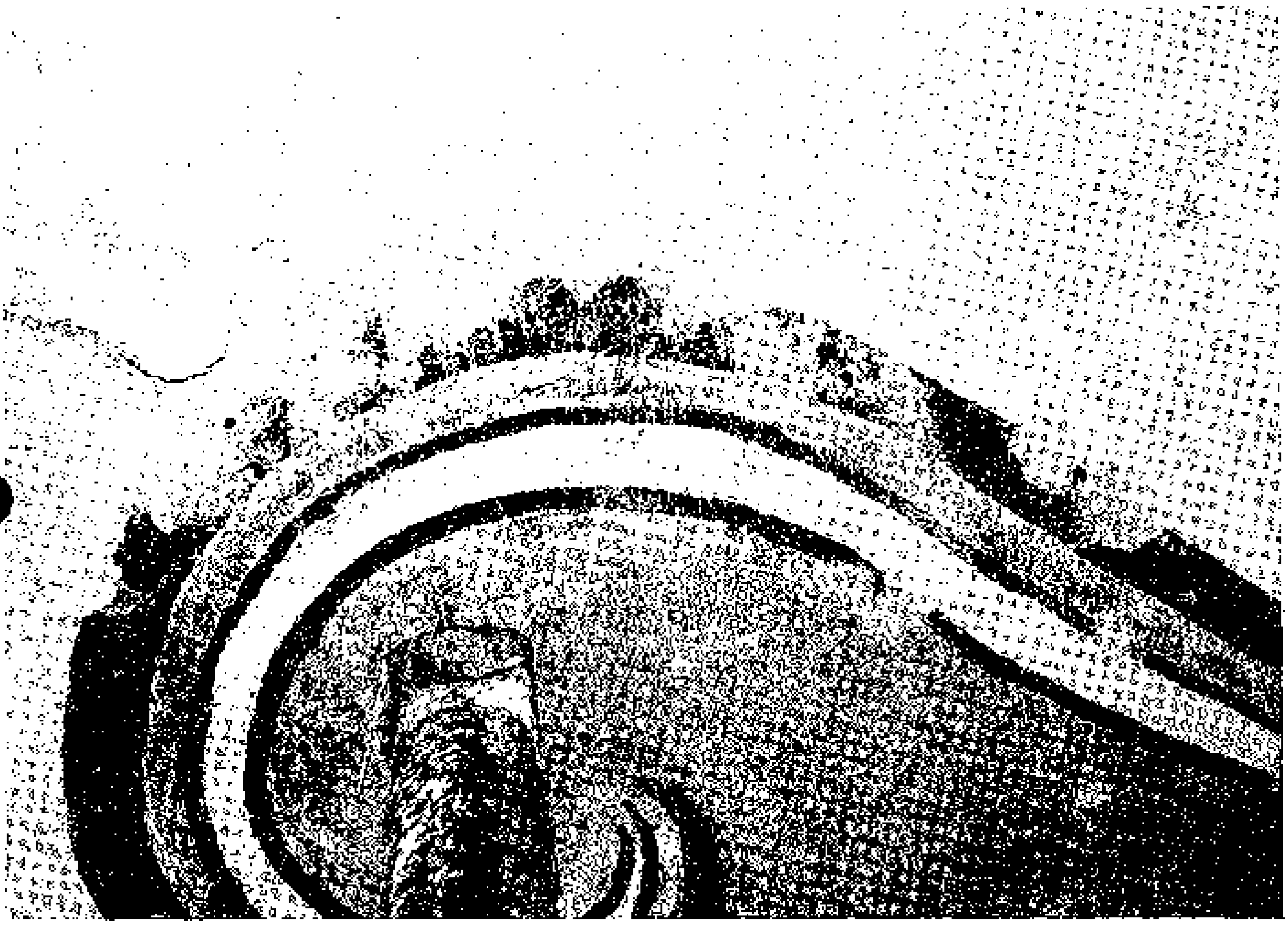
The success of the conservation work was dependent, to a large extent, on the specific conditions at Tumacacori and the effectiveness of specific techniques that had been developed elsewhere. However, another important reason for the success was the skills of the conservators from ICCROM and the dedication and hard work by NPS conservators. As the work progressed, the employees began to develop skills and a great deal of sensitivity, which made the work proceed more quickly and produced better results than when they first began.

16. South side of the sanctuary dome before treatment, 1981.

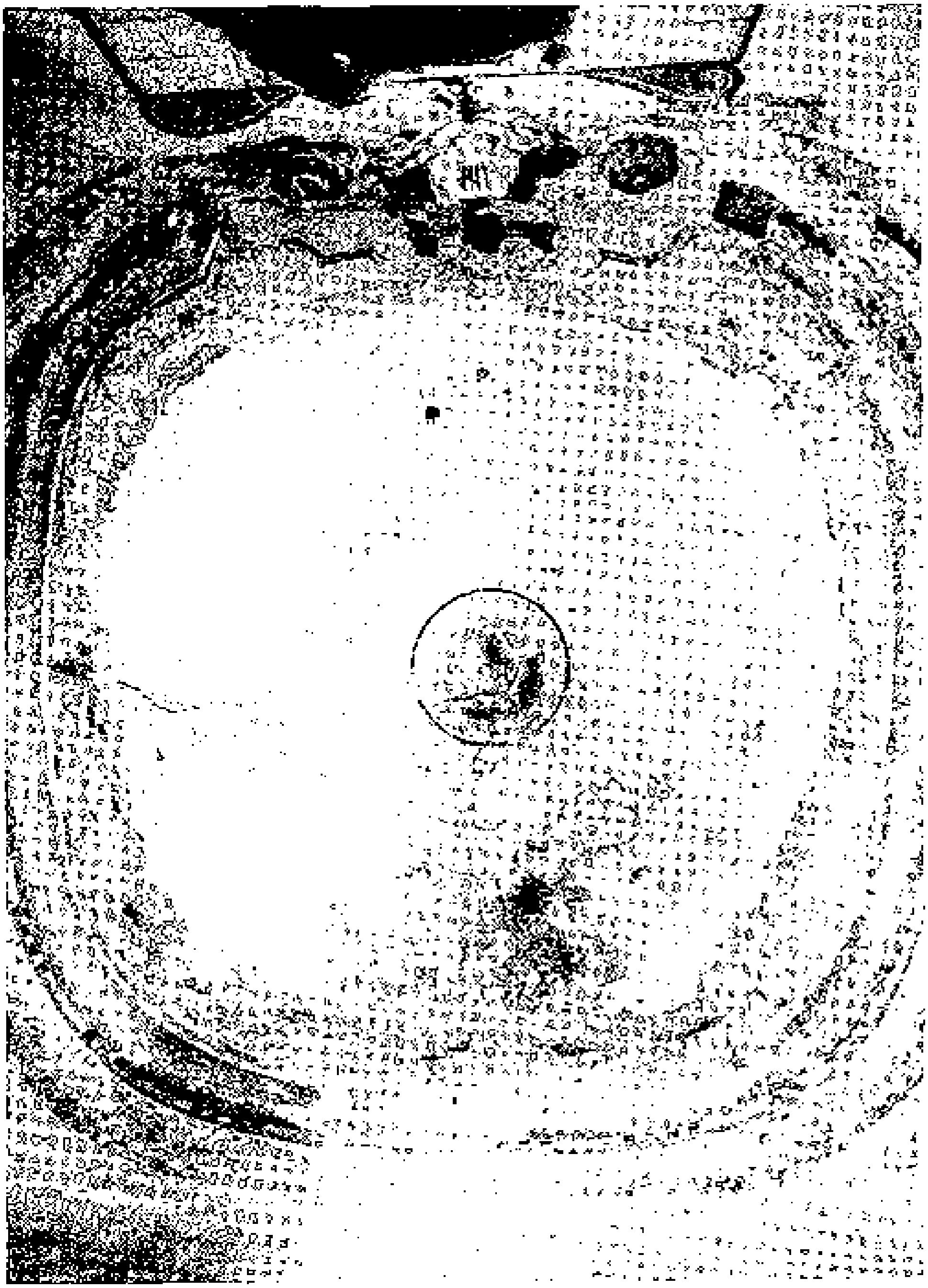
17. South side of the sanctuary dome after treatment, 1982.



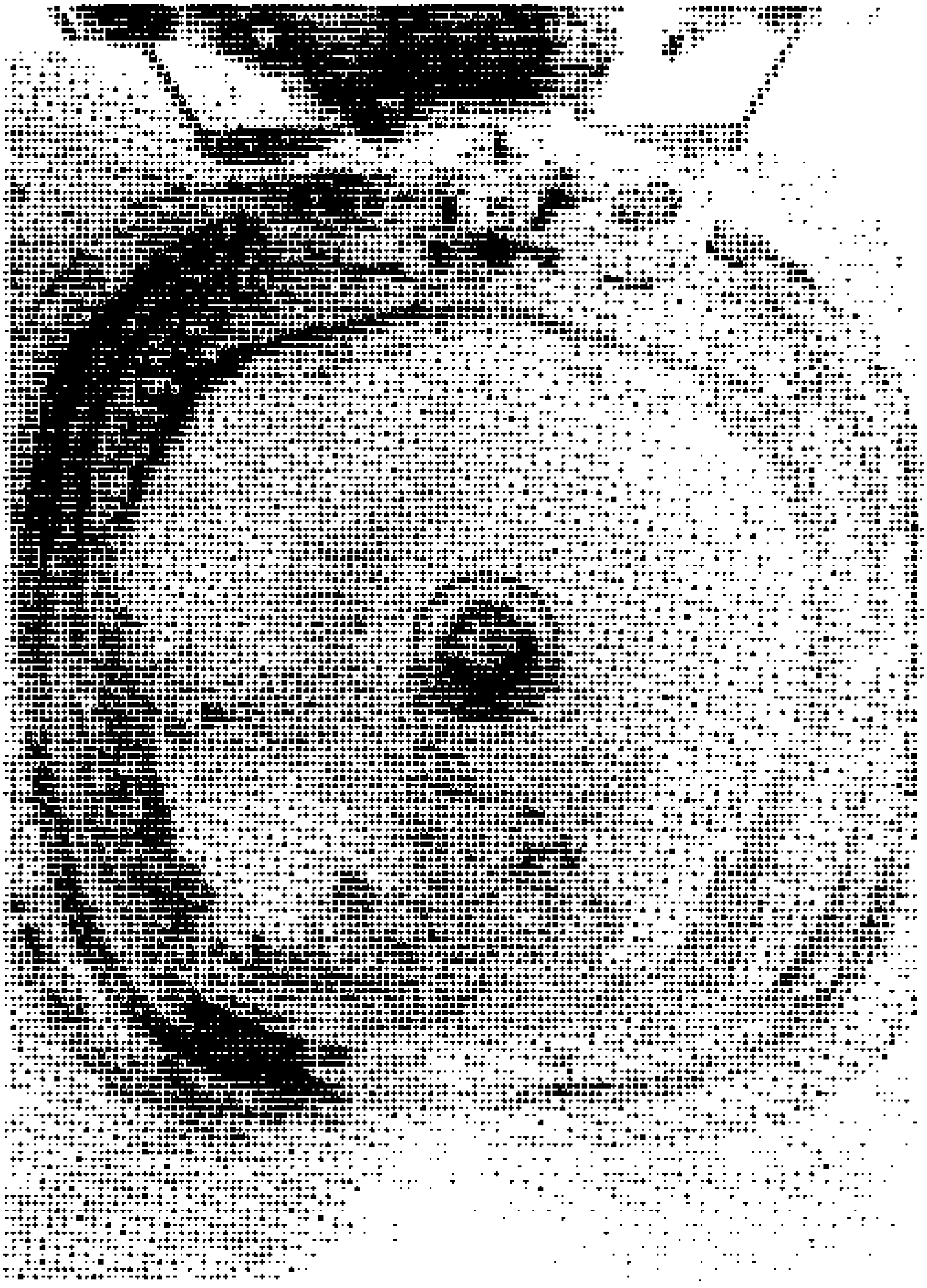
18. Painted volute on the sanctuary's north wall before treatment, June 1982.



19. Painted volute on the sanctuary's north wall after treatment, August 1982.



20. Interior of the dome before treatment, 1979.



21. Interior of the dome after treatment, August 1982.

Proposal for Future Conservation Treatment

The proposal for the remaining conservation work is based on the results of the initial testing and the success of the initial conservation work. Another important aspect of the proposal is that if the remaining work can be undertaken in a timely manner, many of the same participants will likely be available, thus saving the cost of training new people. The components of the proposed conservation work are generally the same as outlined at the beginning of the conservation project except that (1) most, if not all, of the reattachment of the friable paint film with water and tissue paper has been completed; and (2) epoxy wood lintel consolidation has been added in the sanctuary.

The general components of the remaining conservation work are listed below: (1) consolidate and reattach paint and plaster, (2) clean plaster surfaces as appropriate, (3) reconstruct missing plaster as appropriate, and (4) replace cement bead in lower plaster edge.

The extent of the remaining plaster consolidation work on the lower sanctuary walls, in the sacristy, and in the nave is limited. A much more critical situation exists with the original plaster on the exterior north and south walls of the church.

The reconstruction of missing plaster will also be less extensive than was necessary during the summer of 1982, but some is needed on the original plaster in specific locations on both the interior and exterior of the building.

The replacement of the cement bead along the lower edge of all original interior plaster was also planned for the summer of 1982, but it was not begun.

The remaining conservation work is listed here in order of priority.

Complete sanctuary work including the critical wood lintel consolidation treatment.

Consolidate original exterior plaster on the north sanctuary wall and the south façade.

Reattach delaminated plaster and repair edges and fill holes in the important original painted plaster existing on the intrados, or underside of the main arched doorway opening.

Consolidate plaster where necessary and reattach to the adobe walls.

Replace cement bead on the lower edges of original plaster in sacristy and nave.

Clean walls where necessary.

Appendix G contains a further explanation of this work and a 1982 cost estimate.

CHAPTER VI: MOISTURE CONDITIONS AND THEIR EFFECTS

GENERAL CONCERNS

The areas in the church that appear to have been affected by capillary moisture occur all along the east nave wall, north of the bell tower, a small spot on the south wall of the sacristy, the south end of the west nave wall, and possibly one other spot farther north along the west nave wall.

Monitoring of the resource based on a cause-effect relationship was continuous in varying degrees during the life of the project. Initially the monitoring consisted of simplified methods such as a mechanically operated sling psychrometer, visual observations, and material sampling. Later the monitoring became more comprehensive, using hygrothermographs, a recording weather station, moisture sensors, crack propagation gauges, conductivity meters, surface thermometers, and more specific information on the actual performance of adobe materials with the visual observations and sampling program.

Subtle changes in the cause-effect relationship indicated by data from the monitoring program provided a much clearer picture of the actual migration of moisture through the building fabric. Most of the intrusion of moisture into the structures was from capillary action.

The initial testing directed to determining the source of the moisture that was visible along the tower portion of the east nave wall of the church consisted of taking material samples along the upper several feet of wall both before and after the roof and exterior upper walls had been subjected to water (NPS 1976). The results of this testing indicated that, except in the area of the third canale from the south on the west church wall, water was not penetrating down from the top of the walls. while the moisture content near this canale was not excessively high, 4 to 5 percent by weight compared to 1 to 2 percent of other samples, the higher reading did indicate at least that water had probably entered the wall via a leaking drain box sometime in the past. Samples taken after rains and artificial flooding showed no significant change in this area, probably indicating that the leak, if still active, was slight. A significant amount of deterioration of the exterior cement stucco in the area was visible, causing concern that even a small amount of moisture might be building up behind the stucco and not being removed from the wall by evaporative processes.

It was obvious that while water had previously penetrated the roof or parapet, with the one exception mentioned above, it was not doing so at the time of the initial sampling. Several voids detected in the interior of the walls and areas on the interior wall surfaces where water had washed down was ample proof of the previous penetration.

During the removal of the polyurethane foam that had been placed over the nave roof in 1974, several holes were inadvertently punched through the built-up roofing, particularly at the juncture of the roof and the parapet. Consequently, some water leaked down from the roof through the interior brick cornice and ran down the interior face of the wall. Even then, the amount of moisture that reached the interior of the walls appeared slight and only in a relatively few areas. The nave roof was patched in August 1977, and water no longer was visible on the interior wall surfaces. The entire roof was replaced in 1980.

SUBSURFACE CONDITIONS

In October 1977, a contract was let with a soils engineering firm to conduct a subsurface investigation to determine the capillary moisture source. The borings were located in a traverse perpendicular to the main axis of the church. Each boring, with one exception, extended to the water table, and selected samples were taken to determine properties such as moisture content, particle size, liquid and plastic limits, and amount and type of soluble salts. Perforated PVC pipe was placed in holes 3 and 6 so that the water table could be monitored continuously.

The results of the investigation indicated that in holes 4, 6, and 7 a somewhat different situation existed than in the others. In all borings, except hole 1, where the boring was terminated at 20 feet because of difficult drilling, the water table was reached between 23 and 27 feet. The normal occurrence of alternating layers of cobbles and hard pack would seem to preclude the possibility of water at approximately 25 feet as being the capillary moisture source. Subsequent evaluation of the material has indicated that, in fact, it is impossible for this to be the source. However, a somewhat higher moisture content was noted between the surface and 10 feet in the holes located off the southwest corner of the church (hole 4) and the east of the church (holes 6 and 7). The maximum amount of moisture of 10 percent in these locations was not high enough to serve as a capillary source at the time of the investigation.

For the material in or on which the walls rest to serve as a source for capillary action, there has to be free water available (Vos 1973). Free moisture will occur when the force of gravity pulls moisture through the material, normally at less than an actual saturated condition because a substantial amount of air pockets will still remain in the wetted material. Depending on the specific material, this could occur when the actual moisture content is as low as 15 percent.

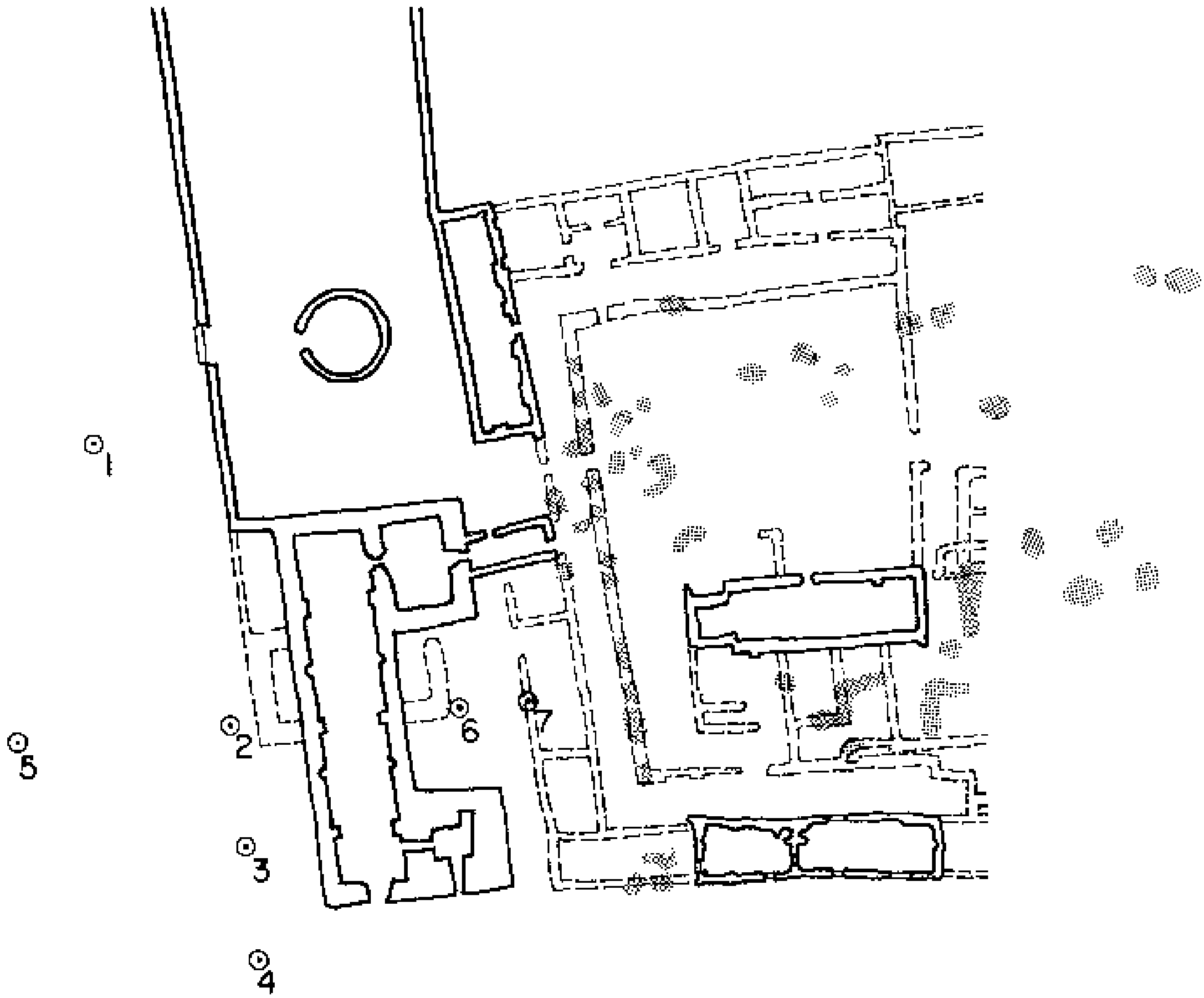
The gathering of data on soil moisture conditions in the two critical areas identified by the subsurface investigation continued. The information that follows provides a picture of abnormal moisture contents periodically reaching extreme levels.

Sample Location	Depth	% H_2O	Date
A	1'	11.0	12/01/76
A	2.5'	12.0	12/01/76
B	1.7'	6.8	12/01/76
B	2.5'	6.3	12/01/76
C	2.3'	7.2	12/02/76
C	3.5'	6.6	12/02/76
D	2.5'	10.2	12/02/76
D	2.5'	10.0	12/02/76

E	0.3'	8.8	11/30/76
F	0.6' below PVC	9.9	01/20/77
F	2.3'	11.2	01/20/77
F	2.8'	10.2	01/20/77
F	3.4'	10.3	01/20/77
G	2.3'	5.7	01/20/77
G	3.3'	6.5	01/20/77
H	2.3'	8.1	01/20/77
H	3.3'	7.7	01/20/77
I	0.8'	6.2	05/26/77
J	0.8'	8.6	05/26/77
K	0.8'	1.5	05/26/77
L	1.0'	13.6	07/19/77
L	2.5'	12.4	07/19/77
M	0.5'	10.38	10/19/77
M	2.0'	13.64	10/19/77
M	3.0'	9.05	10/19/77
N	0.5'	9.75	10/19/77
N	2.0'	15.13	10/19/77
N	3.0'	22.0	10/19/77
O	0.5'	9.03	10/19/77
O	2.0'	14.82	10/19/77
O	3.0'	14.74	10/19/77
P	0.5'	9.97	10/19/77
P	2.0'	13.95	10/19/77
P	3.0'	10.31	10/19/77

At the time of the subsurface investigation, Doug McCollough, chief of maintenance at Tumacacori, pointed out several spots in the area of the convento patio that appeared to be wet (illustration 22). A continuous monitoring of these spots indicated they remained dark, or stained, and at relatively high moisture contents throughout the year. On May 26, 1977, after a period of two months without rain, the moisture content by weight of the soil only 1 inch below the ground surface in two of these dark spots was 8.6 percent and 6.2 percent. A nonstained area used as a control contained 1.5 percent moisture.

The darkest areas were approximately 40 feet east of the east nave wall of the church, just to the west of the paved walk, southeast of the granary, and just east of the concrete block foundations that mark the apparent foundations of an earlier Jesuit church. The architectonic quality of these stained spots seems to indicate some direct relationship to subsurface architectural remains. The one area that extends parallel to



SOIL MOISTURE MAP

⊙2 location of borings

surface stains

ILLUSTRATION 22.

the church is near the foundations of the original convento arcade. Also, the dark spot just south of the Jesuit church foundation formed a perfect right angle being approximately 2 feet wide, the normal single wall thickness. However, when compared with an archeological map of this same area, this particular feature was not indicated.

These dark spots contain a much higher salt content than the surrounding soil, and it seems possible that the spots themselves were the results of salt being leached out of subsurface architectural features and migrating to the surface of the ground. There existed, however, a relationship between portions of buildings affected by capillary moisture, the abnormal subsurface condition southwest and east of the church, and these dark stained areas. A relationship that did not exist in other areas of abundant subsurface remains. Consequently, while the stained areas probably did relate to subsurface features, an abnormal amount of subsurface moisture affected them, causing them to show up in this area. In addition, this same abnormal subsurface moisture condition probably contributed to the capillary moisture of the building aboveground.

Several professionals with landform backgrounds were consulted regarding the possibility that an ancient drainage system had been located diagonally across the monument grounds. They acknowledged the possibility given the general drainage conditions in this part of the Santa Cruz River Valley (Winkler pers. com. 1976).

Evidence that the church complex is in a natural drainage area is supported by historic period as well as 20th century evidence. The extensions to the lower part of the walls along the west side of the church and campo santo walls were not part of the original construction but rather a historic response to a basal erosion problem. Since this historic period addition occurs only on the upstream side of the structures, the basal erosion that resulted in the addition was probably caused by floodwater. Photographs taken ca. 1940 show an extensive amount of flood debris deposited along the west boundary wall--additional evidence that this area is part of a natural drainage system.

At the present time, there is no concern for flood damage because adequate drainage was provided during the highway work in the 1960s. However, there is little doubt that Tumacacori National Monument is in an area in which a subsurface capillary moisture source could be continually recharged by rain falling in the drainage area.

Another possible explanation of the capillary moisture source is that the material of higher moisture content in bore holes 4, 6, and 7 also contained a significantly greater amount of salt than material in the other borings. These salts could have acted hygroscopically, attracting moisture during periods of rainfall and holding it.

The capillary moisture in the church was greatly influenced by the coatings and veneers attached to the exterior and interior walls. The removal of these relatively impervious membranes relegated the capillary problem to one of minor importance which is being handled by routine maintenance.

WALL MOISTURE CONDITIONS

The determination of the location and extent of significant amounts of moisture in the walls was recognized as one of the primary questions early in the preservation project. Early work by Daniel Evans of the University of Arizona indicated some areas of extremely high contents, but no systematic monitoring of wall moisture conditions had ever been undertaken (Evans 1972).

Most of the stabilization projects undertaken in the past at Tumacacori were direct responses to obvious moisture problems. As later information began to indicate, the action that resulted in the most deleterious effects was the continued covering of the exterior and some of the interior walls with relatively impervious coatings and veneers. Frank Pinkley began this type of action in the 1920s and continued it periodically until 1973 when soil cement adobes were used as replacements for some eroded adobes along various portions of the east and west nave walls.

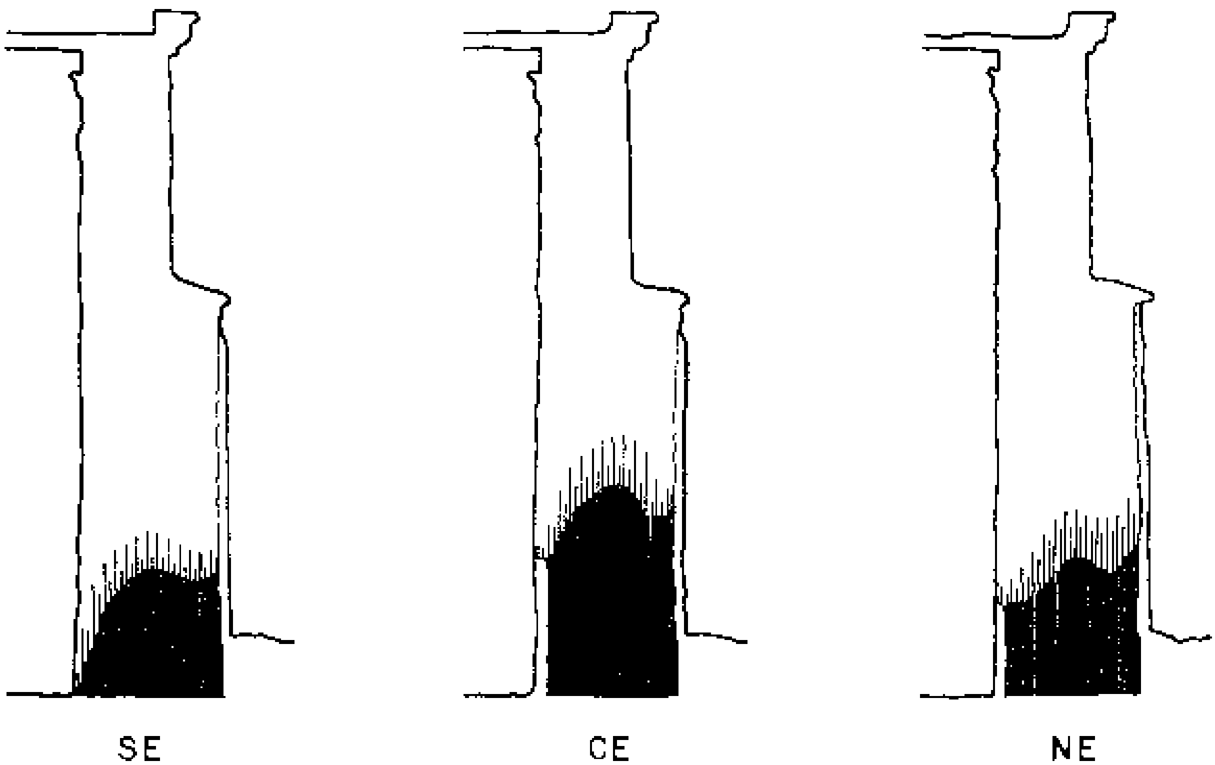
From the outset it was essential to determine the distribution of moisture in the walls, and it was hoped that these conditions could be determined nondestructively by the use of microwave, ultrasonic, infrared, and electrical or thermal conductivity techniques. However, after investigating the actual use of these techniques, none of them seemed capable of providing the type of detailed information necessary at Tumacacori. Consequently, it was decided to gather this critical information by drilling holes in the walls and taking material samples to determine the actual moisture content.

Material Sampling

A pattern of sampling holes was located in such a way as to provide the most comprehensive information possible. There were some limitations in order to avoid certain architectural and decorative features on the interior walls of the church, but generally the locations related to a general coverage of the height, length, and thickness of the walls and to areas of known or suspected problems. The actual locations of the holes can be seen on the plan and the interior elevations of both the east and west nave walls (illustrations 23 and 24). The holes were drilled approximately halfway through the walls on one side with matching holes drilled from the other side. In addition, a lower hole was drilled at each location on the interior, but because of the difference between the interior and exterior grades, a matching exterior hole was not drilled. Also, additional holes were drilled in the exterior of the west nave walls as unsuspected conditions were encountered.

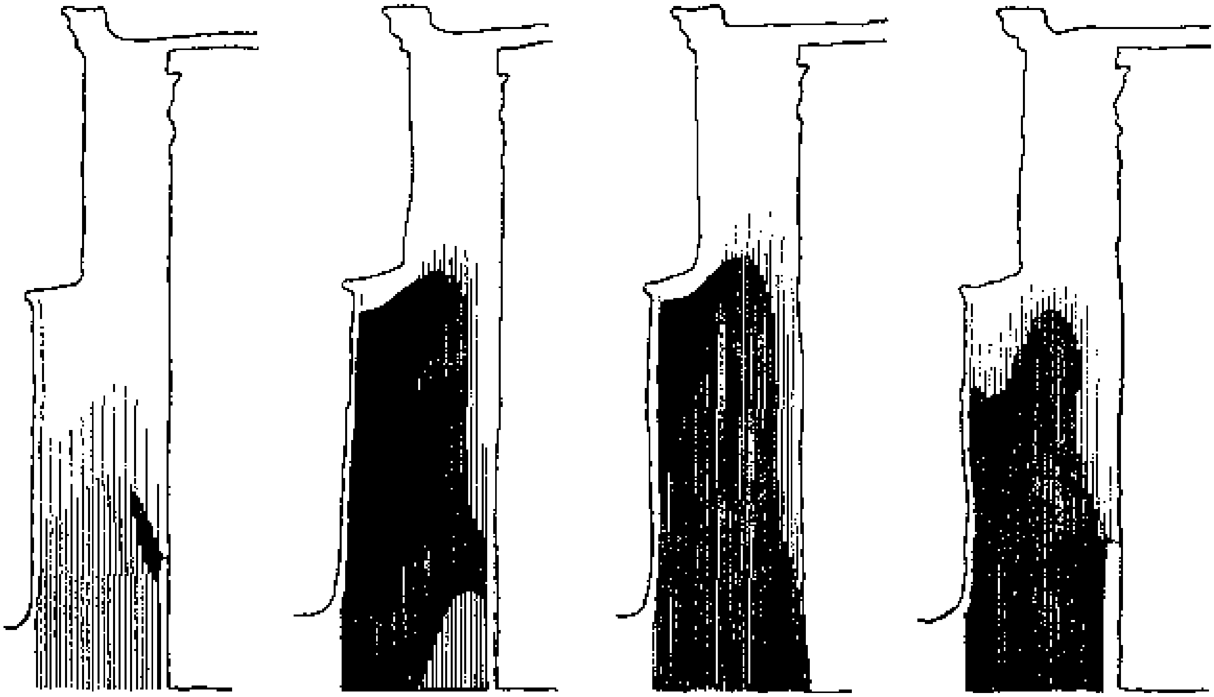
Samples were taken at the wall surface where possible, at approximately 1-foot, 2-foot, and 3-foot depths. If the wall midpoint or 3-foot sample was taken from one side, it was normally not taken from the other.

Profiles based on the actual moisture contents of the seven different locations are shown in illustrations 25 and 26. The profiles at locations SE, CE, and NE are classic capillary moisture profiles with little abnormal moisture occurring higher than 4 feet above the exterior grade.



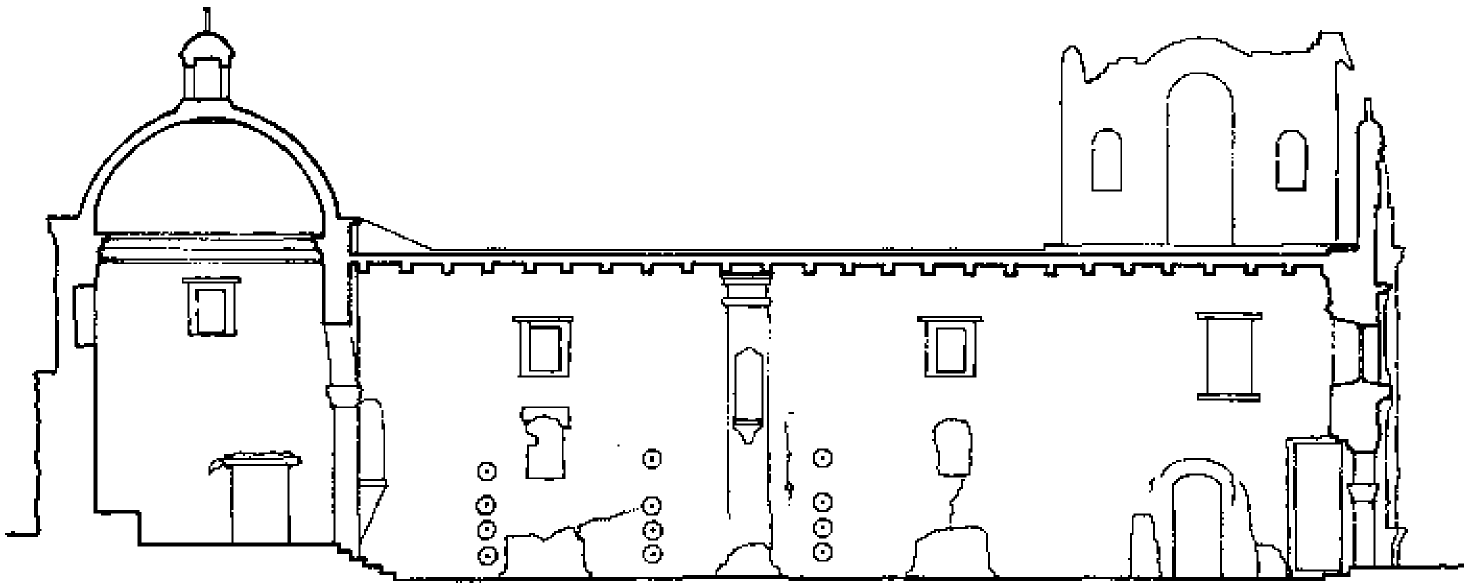
MOISTURE PROFILES: EAST NAVE WALL
Based on samples taken 1976.
% Moisture ☐ 0-3 ▥ 3-6 ▥ 6-8 ▥ 8-11 ■ 11+

ILLUSTRATION 23.



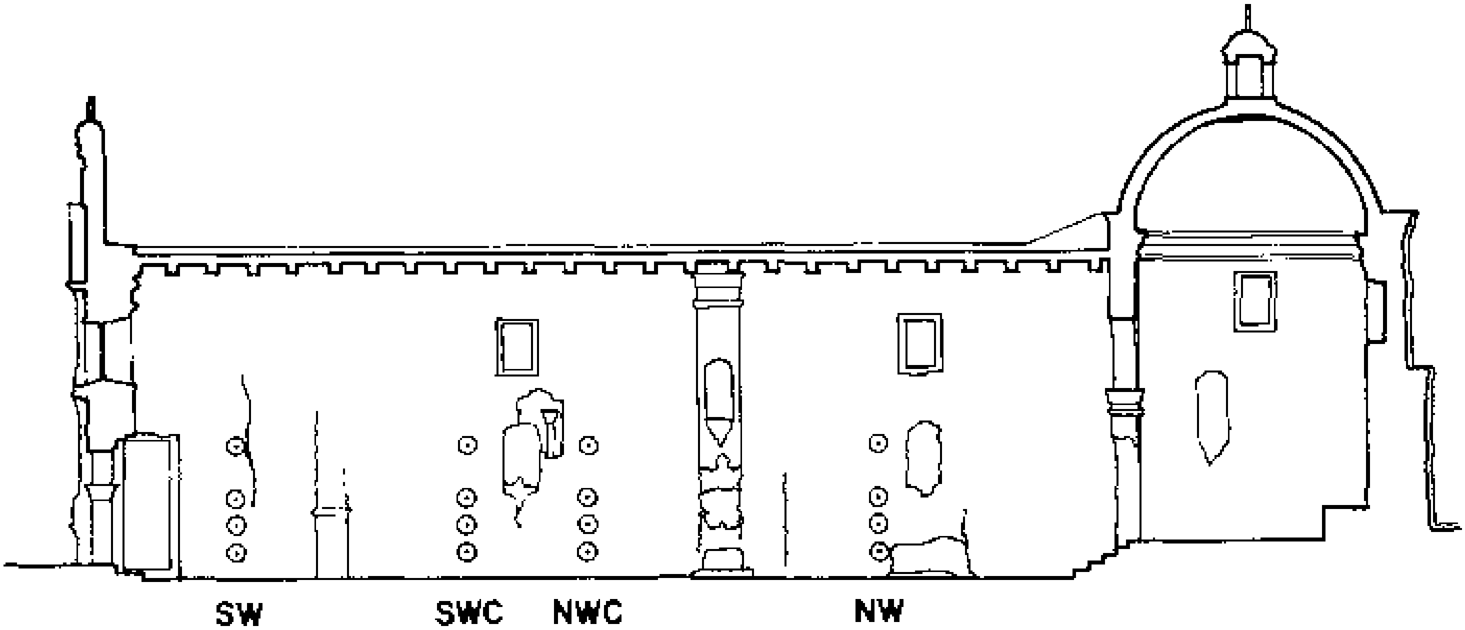
MOISTURE PROFILES: WEST NAVE WALL
Based on samples taken 1976.
% Moisture □ 0-3 ▥ 3-6 ▥ 6-8 ▩ 8-11 ■ 11+

ILLUSTRATION 24



EAST NAVE WALL SAMPLING LOCATIONS

ILLUSTRATION 25.



WEST NAVE WALL SAMPLING LOCATIONS

ILLUSTRATION 26.

The two south locations on the east wall, SE and CE, had maximum moisture contents in holes 1 and 2 in the 11 percent to 13 percent range with the sample at CE located at midwall, approximately 2 feet above the foundation, having the greatest amount, 16.7 percent by weight. Hole 3 in both the NE and SE locations were consistently in the 2 to 3 percent range, with hole 4 at these two locations having even less moisture. Hole 3 at the CE location contained material samples in the 7.5 to 10 percent range, undoubtedly a situation influenced greatly by the relatively impervious soil cement membrane located in this area.

Samples from the north location, NE, were generally much drier than either of the other two locations, which seems to indicate that a much greater amount of capillary moisture was affecting the CE and SE locations than the NE location.

The profiles through the west nave walls reflect a significantly different situation than the typical capillary profiles of the east wall. In the west wall the highest moisture content sometimes occurred as much as 12 feet above grade indicating a source other than subsurface. It seems obvious that either the ledge was leaking at the time of the sampling, allowing water to percolate down through the walls, or the ledge had leaked in the past and water simply could not evaporate.

Results of the sampling seemed to indicate a concentration of wall moisture below the scuppers located on the ledge in association with each canal. In the highest sampling location at hole NWCX, there was an obvious difference in the moisture content at approximately 2 feet into the wall. The exterior part of the sample contained 17.5 percent moisture, and the interior part contained 12.2 percent moisture. This sample was located along a vertical plane extending down from the exterior surface of the upper portion of the wall. This seemed to lend credibility to the supposition that the moisture entered the lower wall at the juncture of the upper wall, and the ledge and percolated straight down through the wall.

The material samples, with two exceptions, were taken at locations near the canales. One of the two exceptions was taken at a point midway between locations NWC and SWC, 8 feet above the exterior grade and contained 2 percent moisture. The other exception was a sample taken between locations SWC and SW at the same elevation, and it contained 8.7 percent moisture. This latter sample seemed to indicate that a significant amount of moisture had entered the wall between the canales in at least one place.

When the large amounts of moisture were encountered relatively high in the walls, additional holes were drilled still higher. At locations SW, SWC, and NWC, holes were drilled 2 feet above hole 4, called 5, and 1 foot above hole 5, called 6. In addition, another hole, called 7, was drilled above the ledge at the NWC location. This highest hole contained material with a moisture content of 5.7 percent, certainly higher than normal, but the source for what was probably capillary moisture is probably the large amount located below the ledge at this point.

The ledge at this canal was removed in August 1977 in an attempt to further define the moisture condition and to determine whether or not the ledge was still leaking. There was a small hairline crack in the scupper itself, which was probably allowing some moisture penetration. The amount was probably not enough to significantly wet a totally dry material, but was probably enough to keep the previously wet area wet. Another section of the ledge was removed a few feet south of the scupper, and the adobe material immediately below the cap was significantly dryer than the material at the scupper. This entire ledge was rebuilt during the project, and a lateral drain was removed.

The profiles also show the effect of the impervious membranes on the wall moisture conditions. In most cases the highest moisture content was located immediately behind the cement stucco or soil cement veneers. This was caused by moisture moving through the wall and condensing at the surface of the more impervious barrier. Because of the restriction on normal evaporative processes, the adobe material will remain at higher contents and will rise higher in the wall, adversely affecting some of the building material that otherwise would not be affected. The most obvious example of this is the adobe material located above the large soil cement patch along the east side of the nave wall. The material above the patch was sound until the patch forced the wall moisture higher before it could move to the surface to evaporate. The subsequent removal of this impervious patch has positively affected the wall moisture content.

The significance of the high moisture contents is apparent when compared with some preliminary data developed by the National Bureau of Standards for the National Park Service. This data indicated that adobes mixed to appropriate proportion as some of the Tumacacori adobes yielded compressive strengths near 25 pounds per square inch (psi) at moisture contents of approximately 20 to 25 percent (Clifton, pers. com. 1977). This data can only be taken generally because it is based on recently made adobes and not actual adobes from Tumacacori. However, since the actual loading on the base of the nave walls at Tumacacori is between 20 and 25 psi, it was at least possible structural failure could occur if the entire thickness of a wall was greater than what appears to be a critical moisture content of approximately 20 percent. Of course, a much more likely situation would have been that sloughing or sliding of a portion of a wall would occur when subjected to the critical moisture contents.

The moisture in the east nave wall of the church appeared to result exclusively from capillary action. The capillary influence in the west wall was minimal and not to an extent that is of more than a maintenance concern.

An obvious difference could be noticed by visually inspecting the exposed surfaces by the east and west nave walls. The entire lower portion of the interior of the east nave wall between the bell tower and the sacristy wall suffered from the movement of moisture up through the walls, evaporating approximately 2 feet above the interior floor. The evaporating moisture redeposited soluble salts in the area causing some damage as the salt crystals expanded during recrystallization. However, just as important as the growth of salt crystals was the deleterious effect of wetting-drying cycles on the surface material.

As mentioned previously, the evidence of capillary moisture along the west interior surface was somewhat inconsistent. Capillary moisture was definitely affecting the south end of this west wall and perhaps just south of the pilaster. The extensive patching with the soil cement adobes on this wall which was removed in 1979 obscured the actual effects, but there were several unpatched areas that showed no evidence of being affected by capillary moisture. Also, some portions of the adobe wall above the patched areas showed no evidence of capillary moisture as did the east wall.

The determination of the actual wall moisture contents was extremely valuable, but the actual information somewhat limited since it represented moisture contents at only one particular point in time. Consequently, it was necessary to secure data on possible changing conditions throughout the year.

Continual Wall Moisture Monitoring

After the holes were drilled in the walls of the church and material samples were taken and evaluated, moisture sensors were placed in some of the holes before they were sealed. It was hoped that the sensors would provide some information on the moisture conditions which, when compared to changes in the microenvironment, could determine the specific cause-effect relationship necessary to provide a satisfactory solution.

The sensors chosen were a simple resistivity type. Two metal surfaces are insulated by a material that absorbs moisture from surrounding material. A reading meter sends an electrical current between the plates through the insulating material and measures the electrical resistance encountered. The wetter the insulating material the less resistance recorded. Conversely, the dryer the material the more resistance recorded, resulting in a higher reading. The actual moisture contents are not determined, but rather a relative change is indicated when various readings from the same sensor are compared. In this case, the relative moisture change was sufficient.

The manufacturer of the sensor indicated that it is possible to calculate a relation between resistance and actual moisture content for any type of soil. However, the accuracy is probably poor at the relatively low moisture contents of approximately 10 percent which could be significant in adobe. The actual moisture content was not calculated because of the difficulty of placing the sensors in the wall and packing them with similar soil at the same density as the adobe.

Initially, some of the sensors indicated portions of the walls were slowly drying, but several sensors seemed to change with some relationship to rainfall. For example, sensors SWI-1C, SWI-2C, and SWX-4C all increased in relative moisture content with rains over a three-and-one-half month period in 1978. Sensor SWX-4C showed a trend toward an increasing relative moisture content from late spring through October 1977 before establishing a decreasing trend until January 1978 when it appeared to increase again. SWI-2C showed little change since August 1977 until a very slow decrease in apparent moisture content in late October 1977. The decrease continued until January 1978 when another increase began.

The close association of sensor SWI-3C to the others mentioned above make its somewhat drastic behavior even more interesting. Readings taken in late April and mid-May showed a drastic decrease in resistance or apparent increase in relative moisture. After a leveling trend, an apparent moisture increase took place until mid-October when the material began a drying trend that continued until March. The increase in mid-July does relate to the summer rains, but the decrease began in mid-October, the wettest month in 1977. Although it is possible that these changes reflect an erratic behavior in the functioning of the moisture sensor, the changes are most likely linked to some other influencing change in the microenvironment.

A change on the interior surface at the extreme south of the west nave wall was also observed during 1976 and 1977. The original adobe material immediately above the soil cement patch became more stained, indicating an increase in moisture. The increased moisture above the soil cement adobes was observed before the obvious leaking of the roof took place. There might have been some influence from water penetrating down at the exterior juncture of the ledge and upper wall, but the primary damage was apparently from capillary moisture.

Surface Moisture Monitoring

In addition to monitoring moisture conditions within the church walls, a monthly monitoring of surface moisture conditions began in the fall of 1976 and continued until the summer of 1982. A small conductivity meter was used on the interior surface of the east nave wall. Other walls were checked periodically but not as often or as comprehensively as the east nave wall.

There appears to be a direct relationship between the surface moisture on the adobe walls and the ambient relative humidity. Experiments conducted during the summer and fall of 1976 indicated an increase in the moisture content of the stained material along the east nave wall for a period of time as the relative humidity increased. However, a direct relationship ceased after a period of time, probably because of the greater influence of capillary moisture. At that time this surface material occasionally contained as much as 10 percent moisture by weight. After being placed in a humidity cabinet for 24 hours at approximately 80 percent relative humidity, this same material contained 25 percent moisture by weight.

Laboratory analysis of this same material at the National Bureau of Standards showed a weight increase of 59 percent at a much lower relative humidity. The significantly lower moisture percentage in the in situ samples was expected since this material is subject to the drying effects of air movement.

The large increase in moisture in this material is directly related to the high concentrations of soluble salts present. The actual percentage of soluble salts has been determined to be as high as 8.78 percent by weight.

The one critical question, of course, was whether an ambient high relative humidity can contribute to moisture conditions to a significant depth in the wall. Moisture can gain access to a material from the surrounding air by two closely related but different methods. The ambient moisture can condense on the surface of the wall and move horizontally into the wall by capillary action, or it can move through the wall as water vapor. In the case of the adobe material at Tumacacori, condensation does not occur at the surface of the material except in those areas of extremely high salt concentrations. The lack of surface condensation was confirmed by an insufficient temperature differential between the ambient moisture and the material over a wide variation of climatic conditions.

Moisture vapor continually moves through the material but is not of any importance in that form. However, the vapor can condense to a liquid form when it comes in contact with a material that cools the vapor to the dew point; when the vapor pressure is increased sufficiently as it moves into extremely small pores; or when there is a combination of the two. This liquid moisture can then move through the wall in capillaries or from the force of gravity.

Horizontal capillarity moves moisture at a much greater rate than vertical capillarity (Winkler 1975). Moisture does not move along the horizontal arbitrarily but is influenced by the relative vapor pressure on either end of the capillary, the capillary moisture source, and the temperature gradient. When the source no longer exists, the amount of moisture at the waterfront necessary for the capillary action to continue decreases and the movement into the material stops. At this time the moisture begins to move back to the surface of the material as the vapor pressure is less in the surrounding air. If the other two influences are the same, the moisture will move toward the lower temperature.

It has been suggested that the large amount of gypsum found in the Tumacacori adobes comes from the thin gypsum wash that was applied over the lime plaster during the original construction. The gypsum from the wash would have been carried from the surface by water into the wall fabric, indicating that significant amounts of moisture would travel from the exterior to the interior of the wall. Since the gypsum could have been carried only by water and not water vapor, moisture would have had to condense on the surface of the plaster itself, at the very least, a rare occurrence. Also, the relative insolubility of gypsum would seem to negate the transfer of any significant amount into the wall. A third reason for the unlikelihood of the gypsum in the wall coming from the surface is the many small voids that exist at the interface of the adobe wall and the lime plaster. The interface between these two materials would have prevented reasonable access of the dissolved salt into the adobe. The interface is most likely not a recent occurrence but has probably existed since soon after application of the plaster.

There is little doubt that ambient moisture does influence the amount of moisture in the adobes near the surface. Under laboratory conditions small cubes of adobe material have shown a marked increase in total moisture content and a significant loss in strength when subjected to high ambient relative humidity (Clifton, pers. com. 1977). However, in field conditions, changes in the microenvironment that influence the potential travel of moisture into material occur rapidly, resulting in conditions not conducive to ambient moisture traveling into the wall and significantly affecting the overall interior wall conditions. Conclusive evidence of this fact appears in the wall moisture profiles where interior wall moisture conditions not obviously affected by subsurface capillary moisture or rainwater from a leaking ledge were never above 3 percent, an insignificant amount.

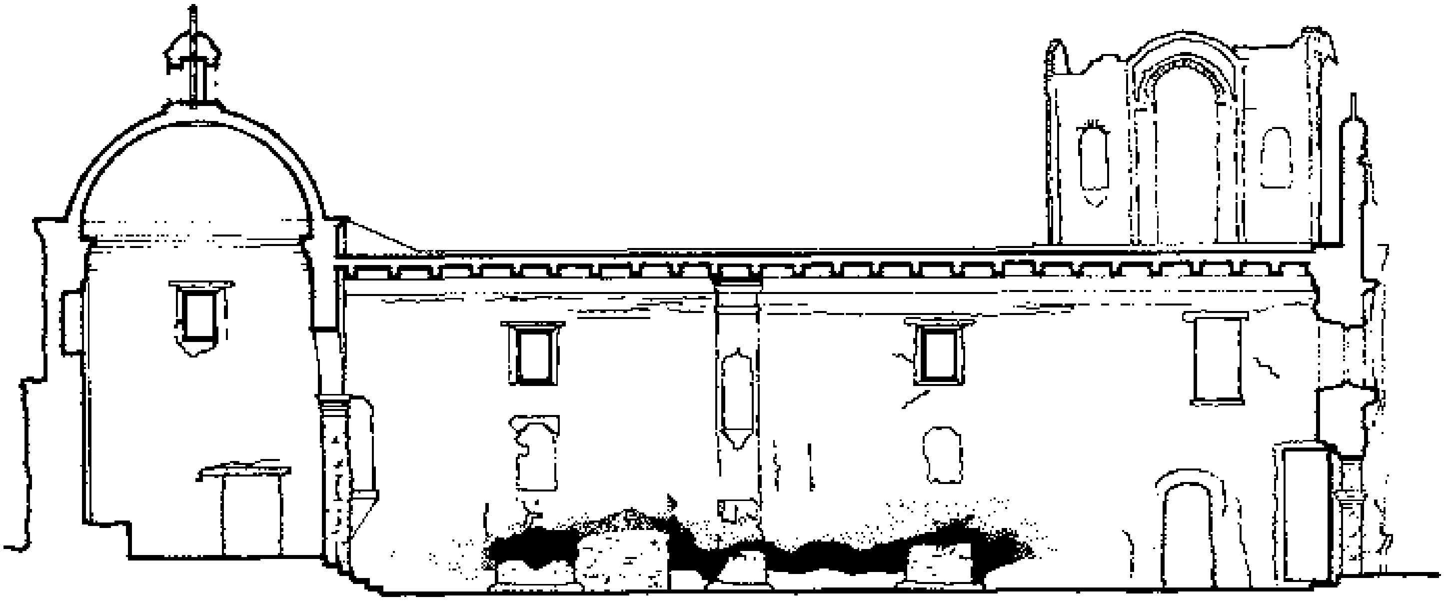
The surface monitoring technique was based on a procedure developed and reported by Brown Morton, Chief of Technical Services in the Office of Archeology and Historic Preservation (NPS 1976). The primary difference in the procedure used at Tumacacori is related to the more inconsistent material normal in adobes. For example, an adobe with a higher salt concentration could give a higher reading even though the actual moisture content was lower. The procedure consisted of taking readings on a small grid that averaged approximately one reading per square foot.

The comparison of different readings was primarily important when comparing the same spot over a period of time rather than comparing, in any significant detail, one area with another at the same time. Illustration 27-30 show the results of the mapping of the east nave wall during both wet and dry periods in 1976 and 1977. The various shadings are related to readings on the conductivity meter, but the readings themselves are only relative numbers and do not indicate any specific moisture content.

Readings taken in February 1977 (illustration 28) indicate that the surface moisture was greater, much higher on the wall than it was in December 1976 (illustration 27). This change was not unexpected because the rainfall in January added to the capillary moisture source, causing more moisture to rise into the structure.

A surface survey conducted in April 1977 (illustration 29) indicated a relative decrease in surface moisture which, again, probably related directly to the absence of significant rainfall during the period since January. However, a survey conducted on May 14 of that same year showed an apparent increase in surface moisture although there had been no rainfall at all for six weeks (illustration 30). This increase did not relate to any known cause in the cause-effect relationship except an increase in the relative humidity from May 4 to May 10. It is highly unlikely that the increase in ambient moisture would have a continuing effect on the actual surface moisture content several days later.

The only data that related in any way to this apparent surface increase is the relative increase observed during this same period in moisture sensors SEX-2C, SWI-3C, SWCX-6C, SWX-4C, NEI-1C, CEI-2B, and CEI-1C. All

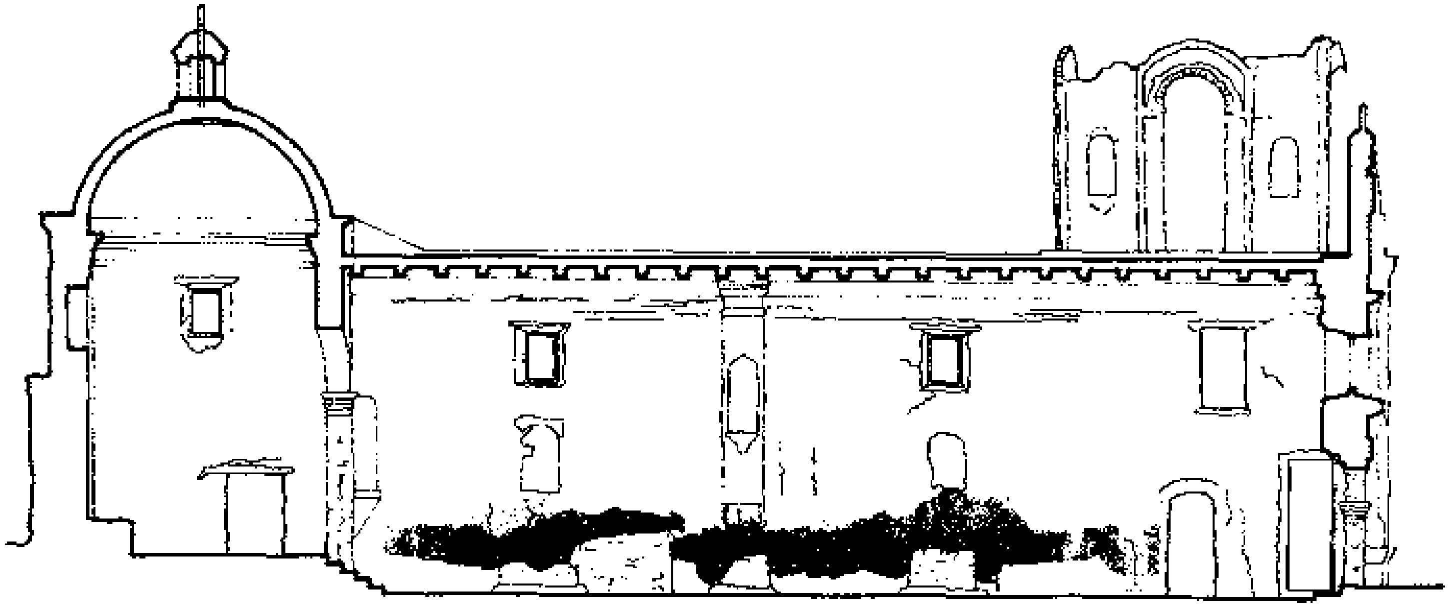


SURFACE MOISTURE SURVEY: EAST NAVE WALL

Dec. 1, 1976 reading ☐ 0-30 ☐ 30-60 ■ 60-85 ■ 85-100

Readings taken with Protimeter Mini.

ILLUSTRATION 27.

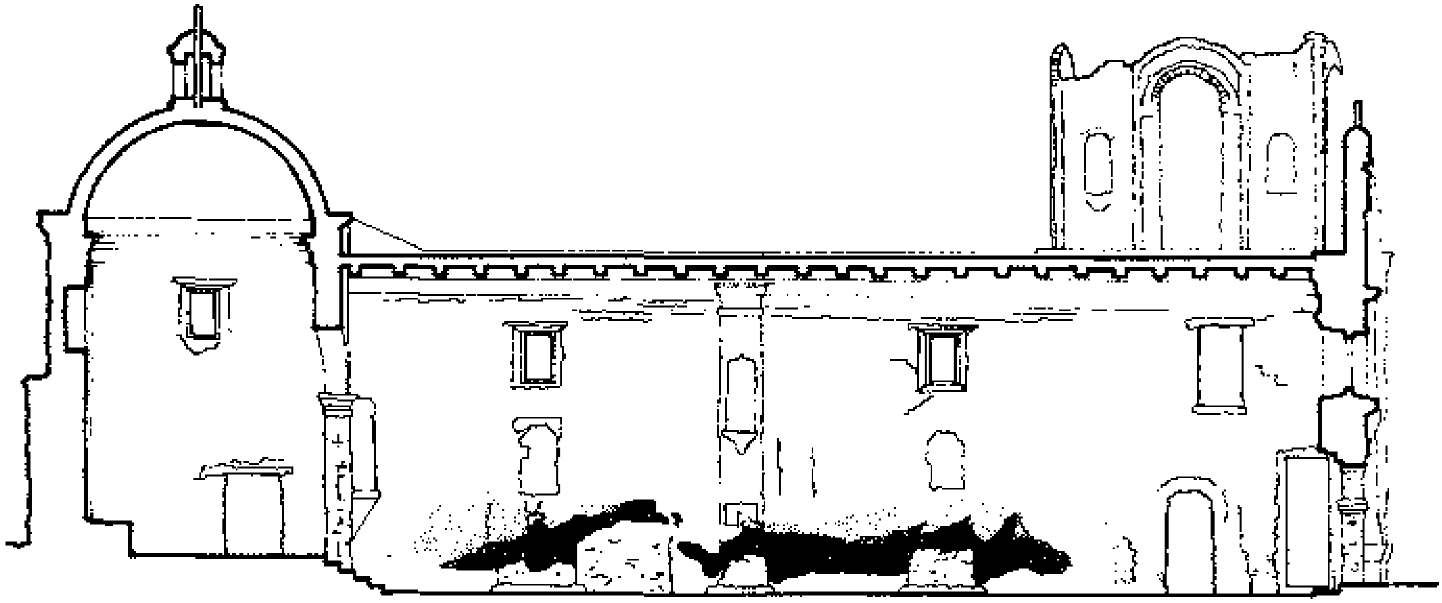


SURFACE MOISTURE SURVEY: EAST NAVE WALL

Feb. 11, 1977 reading ☐ 0-30 ☐ 30-60 ▩ 60-85 ■ 85-100

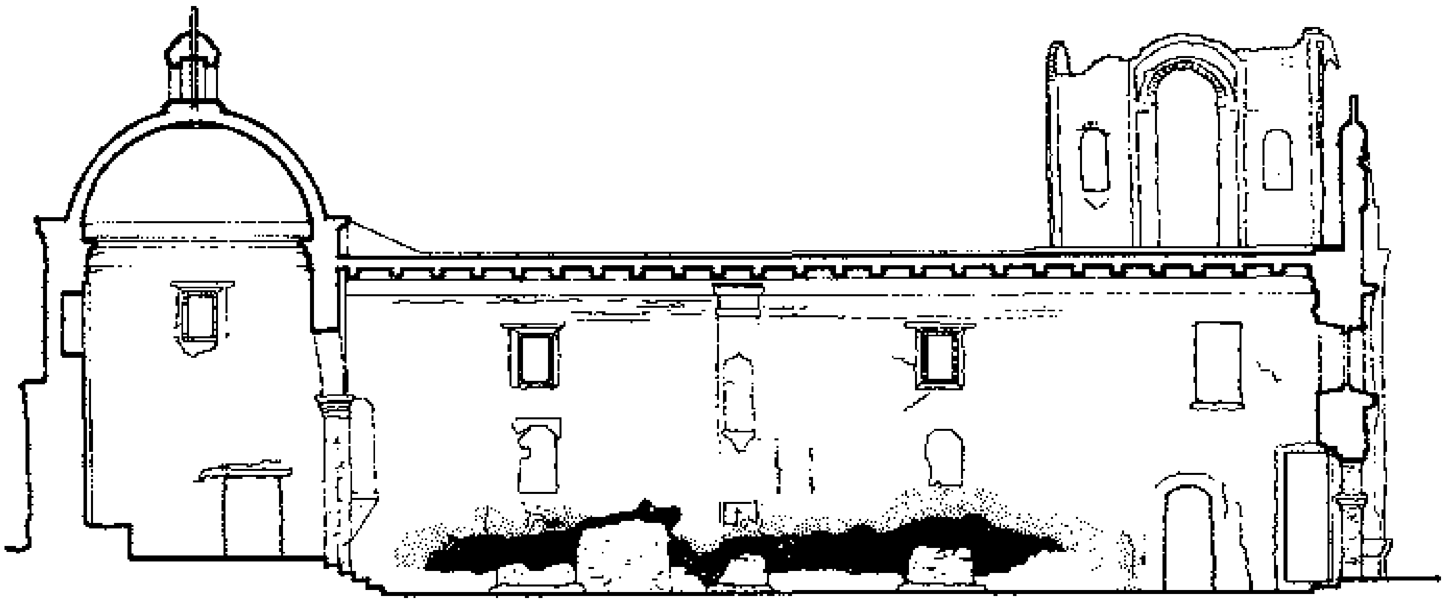
Readings taken with Protimeter Mini.

ILLUSTRATION 28.



SURFACE MOISTURE SURVEY: EAST NAVE WALL
April 1977 reading ☐ 0-30 ☐ 30-60 ▩ 60-85 ■ 85-100
Readings taken with Protimeter Mini.

ILLUSTRATION 29



SURFACE MOISTURE SURVEY: EAST NAVE WALL
May 14, 1977 reading □ 0-30 30-60 60-85 85-100
Readings taken with Protimeter Mini.

ILLUSTRATION 30.

but one of these sensors, SWCX-6C, were in areas known or suspected of being influenced by capillary moisture. However, there were three sensors, NEX-2D, SWI-1C, SWI-2C, in areas of suspected capillary moisture that showed no corresponding increases. Normally, although there was some minor variation, the sensors placed in likely capillary moisture areas indicated an apparent increase in relative moisture during periods of concentrated rains.

This higher surface moisture condition coupled with the apparent moisture increase in some of the sensors seemed to indicate a capillary moisture source supplied by moisture actually moving into the area from the west or upstream from the site. The actual source of this additional moisture was not determined, but with the extensive work on Interstate 19 just west of the site, an abnormal situation was certainly possible.

EFFECTS OF MOISTURE

The most dramatic effect of moisture on an adobe structure is the collapse of the structure when the moisture content reaches an extreme level. The result is sudden and obvious. However, this is a relatively rare occurrence unless the building is simply not maintained at all. Even then, the wall will normally collapse in a section weakened by a much slower deleterious action. The causes of this slower action were the primary concern at Tumacacori.

The weathering of adobe brought on by internal moisture is complex and difficult to analyze (Winkler 1975, 134). Generally, the disruptive action is a result of one or a combination of the following: (1) the expansive action of soluble salts under hydration or dehydration conditions, (2) the expansive action of the moisture as it is heated, (3) the differential thermal expansion of the salt crystals, and (4) the wet-dry cycles, although this is not a separate phenomenon but is probably based on several of the previous actions.

Pressure is exerted by the salts on surrounding material by both hydration and dehydration, but apparently the hydration pressures are much greater. For example, hydration pressure of gypsum (CaSo4.2H2O) at 25°C. and 70 percent relative humidity is approximately 1,000 atmospheres or 14,000 psi (Winkler 1975, 123-34).

Expanding moisture when heated from 0° to 60°C. may develop pressures in pores as great as 7,500 psi. A temperature increase of 60°C. on the adobe material at Tumacacori will not occur, but exterior plaster surface increases in the range of 20° to 30°C. are not uncommon. Based on the extremely low tensile strength of adobe, which is normally less than 100 psi, even this relatively small increase could have disruptive effects (Eyre 1935, 17). However, this action would not occur significantly in an open pore situation. In that case the water would simply move from one pore to another and eventually to the surface where it would evaporate. It is possible for the movement of ordinary moisture to be impeded by ordered water because of its higher density and electrostatic attraction to the material-water interface (Winkler 1975, 116 and 108). In this situation the expansive pressures could affect the material.

The expanding water will probably only have an effect on exterior surfaces and then only under certain conditions. The surfaces not exposed to the heating effects of the sun will probably not increase sufficiently in the relatively short time the material is subject to this action. Consequently, the amount of weathering on the interior surfaces of the roofed church is probably minimal.

The differential thermal expansion of salts present in the material probably does have some disruptive effects, but it is apparently not as important as others (Winkler 1975, 134). Consequently, the actual effect becomes significant only in combination with other disruptive actions or after these other actions have had their effect on significantly weakening the material.

The disruptive action caused by wetting-drying cycles is the most significant of the four mentioned. The specific causes are not well understood but have long been recognized as an important factor in stone deterioration (Winkler 1975, 110). The same mechanisms are at work in adobe but probably to a much greater extent. This is especially true of adobes that have a significant amount of expansive clays as do the ones at Tumacacori. While the Tumacacori adobes have a relatively low average clay content of approximately 12 percent, the predominant clay is montmorillonite. The results of the wetting-drying action are most dramatic during drying conditions when the most significant amounts of surface material become friable and fall from the walls at the slightest touch. The actual amount of friable material varies considerably, being most significant in the areas also affected by salt crystallization and hydration, but a depth of friable material of approximately 2 to 3 centimeters is average.

It was important to understand the mechanisms of the deterioration process so that the most appropriate action could be taken. For example, increased circulation at the wall surface may have been desirable to lessen the damage caused by alternate wetting-drying cycles, but may not have been desirable in the areas of salt crystallization damage as dehydration would have increased the rate and subsequent damage caused by the expanding salt crystals.

CONCLUSION

The primary source of moisture in the church was capillary. Most of the east nave wall and two spots on the west nave wall were primarily affected. The damage has probably been occurring periodically since the building was constructed with seasonal variations being the influencing factor.

The actual source for the capillary moisture was rain falling on and around the church, soaking into the soil near the wall foundations. A supplemental source upstream, which periodically moved moisture through the area just a few feet below grade, was also a distinct probability. However, this secondary source was not thought to be significant by itself but became important when combined with the primary source.

Because of the shade provided by the bell tower, the rainwater that drained from half of the nave roof to this shaded east side was slow to evaporate. When the nave roof was rebuilt in 1980, all of the drainage was directed to the west side where it was then directed into a subsurface drain that extends along the foundation of the west nave wall. Both of these actions along with the removal of the impervious wall treatments resulted in a continued lowering of the internal moisture of the nave walls.

CHAPTER VII: PRESERVATION THROUGH MAINTENANCE

GENERAL CONSIDERATIONS

The continued maintenance of Tumacacori is addressed in detail in the "Historic Structures Preservation Guide," hereafter called HSPG (NPS 1983). Much of this chapter is taken from that document. It reflects many of the concerns, ideas, and solutions that have gone into the preservation of this important monument since 1908 when the federal government assumed responsibility for its preservation. More specifically, this maintenance guide is the end of the major preservation effort that began at Tumacacori in 1976. Many of the ideas that resulted from the intense investigation of adobe, the principal building material, by contractors outside the Park Service as well as professionals within the Park Service are incorporated into the HSPG. A great deal of hands-on experience and knowledge of the performance of adobe as a building material are incorporated to an even greater extent. In fact, Tumacacori's preservation will always depend more on a respect and knowledge of the building's materials and for the place itself than on a new technological breakthrough. That is the nature of the place and that is the nature of adobe.

Returning Tumacacori to a condition in which it could be maintained was the goal of the preservation project. This meant selecting appropriate materials that would provide protection and not contribute to another mechanism of decay. The cement stuccos used previously certainly provided some protection to the adobe from surface erosion, but contributed significantly to an increased moisture content of the material, or forced moisture to seek a different path, resulting in the decay of previously sound material. In most all cases during the preservation project, the material selected for use was similar to the material originally used.

The use of these traditional materials, unamended adobe and mud for repair of an adobe wall and unamended lime plaster for either replastering or for plaster infill, is also a rather conservative approach to preservation problems--conservative because these materials have a long history of use (consequently, we know how they will perform); conservative because they do not change the important characteristics of the original materials with which they are used; and conservative because they can easily be applied and removed without damaging what they are intended to protect. Of course, these characteristics are also the characteristics of any material that should be considered for use in a preservation project. And a general conservative approach to preservation through sound maintenance is also an idea that is reflected in the HSPG.

In the actual repair, materials are used to stabilize unstable fabric, such as adding a plaster bead to the edge of original plaster. Also, consideration is given to eliminating visual distractions by making sure that existing or new patches or replacement materials do not detract from either the original surrounding materials or from the building or group of buildings as a whole. A new plaster patch in original plaster should not stand out visually because of an inappropriate color or texture. Neither should an entire replastered wall be the whitest, brightest feature of a wall that also contains a large amount of faded and cracked original plaster.

The replacement plasters on the exterior protect the adobe substrate from water erosion, and even more importantly, do not allow excessive amounts of water to penetrate behind original plaster. This action could increase the chances that original plaster keys could be eroded away, or increased pressures could result in large amounts of plaster simply falling from the walls. This protection can be provided by patches and replacement materials that do not detract visually.

The HSPG was organized to fulfill the need for periodic, systematic inspections and to provide directions for the actual maintenance or repair when it becomes necessary. Its basic components include the inspection forms, two summary forms, and the specifications.

The HSPG calls for labeled, expandable folders for each building. These folders will contain all inspection forms, summaries, drawings, photographs, and other materials that may be related to the actual maintenance of the specific building or structure. The original forms and drawings on clear film are located elsewhere in a permanent file for added protection. Periodically a supply of copies can be made from the originals as they are needed.

COMPONENTS OF A MAINTENANCE PROGRAM

The Inspection

The orientation of the inspection is toward the logical way the building would be viewed. The inspection forms are oriented toward a part of a building rather than a particular problem or area of concern that may occur throughout a building. Rather than making a list of inquiries about a specific problem (e.g., original plaster), the inquiries on a particular form pertain to what can be seen from one particular place--beside, on top of, or inside a building--and includes all materials, items, and potential problems. One advantage of this approach is that it requires less time to conduct the inspection because it will not be necessary to continue walking around a structure and recording all examples of a specific problem prior to going on the problem. However, the most important advantage is that a problem is seen in context with other materials and problems that may be related (see accompanying inspection form).

Some buildings are broken down in much greater detail than others. There are approximately 30 separate inspection forms for the church exterior alone, but only one inspection form for the entire lime kiln. However, the lime kiln is small enough to be observed in its entirety from one basic vantage point.

INSPECTION FORM

HISTORIC STRUCTURE PRESERVATION GUIDE
TUMACACORI NATIONAL MONUMENT

Building name CHURCH EXTERIOR, SOUTH FRONT

Building number ____________

Page 1 of 4

Weather Conditions: rain ____ clear ____ overcast ____

Approx. Temp. ________ Wind Cond. ____________

Check ☐ to left of headings if inspected

Inspector ____________ date ____

Supervisor ____________ date ____

Time of Inspection ____ am ____ pm

Scheduled inspection ____ Nonscheduled ____

> = greater than; < = less than

condition good; does not need attention	needs immediate attention	needs attention at time of normal maintenance	requires continual observation	spec. section and page	
				Sec. 1 p.167	ORIGINAL PLASTER
				p.181	ORIGINAL PAINTED PLASTER (INTRADOS OF ENTRANCE ARCH)

ORIGINAL PLASTER

Cracks: Hairline____. >1/16"____. Spalling at crack____. Appears active____.
Edges: Separating from adobe____. Beads missing____.
Holes: Small (<1")____. Large (>1")____. Insects____. Into adobe____.
Deterioration: Delaminated, from base plaster____ and from adobe____. Missing____.
Soft, powdery____. Appears damp____.
Surface: Color/texture of patches is not appropriate____.
Other:

ORIGINAL PAINTED PLASTER (INTRADOS OF ENTRANCE ARCH)

Edges: Separating from adobe____. Edge beads intact____. Spalling at juncture of edges and original plaster____.
Holes: Filled holes intact____. Separation between original and fill materials____.
Insects____.
Deterioration: Delaminated from adobe____. Soft, powdery____. Additional surface graffiti____.
Other:

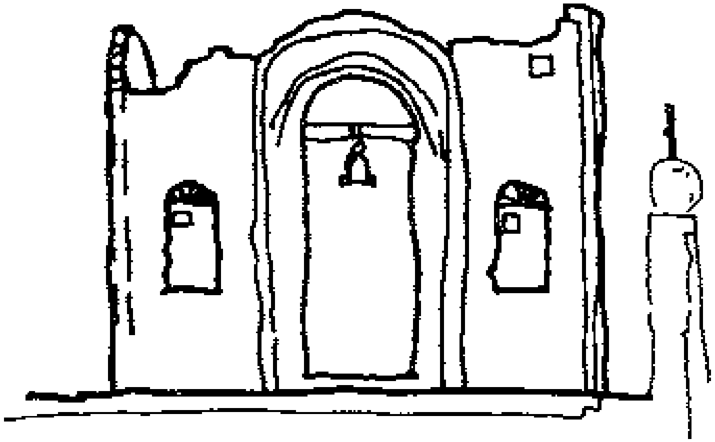
Inspector's comments

Supervisor's comments

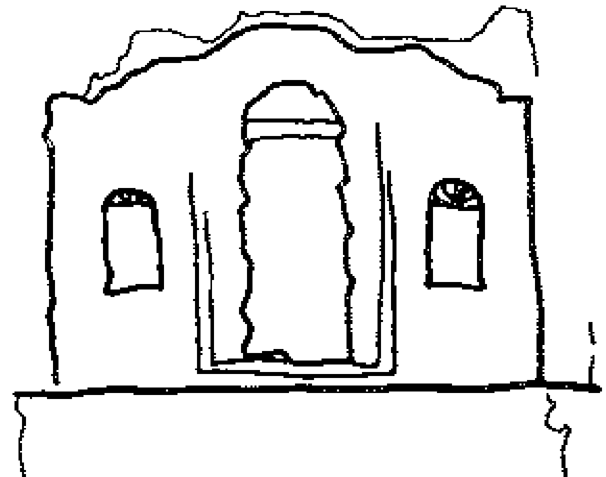
While the inspection forms are seen as the single most important part of the HSPG, in themselves they do not specify the exact material that should be used nor do they specify the technique by which the repairs are to be made. But as long as deficiencies are pointed out and recorded and sound conservative conservation approaches are followed, an appropriate material and technique could be found by the maintenance staff.

The inspection forms are not only oriented toward certain known or potential problems but also suggest solutions to those problems simply by asking the questions. The inquiries, or items of what to look for, are directed only to problem areas and do not ask for information not related to these problems. For example, the form does not ask if a plaster bead is good, but rather if it is bad. Likewise, it does not ask if the color and texture of a plaster patch in some original plaster are good, but rather if the color and texture are inappropriate. In most all cases, if a check appears on a completed inspection form, then there is a problem. If no check appears, then presumably there are no problems and nothing needs attention.

There are a limited number of inquiries that when checked do not in themselves call for corrective action. They are there to provide additional information about the condition of the building or material. For example, an inquiry related to a hole in some original plaster may ask if the hole was patched previously. It is important to know if a hole was patched previously to determine if the material and techniques used were good. Another inquiry may ask if additional graffiti is present. A check in the following blank may indicate a visitor misuse problem. If during an inspection an inquiry is checked, the problem should be located on the drawing of that portion of the building provided with the inspection form (see accompanying example of bell tower). In some cases, it will also be necessary to more accurately record conditions by photographing them and attaching the photographs to the inspection form as well. The photographer's location should be noted so that subsequent photographs can be taken from the same position.

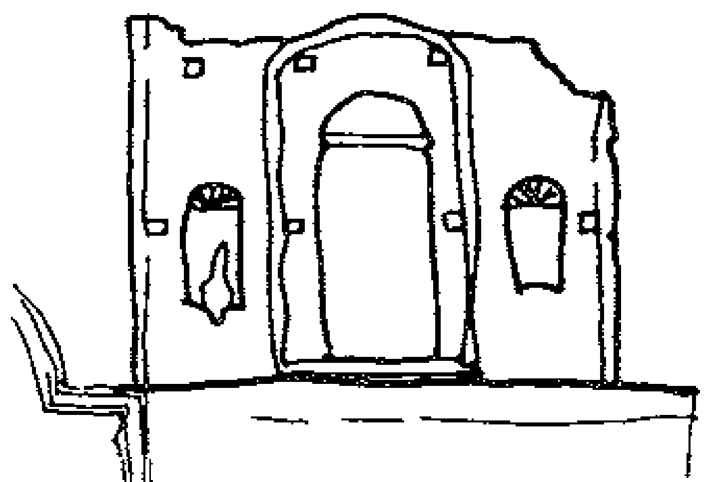


WEST ELEVATION



NORTH ELEVATION

EAST ELEVATION



SOUTH ELEVATION

BELL TOWER

It is intended that a formal inspection be conducted twice a year. During these inspections each part of every building is systematically gone through with the appropriate forms in hand. This biannual inspection does not imply that corrective actions can wait six months to be undertaken. For example, if ants are seen coming and going from a small hole in an adobe wall or plaster surface, the problem should be resolved as soon as possible.

A hairline check in some replacement plaster at the juncture with original plaster may not be an immediate problem and can simply be observed until the crack develops to the extent that excessive moisture can gain access behind the plaster. A plaster patch that is not the appropriate color or texture and stands out from the original plaster in which it has been placed should be noted and recorded on an inspection form. It represents no material preservation problem, however, and could appropriately be scheduled for corrective action at a time when all similar problems are corrected.

Because of the nature of the site, its size, the materials, and how those materials react under various conditions in the microenvironment, potential problems will more likely be spotted during the normal course of daily activities by the staff at Tumacacori. In fact, it would be unusual if a large number of problems are recorded only during a formal inspection. The inspection forms are also to be used to record problems uncovered at other times as well, in which case, a check is made in the "nonscheduled" blank on the upper right-hand portion of the form.

In this latter use of the forms, only items that require immediate attention will likely be noticed and recorded in the appropriate space. For example, if during the normal daily policing of the grounds a plaster bead used to support some original plaster is found to be missing, it should probably be replaced immediately. The absence of the plaster bead should be recorded on the inspection form and located on the appropriate drawing. The inspection form will then become the permanent record to be filed along with other inspection forms in that particular building's file.

Maintenance and Repair

Two forms are used to record the maintenance needs or tasks so that the actual maintenance can be planned and organized (see accompanying inspection summary and maintenance summary forms). The inspection summary form is used to list the maintenance activities or tasks for each building, which are taken directly from the inspection forms. For example, a thorough inspection of the corridor may indicate that the only maintenance needed is to fill several small holes in the original lime plaster. That information is entered on the inspection summary form along with the list of similar problems from other buildings. Since the data from the actual inspection forms will be listed by scanning the forms looking for checks, it will be helpful if the inspector used red pencil or ink so that his remarks and the checks can be seen more easily.

Once all the maintenance needs are summarized on the inspection summary form, the actual planning of the work can begin. At this stage the summary is oriented toward a particular building. However, actual maintenance is normally organized on a task basis. To get from a structure specific summary to a task specific summary, the maintenance summary form is used.

The maintenance summary form provides for the actual planning and organization of the maintenance through provisions for estimating material and labor requirements and actual scheduling of the work. The directions for the actual repairs, once they have been identified, are found in the specifications. The specification for a task can be located by simply using the table of contents and then turning to the section and page number indicated.

An important additional part of preventive maintenance is the housekeeping or routine tasks that are now being performed at Tumacacori. The current list prepared by the maintenance staff is included in the appendix of the HSPG. It too will change from time to time.

INSPECTION SUMMARY

HISTORIC STRUCTURE PRESERVATION GUIDE
TUMACACORI NATIONAL MONUMENT

Compiler ______________

Date ______________

Structure	Building Component or material	Task Description and Extent of problems	emergency	monitor	repair on schedule

MAINTENANCE SUMMARY

HISTORIC STRUCTURE PRESERVATION GUIDE
TUMACACORI NATIONAL MONUMENT

Compiler ____________

Date ________

Task	Location	Material Estimate	Man Hrs	Cost Estimate	Actual Cost	Comments	Date Scheduled	Date Complete

The specifications section of the HSPG is composed of two parts. Part I, the inspection guide, explains and describes the problems, the details that are important to note about them, and the general aspects of the preservation approach. Part I covers the exterior of the church because it is the most important preservation concern. However, the general concepts of the inspection guide should also be used for other buildings or building components.

Part II, the actual method and material portion of the specifications, also varies in its degree of detail. The important preservation concerns are described in great detail. However, specifications for nonhistoric materials for which normal maintenance practices are acceptable are not specified at all. For example, the repair or replacement of the built-up roof of the convento's protective shelter is common and is not covered in the guide. Likewise, the painting of the protective shelter is not specified with the exception of its color and the protection of the convento during painting.

Guide Use Summary

The most important feature of the HSPG is the inspection form, which is used to ensure that each feature of a structure is inspected twice each year for potential or existing problems and to record deficiencies noted during the course of day-to-day staff responsibilities. The inspection and maintenance summary forms are to be used to assist in the planning for future maintenance scheduling and to record the maintenance activity once it has been completed. These forms are to be kept (loose-leaf) in individual building files. When a problem has been identified, the specifications section of the HSPG will be referred to for the appropriate material and method to be used.

CHAPTER VIII: GENERAL CONCLUSIONS AND RECOMMENDATIONS

The preservation project at Tumacacori has resulted in an overall gain in the knowledge of the performance of adobe under the influence of various factors of material decay. It has also resulted in an increased knowledge of how actual decay can be measured and how, in simple terms, the material of adobe can be classified. The classification system developed for the National Park Service by the United States Department of Commerce, National Bureau of Standards, is used and often referred to by adobe preservationists all over the world. At the height of the project, a large number of research projects were underway covering such subjects as the above-mentioned adobe classification, the actual performance of adobe under various environmental conditions, the effectiveness of consolidants and surface treatments, and the analysis of a number of traditional adobe treatments. This research will continue to be of great value to others working with adobe, whether as a contemporary building material or as a material that should be preserved.

There is still much to learn, however. As an example, one important deleterious factor of adobe is wetting-drying cycles, but it is not known whether these cycles are only important in the presence of specific soluble salts, or whether the actual number of cycles or the extent of the cycles are important. The actual composition of the adobe soil with various types and amounts of clays is probably another important factor. Another example is the lack of knowledge of the actual effects of the growth of salt crystals in the interior of an adobe mass. Still another is the significance of the pressures of expanding moisture under conditions of increasing temperature.

During the project many sound decisions were made regarding the use of preservation techniques and materials, but mistakes were also made. Some of these mistakes became obvious immediately and were corrected. The initial mistakes made in the restoration work on the mortuary chapel became dramatically obvious when the restored sections collapsed during a rainstorm. In this case better preservation treatments resulted before the project was completed. Another mistake, which was not resolved, was the installation of the well points for draining the granary. They were effective for much of the first rainy season after their installation, but they have not provided adequate drainage since then. The actual practice of simply pumping water out of the granary depends entirely on the availability of the Tumacacori maintenance staff at the time the rainwater begins to accumulate.

Another unfortunate occurrence was the loss of the remains of the engaged plaster pendentive from the southwest side altar of the nave. In 1976 a temporary support was proposed prior to the development of a more permanent reattachment method. However, the support was never constructed, and no permanent method had been decided on when the plaster fell in 1981. The reattachment of delaminated or partially detached plaster remains a problem, where what this author considers to be an optimum solution has still not been developed. Today, the remains of this plaster pendentive is in storage at Tumacacori and could possibly still be restored.

In addition to the need for resolving the problem of drainage in the granary, there remains the need for completing the conservation of paint and plaster, both on the interior and the exterior of the church. The paint conservation project undertaken in 1982 did not complete the necessary work, and, while recent moisture problems have resulted in the deterioration of some of this work, there are critical areas that need to be addressed. The most important include (1) the completion of the reattachment of the remains of the painted plaster intrados of the main entrance arch and (2) the reattachment and consolidation of the original plaster and the east canal on the north exterior side of the church.

The continued preservation of all structures at Tumacacori National Monument is based on a principle of maintenance and repair. This principle has evolved during the preservation program, and it relates to the original goal of the preservation project, which was to bring the structures at Tumacacori to a level at which they could be maintained. The principle is also supported by many others as the one generally accepted adobe preservation approach on similar adobe structures and building complexes. This principle respects the essential character of the material--the characteristics of change and renewability.

Traditional preservation practices, although simply referred to as maintenance if referred to at all, were basically the same as those being used here. Although there are many advanced technical methods and materials currently being used in preservation, it is not realistically possible to apply any one of them to adobe and halt any further change. However, even if it were possible, it would be a questionable preservation technique because it would alter the adobe into a totally new material--a new material that would then have a totally different character.

APPENDIXES

A: Giffords' Report on Pendentive Removal

B: Giffords-Weaver Report

C: Spot Tests for Anionic Salts in Sanctuary

D: Experiments with Acryloid B-72 on Tumacacori Plaster

E: Recommended Treatments in the 1978 Historic Structure Report, for Tumacacori

F: Recommendations for Further Research in the 1978 Historic Structure Report for Tumacacori National Monument

G: Proposal for Completon of Paint Conservation at Tumacacori

H: Compliance Documentation

A: GIFFORDS' REPORT ON PENDENTIVE REMOVAL

INTRODUCTION

Tumacacori National Monument is 48 miles south of Tucson, Arizona. The colonial church structure, abandoned in 1848, was one of the Pimería Alta mission sites administered first by the Jesuits, and after 1767 by Franciscans from the Colegio de Santa Cruz in Queretaro, Mexico. The existing structure was begun probably around the beginning of the nineteenth century and finished around 1824, or at least as finished as it would ever be.

Tumacacori was proclaimed a national monument in 1908, and after the establishment of the National Park Service in 1916, the mission has been under this agency's protection.

Tumacacori is currently undergoing an extensive preservation program under the guidance of Tony Crosby, project coordinator. As part of this program I was contacted to examine a pendentive in the sanctuary that was peeling. There was a design on the plaster and it was obvious that unless some steps were taken to preserve it, it would be lost.

The following is a report on the subsequent research and conservation of this fresco.

REMOVAL OF THE PLASTER AND PAINTING FROM NORTHWEST PENDENTIVE OF THE SANCTUARY OF THE CHURCH AT TUMACACORI NATIONAL MONUMENT

The church at Tumacacori had recently been experiencing movement of water. There was ground water coming up from the boulder foundations into the walls of the nave and moisture trapped between the adobe walls and dome in the sanctuary area. Reasons for the build up of humidity in the dome may in part be related to the cement covering over the dome added in recent years, the traveling ground water in the walls is not of concern in this report, but merely mentioned as another aspect of the conservation attempt on the structure. It is not related to the pendentive's problem.

In April 1976, it was discovered that in the northwest pendentive of the sanctuary plaster was beginning to peel off the wall. At that time Mr. Walter Nickowitz of the National Park Service Center for Conservation, Harpers Ferry, Virginia, examined the area and attempted several different types of reattachment of the plaster film. He attempted to apply hot wax, but the wax cooled too quickly, and anyway was unacceptable because of the color change it created. He then used a solution of Rhoplex AC 234 dissolved in Acetone. He reattached several of the loose pieces around the top edge of the pendentive, where the entire wall surface seemed in danger of crumbling, and also attached several facing of paper and adhesive at the upper left edge of the painted retablo. His complete report is on file.

In February 1977, this conservator was asked to look at the wall and make suggestions. My impressions were as follows:

> There was an extremely high amount of humidity on the surface of the pendentive.
>
> The problem with the flaking plaster and the painting that had been done on it was due to the efflorescence and in some areas of the plaster loss, subflorescence.
>
> Unless something were done immediately to stop the efflorescence or to protect the painting, the entire design would be lost. (There had been an alarming loss from April 1976 until February 1977, perhaps as much as 50% and about half of it involved the design area.)

Samples were taken of the paint and plaster and it was our conclusion that because of the high amount of nitrate in the wall, unless the wall could be dried out immediately or the efflorescence/subflorescence stopped at that point, the problem of flaking would simply continue. Solutions at this time suggested included removing some of the cement on the dome and the roof above the pendentive and allowing the air to dry the wall behind the water-logged corner, drilling holes in the roof above the pendentive and packing it with silica gel--removing the gel daily and replacing it with dry, or even placing an air tight bag around the face of the pendentive and allowing the humidity to build up on the surface and stopping the efflorescent action. For various reasons these suggestions were discarded. The remaining solution if we could not correct the problem causing the paint and plaster to peel and flake off, was not to treat it cosmetically, but to remove the painting.

We decided the best method was the strappo method. Attached is a xeroxed copy of an article by Paul Philippot and Paolo Mora, "The conservation of Wall Paintings," The Conservation of Cultural Property, UNESCO, 1968, that describes the strappo method.

In the studio we set up a series of tests. We applied plaster of Paris ($caSO_4$) with additional minute amounts of saltpeter (KNO_3) and Calcium Oxide (CaO) and slightly tinted with hemetite (Fe_2O_3), a red earth coloring. On some of the bricks we applied dry pigments mixed only with water, a carbon black, a yellow ochre, and simply whiting.

Using mulberry and rice paper strips we experimented on attaching these pieces of paper to the bricks with a variety of adhesives and with varying proportions of viscosity. The polyvinyl acetates used included AYAC, AYAF, AYAT, Mowilith DMC2 and a commercial product marketed under the name of "Elmer's Glue All." Methyl methacrylates tried were: Acryloid A21, Rhoplex AC234, Acriseal, Versacryl "E" no. 9. We also used varying solutions of white shellac dissolved in alcohol. With the exception of the Bordens "Elmer's Glue All," and the AYAT, none of the adhesives attached strongly enough to the plaster to be of any holding or consolidating benefit.

Contact was made with Gustav Berger, chemist and conservator, fellow of the AIC, in New York. He suggested contacting Piero Mannoni, 282 West 11th Street, New York, N.Y. 10014, and presenting the problem to him, because of Mr. Mannoni's vast experience in mural removal. Although I did not speak to Mr. Mannoni directly, but to his wife Helen, later I received a letter from her in which she suggested that after contact with her husband he recommended a white shellac and ethyl alcohol. One of the concerns we had was the extremely high surface humidity on the face of the pendentive, and whether or not the adhesive would effectively grip the damp plaster.

Further tests were run with shellac and it was eliminated on the basis of its extreme penetration and the deepening of the color due to the change in refractive index. The friable condition of the plaster and its porosity dictated an adhesive that was "plastic," had limited penetration, and could be readily dissolved and removed from the surface. Its gripping quality, because of the method of removal we were proposing, was very important.

We narrowed our choice to AYAT. Several tests were now conducted on plaster coated brick surfaces, plaster that had been applied to cloth and paper and allowed to flake and curl, and plaster applied to masonite panels. We wetted the surfaces on the bricks to check the PVA's ability to adhere to a damp surface. We now used facing materials of cheesecloth instead of paper. Considering the tenuous nature of much of the remaining plaster we had to also resolve some technique in the studio of applying the facing and adhesive to the pendentive. The 20% stock solution that we felt was strong enough to hold the material while it was being peeled from the wall was extremely tacky and it could be foreseen the problem of trying to handle soft pieces of cheesecloth while our hands were coated with adhesive from the previous piece applied. (The various tissue papers were eliminated because of their slow rate of absorption.)

We dipped separate pieces of cheesecloth into the mixture and allowed it to dry. We could now handle the stiffened pieces, cut them to sizes, and even flatten them with a warm iron. They had the advantage over nonimpregnated pieces in that when a brush loaded with adhesive was applied to the piece there was less movement against the fragile plaster. The existing adhesive on the cloth partially dissolved, making attachment much quicker and more effective. The AYAT formed a quick drying bond to the surface, had a tenacious grip, could be manipulated when dry to a certain extent and was easily dissolvable in acetone.

There was a constant trade-off at this stage of material to be used. Reversibility had to be considered, the ultimate disposition of this fragment when it was finally removed, consideration for the effect of the adhesive and dilutent upon the painting.

After studying the various swaths and samples of studio assimilated paint and plaster, it was decided that two layers of cheesecloth, laid at different angles to each other, and an additional layer of unbleached, boiled muslin applied with a water soluble PVA marketed under the name of Elmer's School Glue were enough. We used the commercial product because of its ability to dissolve in water readily. It would be isolated from the surface of the plaster by the AYAT, and we wanted the additional strength and support it would provide with the muslin. We could have considered a more rigid facing, but the angle of the wall, the working space, weight, and the method of removal (strappo), favored a lightweight, flexible backing.

Our original plan called for experimentation on some outside walls in the mortuary chapel area before we approached the main walls. However, time was running out. While we stood on the scaffolding and discussed the plans, we could see pieces falling off. Everyday there would be fresh pieces on the floor immediately below the pendentive. Our test spot for the rate of efflorescent growth indicated rapid activity. We instead applied test areas to the wall immediately adjacent to the pendentive. Here the humidity was identical to the pendentive, the plaster in some cases was suffering from the same detachment, giving identical conditions to the surface we were to remove.

On an area to the left of the pendentive we applied our cheesecloth and adhesive, and a backing of muslin and the water soluble PVA. We allowed it to dry and then removed it. The piece performed beautifully, and even revealed an additional element of decoration, a previously painted walled under the lighter pink plaster!

On April 16, 1977, we began our assault on the removal of the pink plaster coat containing the design of a well and bucket. This layer of tinted plaster and design will be occasionally referred to as a fresco.

Using a micro pipette we first allowed a 50% dilute solution of our stock emulsion of AYAT to seep, ooze, and spread throughout the edges of the plaster, including those edges that were hanging by a thread. Needless to say, firm hands and careful eyes were needed while doing this operation. On the areas that were secure and could be areas of the fresco. In the areas of bare wall, the adhesive was not applied except where it would come in contact with the loosened edge of the plaster that was treated. There were considerable areas of plaster, especially in the mid left side that had been seriously affected by the efflorescence. Here the plaster presented an appearance of pink fuzz. The solvent was quickly accepted by the deteriorated plaster; however, we were skeptical at the time of application whether or not there was enough binder left in the top coat to allow it to be removed as a continuous film. (Our fears later were confirmed when this section was peeled from the wall. Large areas of it remained attached to the wall, but its structure was so disorganized that it wasn't considered a loss.)

We noticed immediately that in some of the severely detached areas the addition of the adhesive not only strengthened the piece, but made it flexible enough to be pressed back to the wall by the impregnated cheesecloth and adhesive without breaking.

The next two days were spent in nursing the AYAT onto the particles. One began to acquire a feel for the amount of adhesive that could be eased from the pipette onto the edge. Done carefully and slowly enough, the loss was miniscule.

We have observed several features about the "Spackling" applied during the Steen ad Gettens conservation project. Very often the repair is not confined to the holes, but is simply smeared in and out, covering the plaster area round it, and with no attempt to smooth the patch, dirt accumulates. The unevenness also provides an unsatisfactory esthetic appearance. Little attempt was made to remove the plaster plugs in the pendentive area, even though they were friable around the edges because of the fragileness of the surrounding plaster areas.

We were well aware of the adhesive quality of the AYAT. In some of our tests in the studio and on the adjacent walls there was no way to control the depth of penetration through the plaster onto the wall. Consequently when the test patches were removed, sometimes the attachment was so deep and strong, more than the plaster film was removed. To avoid removing more than the fresco, glair* was used to coat the pendentive wall where there was no plaster to be saved, and hence where we did not wish the facing to adhere.

After the securing of the plaster and isolation of the wall had been done, the impregnated cheesecloth was applied to the wall. We began by placing the dry piece against the wall and brushing through the adhesive. We quickly realized that the technique that worked so well in the studio on a horizontal surface was not refined enough for a slightly protruding forward vertical surface. We developed a method of grasping an edge of the stiffened cheesecloth and dipping it into the jar of adhesive. The wet section was laid against the wall, and brushed to secure it; then a laden brush was carefully applied to the dry edge until it relaxed and adhered to the wall. Still, the amount of adhesive accumulated on the hands of the appliers was considerable and presented a problem until such a level of AYAT was accumulated that sticking actually became less, than with fairly clean hands.

The cheesecloth was applied from the bottom up, the edges slightly overlapping, the cheesecloth torn or cut into workable and correct sizes. The facing was allowed to dry for a day, and another layer applied, again from the bottom, but placed so the threads were at an angle to the first layer. In some of the larger bare areas of the pendentive, as an additional protection against too much attachment, even through the glair, pieces of waxed paper were cut and taped to the wall, the facing then placed over it, sticking slightly to the wax paper, but very well to other edges of the cheesecloth placed directly on the plaster coat.

After the second layer was applied and dried, a layer of muslin, boiled and unbleached, was applied with a PVA emulsion, water soluble, Elmer's School Glue.

When the muslin layer had dried, a series of lines were drawn with pencil from various points previously marked by pins and marks showing two distinct paths that could be cut through to the wall, if the removal of the entire piece was impossible. We wouldn't know if these cuts would have to be made until the removal was begun. We wanted to remove the plaster and design in one piece, if possible; but if this were impractical or impossible we would have two distinct areas governed by bare areas where very little damage would be done. The cuts were not planned in the areas of design.

A crate was prepared 53" x 60", outside dimensions of the fresco, and 4" deep. The sides were constructed with 2 x 4's and the lid and bottom ¼" masonite. The holes on the lid were predrilled to receive screws, rather than banging the lid shut with nails with the fresco inside. We tried to raise the box to the top of the scaffolding--it would have taken a derrick. Instead, we lined the box with polystyrene padding and left it on the ground, and brought the lid up. We planned on attaching the detached fresco to the lid and lowering it like a pallet.

The removal was begun. We first thought it would be necessary to score the plaster around the area, but it was not. Beginning at the bottom, we pulled the muslin and cheesecloth slowly away from the wall, maintaining pressure from below in an attempt to keep the surface as flat as possible. The film was surprisingly flexible; however, we did not want to introduce any breaks. Then we began pulling the mid-right section away, again trying to avoid pulling straight back, but rather away and to the side. The tops were loosened, and finally the mid-left section. We frequently checked behind the plaster to monitor how we were doing, but it was removing the fresco completely. The entire removal time was probably not more than 7 minutes, the operation flowed smoothly. The angle and altitude of the pendentive increased the problem; i.e., the slightly swaying scaffolding, the view down to the floor some 20 feet below, no support to brace oneself and get a good stance to pull, and the quantity of falling plaster and dirt in the face and eyes.

The pendentive design was removed in one piece and laid face down on the pallet. We attached strips of masking tape to the edges of the cheesecloth and muslin, and lowered it over the side to a waiting crew. The plaster was then removed from the pallet and transferred to the box, faced side down. The lid was secured and the piece brought to the Western Archeological Center for storage the following week.

We returned to the pendentive to analyze our methods and results. There were two small pieces in the upper right mid corner that did not become attached well enough to the cheesecloth to be removed. They were not involved in the pattern, and were small enough to be left. If Mr. Tony Crosby wishes that they be removed, a second facing can be done; however, it is my opinion that they are so small and insignificant, it isn't worth the bother. There was an area, previously mentioned, where the extremely friable plaster had become attached to the wall, but because of its disorganized structure due to the efflorescence, did not remove as a film, and remains, almost as a stain. We removed several plugs of "Spackling" and a few cone shaped pieces of wall plaster. In the center of some of these were small white cores that were identified as calcium carbonate. An analysis for this and other samples taken of paint and plaster are attached in their entire form.

We had discussed with Mr. Crosby possible approaches for the ultimate placement of this piece--musuem, back on the wall in some sort of frame or on some support. The ultimate placement of this piece determines two points not covered previously in this report. First the integrity of the piece--its slightly curved surface, color, and purpose for creation. I feel that the next step should be to place this piece back in as close a proximity to its original location as possible. It does not have enough artistic merit to be viewed separately, out of context. However, it does have historical value and may be one of the clues** to the later reference to the church as "La Purisima Concepcion." Ideas should be explored as to its attachment to a support whereby the original shape, color and texture can be emulated. This may not be possible or practical, as suggested by various individuals responsible for this monument. The facing with PVA, AYAT, does not limit the final disposition of the fresco. It is merely a means for removing and securing the plaster fragments.

The second point is related to the ultimate placement of the fragments. The backside of the plaster was left untreated. We had originally considered placing some consolidating material on the raw exposed plaster and bits of wall that removed with it; but the use of an additional consolidation is not felt to be necessary at this time, and an addition of either a polyvinyl or a dilute water soluble glue might have a determining factor on the ultimate decision of how the piece is to be mounted and displayed and we wanted to avoid locking-in the monument by some irreversible treatment.

For the future, consideration must be given to the purpose of the piece and its display. Molds might be taken of the pendentive and the fresco laid into the tinted plaster placed in the mold. After ??? surrounding areas both in color and height and inpainting done to suggest the lost areas of the wall painting. This is a reasonable suggestion; however, the question of weight if the piece were to be attached to the pendentive, weakened and crumbling, is to be considered. The difficulty of creating the mold and an even layer of reinforced plaster are other factors.

These and other considerations must be explored after the final resting place has been determined. I would like to strongly suggest that the decision be made in the near future. Although I am confident in the materials that were used for the facing and support, the longer the fresco remains in contact with the two PVAs, the greater the possibility of cross-link polymerization between the two PVA facings.

Gloria Fraser Giffords
Conservator

Chemical (qualitative) Analyses Report of Samples from Tumacacori

Defining: plaster: $CaSO_4$-nH_2O; cement - $CaCO_3$

A. Pink Material of Pendentive

Data:

Fe^{++}, Fe^{3+}	- positive
$CoSO_4$	- positive
HgS	- negative (by solubilities)
CO_3	- negative
NO_3	- strongly positive
soluble Cl	- weakly positive

Not soluble in HCl: granules of sand (in small proportions) black, smoky, pink and clear, presumably natural quartz; residue that turned black in hot con HCl.

Conclusions:

The pendentive is composed of a thin layer of plaster stained with Iron Oxide Red (Fe_2O_3) with some sand mixed in. The residue that turned black in hot con HCl could be a PVA or another resin not readily water soluble.

The soluble chlorides and the nitrates which are virtually infinitely soluble in water are probably from both efflorescence (a major part) and original impurities in the plaster (a minor part). Potassium Nitrate is 440% more soluble in water than Potassium Chloride. This implies that we expect four times as much nitrate in the efflorescence than Potassium Chloride.

These results are in agreement with Getten's analysis as published in his and Charle Steen's report on Tumacacori, Tumacacori Interior Decorations," Arizoniana, Vol. III, no. 3, Fall 1962.

B. Sample of Red Paint from Swag Decoration on Main Altar

Data:

white under layer: pure $CaSO_4$ (ver white, looks bleached)
red layer: Fe negative
HgS - vermillion - positive
the brownish layer over the red ? not Fe; not ocher or umber

C. Efflorescence Crystals from Pendentive

Data:

Cl - negligible
NO_3 - positive in large concentrations

Conclusions:

The efflorescence is either saltpeter KNO, or $NaNO_3$, or both. This is characteristic for efflorescence because of the high solubility of NO_3 in water.

D. Green Material on Exposed Plaster on Pendentive

I could not isolate the green component microscopically or chemically; and upon closer examination, I could not even locate the green color.

E. A Whitish Film over Black Pigment on Retablo Wall

Data:

Ca^{++} - negligible
CO_3 - negative
Fe - positive
NO_3 - negative
sol. Cl - negligible

turns brown in con H_2SO_4, hot con HCl. Ash remains after ignition. Contains bits of very fine pigments - red, ocher, and black.

Conclusions:

It could be a spackling compound or an acrylic resin with paper or something. It is not pure organic. It is not a smear of plaster or cement.

F. White Material Inside Depressions from Behind the Plaster After Removal

Data:

soluble Cl	- slightly positive
NO_3	- positive in very large concentrations
CO_3	- positive (major)
Ca^{++}	- positive
$CaSO_4$	- negligible

Conclusions:

This material that seemed to be a core in the center of these depressions can be defined as calcium carbonate. It appears to be a slaked lime that wasn't finely enough ground or not roasted. Because of the high correlation between these white spots in the pits, as freshly revealed when the plaster and design were removed and existing on the pendentive area in areas of extensive pink plaster loss, we were curious if they were somehow related. A similar situation occurs in building bricks when the saltpeter isn't distributed evenly, causing "hot spots" which explode and remove small chips of brick. However, the chemical tests reveal that this is not the case. They may, though, represent a weakened area in the plaster that when subjected to considerable humidity will simply fall, the center being the concentration of lime.

Christopher Stavroudis
Chemical Analyst

*glair - beaten egg white

**The church at Tumacacori has been called San Jose de Tumacacori since 1753 when the site was moved from the east side of the river to its present site. In 1841 the priest in charge of the structure refers to it in his inventory as La Purisima Concepcion. For years it had been thought that this was simply an oversight on his part, perhaps confusion because of the prominent position of a figure of La Purisima. It is the author's feeling that it may have not been a simple error, but that his naming the church may have been encouraged by the fact that the sanctuary was definitely decorated in her honor. The pendentive affected by the paint lost contained a well, the other pendentives--a walled city, a palm and a cypress. These are 4 of the 12 distinct attributes of La Purisima Concepcion.

tests used:

FE++: small amount of sample (c. lmm^2) is warmed to dryness with con HCl in a concave microscope slide. The residue is redissolved in HCl, and a drop of $NA_4Fe(CN)_6$ (Sodium Ferocyanide). A deep blue ppt. will form around the pigment particles and residue.

CO_3: dilute HCl is added to sample. Effervescence of CO_2 is characteristic.

NO_3: dry sample is attacked with con H_2SO_4 and a drop of diphenyl amine (or diphenyl amine sulfonic acid, barium salt). A deep purple color forms.

Cl: sample is mixed with H_2O, stirred or mixed. The H_2O is removed (it should be clear, if necessary decant). To the clear H_2O add Ag+, NO_3 solution; milky white ppt. indicate soluble chloride (or other halide).

HgS: sample is warmed with agua regia (4-1; Hcl-HNO_3). If sample is fairly large (i.e., lmm^2) H_2S could be smelled (rotten egg). The red will not dissolve in any con strong mineral acid, thus it can be identified on basis of solubility in acids. If confirmation is desired, dry the agua regia. Place a c. 2mm drop of H_2O near sample site. Add a few crystals of soluble cobalt salt and 1 or 2 crystals of KSCN. Draw some of the drop across the reside. Deep blue crystals that persist in 1% HNO_3 will form in a few seconds, confirming the presence of Hg++. This is a difficult test to perform accurately with repeatable success. This is based on article in Studies in Conservation, vol. 17, (1972), pp. 45-69.

$CaSO_4$: treat sample with dil HCl, dry, and examine microscopically. Needle-like crystals will form and these crystals forming asterisk patterns indicate $CaSO_4$. Note: if concentration of $CaSO_4$ over spot area is too high, the crystals cannot be seen, necessitating repeat with a small portion of crystals.

Ca++: react sample with very dilute H_2SO_4. Dry. Test for $CaSO_4$.

B: GIFFORDS-WEAVER REPORT

REPORT ON THE CONDITION OF THE PAINTED INTERIOR SURFACES OF THE CHURCH AT TUMACACORI NATIONAL MONUMENT

This report follows a week of investigation, discussion, and analyses of the condition of the paint, plaster, adobe and fired brick by a consulting team made up of Gloria Giffords, art historian/conservator, and Martin Weaver, architectural conservator. Mr. Anthony Crosby, Tumacacori Project Coordinator, provided an introduction to the site and its problems and an outline of areas to be considered. Members of the Western Archeological Center were present for a morning to discuss what their facilities could provide in way of analyses. They took some samples and undertook to report their findings. In addition, Christopher Stavroudis, chemist and apprentice conservator, was on the site for two days providing the team with spot tests for efflorescence and analysing of anionic salts, as well as assistance with an experiment trying to determine the possibility of disturbing the transmission of moisture and salts by electro osmosis.

Because there is evidence of current destruction of the wall and the remaining decoration in the sanctuary, and because our conclusions about the conditions of the walls and the possible methods of treatment would apply to the rest of the church, our efforts were concentrated in the sanctuary. Every square inch was examined to determine the condition of the paint, plaster, build-up of dirt, and the extent of efflorescence and subflorescence. Comparisons were made of present conditions with those shown by a series of photographs taken over the last three years by Tony Crosby, and by other photographs taken in the 1930s and 1940s. The plaster was tapped over all four walls and up to about seven feet into the dome to determine the extent of detachment of the plaster; samples of efflorescence were taken and analyzed; samples of paint and plaster were taken for analysis; a trial removal of the PVA applied by Gettens and Steen in 1949 was tried; an experimental test area was established in the dome where different solvents were used as removers, reforming agents; and where soluble nylon was tried as a binder. The dome and areas of efflorescence were examined under UV light both in the day and at night to determine the extent of efflorescence and the potentials of using the UV as a detector for incipient efflorescence. Spot tests were made for starch binder and for plaster composition. An attempt was made to establish whether there were significant differences in electrical potential between the ground, the lower part of the wall and upper parts of the wall; or between one part of the wall and another. If present such differences could cause the establishment of a large galvanic cell which in turn could "pump" water and dissolved salts up the walls or through the walls in the direction of current flow.

Additionally, the retablo wall was examined with remaining evidence and compared with the "restored" retablo used in the site's museum diorama and publications. All the remaining decorations--the friezes, pendentives and retablo--were individually examined to determine their condition and immediate danger of destruction. The wooden lintels of the windows and doors in the entire church were scrutinized as well as the general condition of the plaster. The condition of an endangered medallion in the retablo area was assessed and a plan for its immediate conservation outlined.

Based on the tactile, visual, and chemical examinations, the following outline is proposed for the continued preservation of the painted surfaces and interior of Tumacacori. Some of the suggestions-such as analyses of pigment and binder--have begun to be acted upon as a result of this week's work--but are included here anyway as part of the overall plan.

A. <u>Environmental Modifications</u>

There is a heavy layer of dirt and dust on the rough surfaces of the walls, accumulated in the texture of the plaster and cement repairs, and on all horizontal surfaces of cornices and retablo stucco work. Before the removal of the disfiguring accumulation there should be some attempt made to control or inhibit to a greater degree than now, the amount of free dirt and dust. Before the circulation of air-borne dirt can be reduced or eliminated one must consider a number of possibilities:

1. Filters on well-sealed windows might allow the passage of air and whatever benefits circulating air would provide to the upper sanctuary.

2. There is the possibility of closing the windows entirely in the sanctuary. Why are the windows allowed to circulate air? Is there any benefit and does this benefit outweigh the disadvantage of allowing dirt to enter the building?

3. Is it not essential to consider filtering or closing the outside openings to the sacristy as well as closing or controlling the air flow through the door between the sanctuary and sacristy?

4. The main door to the church which is left open all the time should either be closed after admitting visitors or perhaps the present door modified with a smaller opening within the main door, i.e. a "wicket door." This is appropriate in most Mexican churches of this type. San Xavier, Caborca, and Tubatama can be cited as examples in this same mission chain. The fact that the design for the door was taken from the church at San Ignacio makes this an even more legitimate solution esthetically and historically.

5. Although not involved with the control of dirt, consideration should be given to the placing of UV filtering plexiglass in the windows of the sanctuary and nave. Because of the electrostatic attraction plexiglass has, a sheet would have to be sandwiched between glass, or a UV filter bonded to mylar might be available for simple attachment to the ordinary glass. The latter option would probably be less attractive because of the comparative low efficiency/high cost of thin UV filters. At certain times of the day undesirably high levels of UV radiation affect the painted surfaces when direct sunlight falls on them.

6. It is conceivable that the inhibition of efflorescence could be effected by the raising of the humidity in the upper portions of the sanctuary. This is not a permanent solution and would be just a method of buying time until the walls could either be dried out or the transmission of salts halted by some other means, perhaps by the establishment of designed active electroosmotic circuits.

B. Survey of All Painted and Decorated Areas

1. Using a superimposed regular grid of lines of fine nylon filament e.g. 2 ft. squares, every square inch of the church should be photographed or recorded in an equally accurate manner - in black and white and in color. This would provide future conservators and maintenance personnel exact areas of decoration and/or deterioration, so that accurate monitoring of the condition of the remaining decoration and wall surfaces could be accomplished.

C. Total Quantitative Analytical Analyses of Pigment, Binder and Support

1. Would provide correct information for future conservation and stabilization.

2. Could allow conservation with materials known to be compatible with original materials.

3. If the stabilization of paint and plaster by the application of another binder such as PVA or soluble nylon is necessary--the reaction to the previous stabilization should be predictable.

4. Historical information on the pigments and binders might help identify sources and decorators.

5. The identification of binder, if any, of the wall painting would be invaluable in cleaning or future stabilization work.

6. Any pertinent information should be tied into recommendation "B".

D. Condition of Walls and Paint and Plaster

1. Exact areas of loose paint, plaster, or detachment from the adobe or brick should be included in the survey described in recommendation "B". This would provide maintenance personnel with exact information of trouble spots and aid in forecasting future maintenance and conservation.

2. Replacement of plaster loss from adobe: A limited "restoration" of the exposed adobe walls in the sanctuary and nave consisting of the removal of the cement bevel between the plaster and the bare adobe and a smooth coat of plain plaster to the original level applied after the surface level had been determined by other existing examples or surrounding evidence. This would dramatically reduce the amount of dirt available for redistribution in and on the church's interior, provide a homogeneous appearance, and provide stabilization benefits to the existing plaster which in most cases is supported by minimal contact with the wall and little if any contact with the floor. A limited restoration of the base-coat only would satisfy the majority of the above criteria.

3. The exploration of an application of a "fixative" material to the adobe surface that would prevent the continuous powdering or "dusting" of the adobe. The need for reversibility and the ability of the material to transmit moisture are important considerations in the selection or development of, for example, a special PVA, or methyl methacrylate "fixative".

4. Reattachment of plaster to the wall by means of an adhesive: tests would have to be made to determine the feasibility and effectiveness of attachment, and a technique to inject an adhesive between the plaster and the adobe walls. While not entirely accurate, tapping the walls indicated very large areas of detached plaster, leading us to believe that

after the stabilization of the humidity within the walls, the next priority would be the reattachment of the plaster. Suggestions for materials to be tested are calcium caseinate and Polyfilla (methyl cellulose). Epoxies should not be used. Because the epoxies are irreversible their use cannot be recommended in this case where there is a definite risk of epoxies accidentally getting into the paint layers.

Acrylic resin/inert filler mixes may be employed as injection media to reattach large areas.

Experimental wall and plaster units should be constructed to facilitate the testing of the suggested conservation media before they are used on the actual building.

5. The amount of UV light available in the structure should be determined before any recommendations for materials for the stabilization of paint and plaster can be made.

6. An additional "probe" is strongly recommended to determine the moisture levels in the NW corner of the sanctuary, above the pendentive. In fact, the continued destruction of the painted plaster in this area and along the north wall involving the painted remains of the main retablo is an intriguing problem. Additional probes indicating increases or decreases in humidity or the transmission of salts might provide clues before wide ranged destruction resulted. Frankly, though, without some dramatic therapeutic treatment, if the moisture continues to spread and the efflorescence proceed, there is little we can do except record the destruction. Conservation treatments for the surface cannot succeed until the problems of the damp and salts are solved.

7. The system of disturbing the ion flow of salts and moisture through the wall should be pursued by additional tests with the proper equipment to determine differences in electrical potential. The inhibition of transmission of moisture to the surface of the church's interior and the growth of salt crystals holds the most important key to the preservation

of the remaining painted and decorated plaster in the area above and below the cornice in the sanctuary. Differences of as little as 5-10 mv may be significant in initiating current flow which will transport water and dissolved salts through the masonry. Negatively charged (anionic) salts e.g. cl^{--} can thus be concentrated at the solution ront and will in turn cause the build-up of progressively larger negative charges. The latter result in more current flow hence more moisture and more salt transportation.

The measurement of the charges must thus be accurate to 1 mv and careful attention must be paid to the quality of the contacts between the electrode rods of the test meter and the adobe masonry.

E. Cleaning

After the church's walls and dome are stabilized and there is assurance that the moisture contents of the walls have been appreciably lowered and loose paint and plaster have been reattached:

1. The walls and cornices should be vacuumed with a reduced system to remove loose dust and accumulated dust.

2. Certain areas might be wet cleaned. After testing pigments and binders for solubility in water, limited tests were carried out using distilled water and wet-strength tissue poultices to leach-out salts. The poultices certainly removed surface efflorescence and some subflorescence and not surprisingly some surface dirt.

F. Determine by correspondence, test, and observation exactly what areas had been conserved previously, how they were reacting now, and place this data on the survey mentioned in "B". There are certain areas in the sanctuary that show distinct differences in color. It is a good possibility that this was the result of a paint stabilization program that took place in 1949. Samples were taken from surfaces treated by Gettens and Steen. The samples have been submitted to the laboratories of the

Western Archeological Center in an attempt to establish whether the PVA formulation has been the subject of undesirable aging phenomena e.g. color changes, changes in permeability, changes in thermal expansion characteristics. Such changes due to aging could explain what some observers claim is a fairly recent marked increase in deterioration.

Further samples were taken to establish whether various sulphate-reducing and other forms of bacteria are responsible for areas of staining and efflorescence on the painted plaster surface of the dome.

If bacteria are found to be present, the solution of the moisture and salts problems is again of paramount importance.

G. A checklist should be made for on-the-site personnel to follow. They should monitor equipment, provide cleaning when necessary and use the survey ("B") for reference in detecting problems should they arise.

H. Structural Members

Although there isn't any immediate danger of the failure of the walls or plaster above these areas, consideration should be given to the replacement of termite riddled lintels over windows in the apse and replacement of the missing lintel over the door to the sacristy. If complete replacement isn't possible, the alternative of using the termite tunnels as tubes into which to inject an epoxy as a replacement for the missing wood might be considered. (Reference to this system is available in the IIC-Oxford preprints, 1978.)

I. During cleaning and examination of the painted surfaces additional plans or ideas might arise that would entail further stabilization and recommendations.

If there were to be priorities assigned at this moment, we feel the conservation of the paint and plaster by the prevention of any more passage of salts and moisture would be the first. After the walls, plaster, and paint have dried out and become stable, then reattachment, mapping, replacement, and cleaning all fall in line.

Gloria Giffords
Conservator

Martin Weaver
Architectural Conservator

C: SPOT TESTS FOR ANIONIC SALTS IN SANCTUARY

Number	Locations and Anions Present			
1	Efflorescence from dome surface, (approximately 1 meter above cornice along west side of dome) (Nonfluorescent)			
	NO_3	CL	SO_4	CO_3
	-	-	+	trace
2	Efflorescence from approximately same spot as No. 1 (Fluorescent)			
	NO_3	CL	SO_4	CO_3
	-	-	trace	++
3	Efflorescence from same location as No. 2 (Nonfluorescent)			
	NO_3	CL	SO_4	CO_3
	-	trace	+	+
9	Efflorescence from dome (Nonfluorescent)			
	NO_3	CL	SO_4	CO_3
	-	-	++	-
10	Efflorescence from dome (Fluorescent)			
	NO_3	CL	SO_4	CO_3
	-	-	+	-

11 Efflorescence on cornice above NW pendentive

NO_3	CL	SO_4	CO_3
trace	-	+	+

12 Efflorescence; 1 of 3 samples from above. NW pendentive, above cornice by 0.5 meter, (first layer)

NO_3	CL	SO_4	CO_3
-	trace	trace	+

13 Efflorescence at same location as No. 12 from friable plaster itself (second layer)

NO_3	CL	SO_4	CO_3
+	+	trace	++

14 Efflorescence from inner layer. Same location as No. 12 (third layer)

NO_3	CL	SO_4	CO_3
+	-	+	+

15 Efflorescence on brick above NW pendentive

NO_3	CL	SO_4	CO_3
+	trace	++	trace

16 Efflorescence over west volute of retablo associated with exposed adobe

NO_3	CL	SO_4	CO_3
+	-	trace	++

17 Efflorescence above toms molding immediately above south corner of NW pendentive

NO_3	CL	SO_4	CO_3
-	-	+	++

18 Square patch over NW pendentive, 0.4 meter above cornice (Not tested)

19 Efflorescence just west of rolute below deteriorated plaster.

NO_3	CL	SO_4	CO_3
trace	-	+	trace

20 Efflorescence above deteriorated plaster approximately 1.0 meter above cornice, NE corner. This is an area of more recent deterioration.

NO_3	CL	SO_4	CO_3
-	-	+	++

21 Efflorescence in deteriorated plaster approximately 0.6 meter above cornice centered on NE pendentive.

NO_3	CL	SO_4	CO_3
-	-	++	++

22 Efflorescence from yellow stained plaster. 1.0 meter above cornice, directly above north jamb of west window.

24 Efflorescence from yellow stained wash. 1.0 meter above cornice, directly above north window jam, west dome surface.

NO_3	CL	SO_4	CO_3
-	+	-	+

25 Efflorescence on plaster immediately below sample No. 24; not in yellow area.

NO_3	CL	SO_4	CO_3
- (brown)	+	trace	++

26 Efflorescence on yellow stain, approximately 30cm above No. 24

NO_3	CL	SO_4	CO_3
-	-	++	-

27 Efflorescence on yellow stain area 1.10 meters above cornice approximately 40cm. north of window jam. West sanctuary wall

NO_3	CL	SO_4	CO_3
+	-	+	+

28 Efflorescence from the surface of fired brick; west side of dome. 30cm above LVDT

NO_3	CL	SO_4	CO_3
-	-	+++	++

29 Efflorescence, west side of dome; immediate vicinity of structural crack; 40cm above cornice

NO_3	CL	SO_4	CO_3
+	-	++	+

30 Efflorescence from plaster at area of spalled and missing finishes

NO_3	CL	SO_4	CO_3
trace	-	++	+

31 Efflorescence on yellow stain immediately above cornice, approximately 1.5 meters above cornice, directly above end of cornice west side

	NO_3	CL	SO_4	CO_3
?	-	-	++	+

32 Efflorescence on yellowish stain above NW pendentive 1.5 meters above cornice

	NO_3	CL	SO_4	CO_3
	trace	-	++	+

33 Large glob of white material in plaster. South side of dome, 0.7 meter above cornice.

	NO_3	CL	SO_4	CO_3
	+	+	trace	++

34 Efflorescence on brick, south side of dome approximately 1 meter above cornice

	NO_3	CL	SO_4	CO_3
?	-	-	++	-

35 Efflorescence from dome, south side; from plaster, no wash

	NO_3	CL	SO_4	CO_3
	+	-	++	++

36 Efflorescence from brick; yellowish under regular as well as U.V. west side of dome, 1.5 meters above cornice

	NO_3	CL	SO_4	CO_3
?	-	trace	trace	+

37 Final wash; lower portion of sanctuary, NW corner
(Test shows it is not calcium carbonate)

38 White mortar used to secure molding in retablo (molding for broken pediment)
(Test shows it is not calcium carbonate)

NO_3	CL	SO_4	CO_3
-		++	-

39 Efflorescence from plaster above NE pendentive; approximately 0.7 meter from cornice

NO_3	CL	SO_4	CO_3
	-	++	++

40 Efflorescence from yellow stained wash above NE pendentive

NO_3	CL	SO_4	CO_3
trace	-	+	++

D: EXPERIMENTS WITH ACRYLOID B-72 ON TUMACACORI PLASTER

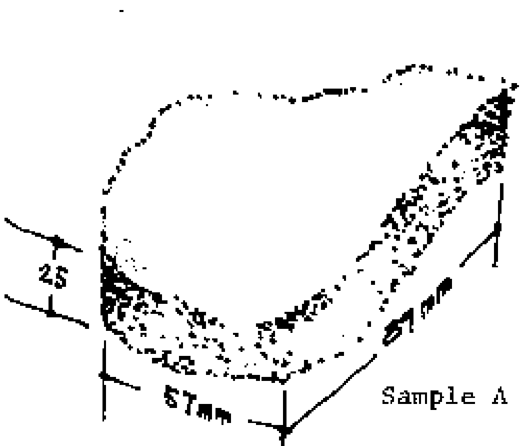
INTRODUCTION

Two samples of painted plaster from Tumacacori were examined over a period of approximately two months. The intent was to look at moisture transmission qualities and to gain some insight as to how they are affected by the application of Acryloid B-72, used as a consolidant. This acrylic resin was used during the conservation testing at Tumacacori during August of 1981, and it is anticipated that it will be utilized to some degree during the actual conservation work. The effects of soluble salts and repeated wetting-drying cycles on the B-72 treatment itself were also a concern and the testing was oriented to address this as well.

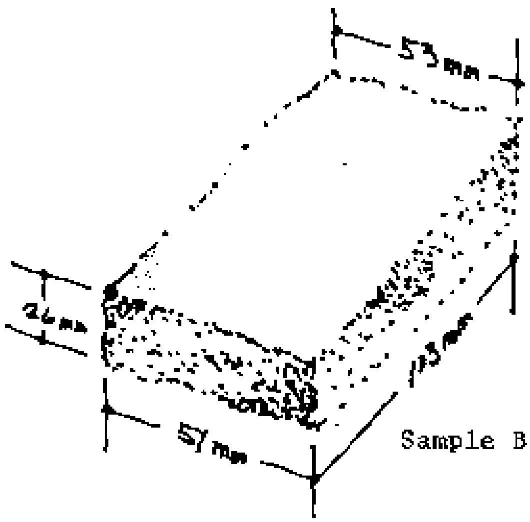
The two plaster samples were fragments of the church's original plaster floor and these observations may not be directly applicable to the plaster on the surface of the dome. However, the physical, mechanical, and chemical properties of both the floor and dome plaster are very similar, hense reasonable comparisons seem entirely suitable.

METHODOLOGY

Two plaster samples were observed initially just as they were recovered from the field. They were relatively clean of soil encrustations, although some soil did remain. The finish plaster surface of Sample B was cleaned with light brushing and paper pulp and water poulticing. Both samples were irregularly shaped originally, but Sample B was trimmed in order to give more uniform results from the capillary rise - weight gain tests. The other sample, Sample A, was not trimmed and was used only during the initial observations. The two plaster samples are dimentioned below. Sample B is as it appeared after trimming.



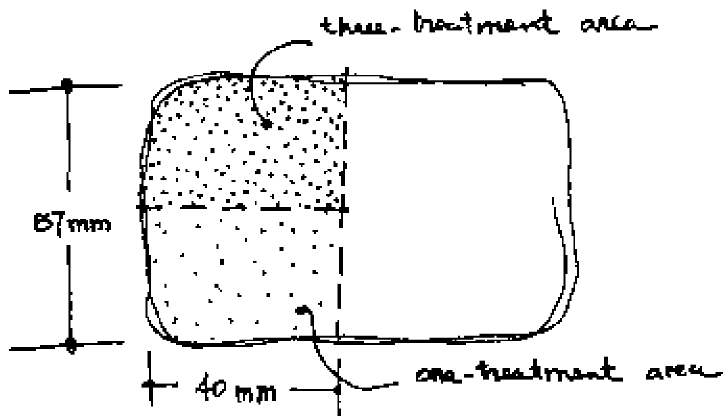
Sample A



Sample B

All the tests were conducted at a room temperature that varied between 65° and 75° fahrenheit and a relative humidity that varied between 38% and 50%. At the beginning of each test the samples were weighed and then placed on end into a dish that contained either plain tap water, or a solution of sodium chloride. The liquid was kept at a constant depth of 10 millimeters with the sample in place. The sample was then weighed periodically and the surface capillary rise measured. This process was continued until the capillary rise was complete and free water remained on the surface when the sample was removed from the water. The sample was then allowed to dry at the ambient conditions, weighed periodically until equilibrium was reached with the conditions in the room and the weight no longer decreased. The results of this process on the untreated Sample B are tabulated in Table 1.

After the initial capillary rise - weight gain test, Sample B was treated with a 10% solution of Acryloid B-72 in toluene. The following sketch indicates the areas treated.



The resin was brushed on both areas on the finished surface, the back or unfinished raw plaster, and the two corresponding raw plaster edges. The application was repeated three times in the three-treatment area. Following the third application some of the resin remained on the finished surface for several minutes. The plaster was then set aside for one week before additional experiments were undertaken.

After each subsequent capillary rise - weight gain test the sample was observed under 0 to 14 power magnification and the observations were noted. Efflorescence was removed with a paper pulp poultice prior to beginning the next test. The results of the experiments were organized in tables and some of the results were also recorded photographically.

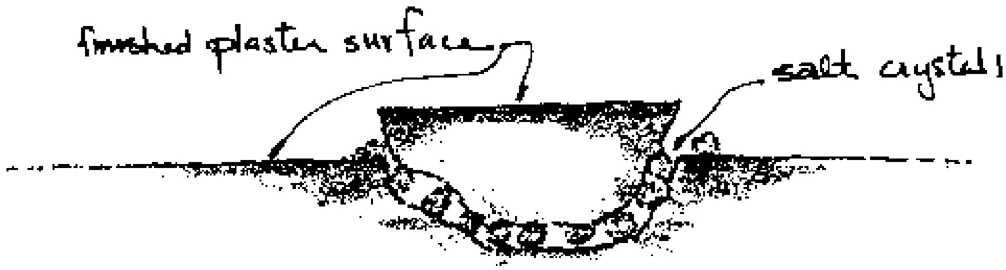
RESULTS OF THE EXPERIMENTS

Plaster Sample A was exposed to the capillary rise - weight gain test on two different occasions, but the results are not included. However, one very important observation was made. After drying, there was clear and distinct evidence of a yellow stain on the upper portions of the sample (upper, in terms of the relationship to the capillary moisture source). This stain is very similar in appearance to the yellow stain that exists on large portions of the surface of the sanctuary dome. The stain on the sample also migrated as it was rewetted just as did the stain on the dome. The second test on Sample A simply appeared to add to the concentration of the yellow stain. The stain was most prevalent on nodes on the raw plaster edge and on the finished surface. Later the finished surface was cleaned with an ammonium carbonate poultice and the stain came off easily.

Sample B was subjected to the capillary rise - weight gain test on six different occasions. The results are in tables one through six. An examination of the tables shows one very obvious trend. After an initial significant effect on the weight gain of the plaster, on repeated cycles, the resin lost some of the effectiveness. Specifically, Table 1 shows a weight gain of 7.2 gram after 2 minutes while Table 2 shows only a weight gain of 0.1 grams after the same elapsed time of a treated Sample B. The results of the second test on the treated sample, Table 3, shows a gain of 1.4 grams after 2 minutes. The weight gain on the next test, Table 4, is up to 4.4 grams. By the last test, Table 6, the weight gain is 5.8 grams.

The tests reported on in Tables 3 and 4 were conducted with a sodium chloride solution. While there was some efflorescence after the first test using tap water, it was minimal when compared with the efflorescence on drying after tests 3 and 4. The efflorescence formed primarily on the untreated portions of the treated surface after test three, but began to form on both the treated portions of the finished surface after test 4. In comparing the treated areas, the efflorescence was much heavier in the one-treatment area than in the three-treatment area. Figures 1a and 1b are two photographs of the rear or unfinished side of Sample B after the drying associated with test 3. The efflorescence was removed prior to the next test by poulticing with paper pulp. After the poultice was removed, the plaster was allowed to dry again to equilibrium at the ambient room conditions. When the drying was completed, surface efflorescence did not reappear to a significant degree. However, the presence of some salt could be detected with a light under magnification.

Tests 5 and 6 were conducted using room temperature tap water again. Figure 2 is a photograph of the front or finished side of plaster after drying associated with test 5. There is certainly some variation in the amount and distribution of the efflorescence, but there appears to be little difference in the one-treatment and three-treatment areas. In addition, visible surface decay began to occur. This decay is in the form of more friable raw plaster edges, fractures near the plaster perimeter, Figure 3, a more rough surface texture, and a general powdering of the surface. The powdering and increased roughness of the surface results as individual sand particles are isolated as the calcium carbonate binder erodes away, and as small sections of the surface is pushed up from the original surface plane. The erosion of the calcium carbonate binder can be seen in the photographs of Figures 4a and 4b. Examples of the surface being lifted are pointed out in Figure 5 and in the sketch below.



In this latter case, the salt crystals, lifted the surface material, then recemented it in place. However, when the salts went back into solution as the material was rewetted, the separated area would come off under minimal pressure.

The amount of visible efflorescence after test 5 is much less than after previous tests. However, the decay of the material is significant. It is obvious at this point that generally, the actual surface decay is more significant in the untreated areas of the finished side, although there are some areas of severe decay in the one-treatment area as well. On the back side of the plaster, decay has occured on the one-treatment portion. The untreated area with the excessive salt buildup does not show as much decay, probably because the salts continue to bind the sand particles together. No efflorescence is visible on any of the treated areas of the back side. The heavy salt concentration above a diagonal line near the upper third of the sample could define a natural cleavage plane in the plaster.

Some plaster fragments also began to come off in the dish during test 4 and is subsequent tests. The losses after tests 4, 5, and 6 were consistant as the weight of the loss material was 0.5 grams, 0.4 grams, and 0.4 grams, respectively. However, an additional wetting resulted in a much more significant loss of an approximately four grams.

After test 3, the Acryloid B-72 was clearly visible on the surface. After test 4 the B-72 appears to have been pushed from the surface, was somewhat fuzzy, and some had disappeared. It remained clearly visible after the subsequent tests in the three-treatment area. One of these is pointed out in the detailed photograph of Figure 6.

During and after the final test a conductivity meter was used to further indicate how the moisture movement on the surface of the plaster was affected by the treatment with the Acryloid B-72. The sketches of Figure 7 represent the visible presence of moisture on the surface material and the relative conductivity of the surface.

CONCLUSIONS

The conclusions can best be thought of as (1) those that relate to the effect of the Acryloid B-72 treatments on the plaster's water transmission properties, (2) the effects of the wetting-drying cycles on the treatment, and (3) the overall effectiveness of the resin as a consolidant.

The movement of water is definitely affected by the acryloid B-72 treatments. In the area that was treated with three applications, the capillary movement was affected the most initially, although the difference between the one-treatment and three-treatment areas became less in each subsequent cycle. The restriction of the movement of moisture in these areas eventually resulted in an increase of moisture into the nontreated areas and additional decay could have been the results of this added moisture movement. Of course this is of minimal importance if a significant amount of moisture is no longer moving through the material, which appears to be the case in the dome at Tumacacori.

The repeated wetting-drying cycles do have an effect on the treatment itself. The continual increase in moisture movement and weight gain in subsequent tests gives the best indication of this. The increased decay in the treated areas associated with additional cycles also indicates a loss in effectiveness.

While there should be consideration of the effects of the treatment on the plaster and also consideration of the effects of the repeated wetting-drying cycles on the treatment, the overall conclusion is that on this particular material, Acryloid B-72 appears to be an effective consolidant. Some of the problems that might have been expected, such a delamination because of the dissimilarity of the treated and the untreated areas simply did not occur.

In fact, the surface delamination that did occur was related to the crystallization of the soluble salts which occurs more in the untreated areas. Also, the cracking along the periphery of the plaster sample occured less in the three-treatment areas. These latter cracks and fissures probably result from the wetting and drying cycles as one parion of the plaster, the outside edge, has a much larger evaporation surface area relative to its mass than the portion of the material on the other side of the crack.

Obviously, the treatment can be applied too heavily as occured in the area which was treated three successive times. This area deteriorated less than the area that was treated just once but the presence of the film in small amounts is a distinct disadvantage that should be guarded against in sebsequent use of the consolidating material.

TABLE 1: WEIGHT GAIN
TUMACACORI PLASTER SAMPLE B
UNTREATED; TAP WATER

Elapsed Time	Capillary Rise	Weight Gain
1 min.	25.8 mm.	4.9 grams
2 min.	28.5	7.2
4 min.	35	8.4
8	42	10.1
30	61.5	15.1
1 hour	74.6	19.1
2 hours	97	23.8
3 hours	complete	25.8
Free Water on Surface		27.6
Drying		**Weight Loss**
1 hr., 30 min.		2.1
3 hrs.		5.3
18 hrs., 45 min.		22.1
21 hrs.		24.3
27 hrs.		26.4

TABLE 2: WEIGHT GAIN
TUMACACORI PLASTER SAMPLE B
TREATED; TAP WATER

Elapsed Time	Capillary Rise	Weight Gain
2 min.		0.1 grams
7 min.		0.2
16 min.		0.4
41 min.		0.6
55 min.		2.5
2 hrs., 21 min.		8.7
3 hrs.		11.9
3 hrs., 30 min.		14.0
18 hrs.		23.3
Drying		**Weight Loss**
30 min.		0.7
3 hrs.		3.5
4 hrs., 45 min.		5.2
6 hrs.		6.6
8 hrs.		8.7
24 hrs.		16.3
32 hrs.		19.0
120 hrs.		23.7

TABLE 3: WEIGHT GAIN
TUMACACORI PLASTER SAMPLE B
TREATED; SATURATED SODIUM CHLORIDE SOLUTION

Elasped Time	Capillary Rise, mm.	Weight Gain
2 min.		1.4 grams
7 min.	more in 1-treatment area	2.8
12 min.		3.9
20 min.	25 in 1-treatment area 18 in 3-treatment area	5.3
30 min.	29 in 1-treatment area* 25 in 3-treatment area	7.0
42 min.		7.4
1 hr., 3 min.	10 on both side	10.3
1 hr., 16 min.	32 on front side	11.3
2 hrs., 26 min.		15.5
3 hrs., 20 min.		18.0
4 hrs., 20 min.	85 on front	20.3
5 hrs., 30 min.	complete	23.0
7 hrs., 45 min.		25.3

* Capillary rise on back side is far below the rise on the front, or finished side.

TABLE 4: WEIGHT GAIN
TUMACACORI PLASTER SAMPLE B
B-72 TREATED; NaCl SOLUTION

Elapsed Time	Capillary Rise, mm.	Weight Gain
1 min.		4.4 grams
2 min.	25	5.4
5 min.		6.2
30 min.	51	11.0
1 hr.	65	14.7
2 hrs.	83	19.3
3 hrs.	93	22.6
3 hrs., 45 min	complete	23.6

TABLE 5: WEIGHT GAIN
TUMACACORI PLASTER SAMPLE B
B-72 TREATED; TAP WATER

Elapsed Time	Capillary Rise,mm.	Weight Gain
1 min.		4.7 grams
3 min.		5.9
7 min.		7.9
16 min.		9.6
1 hr., 34 min.	82	18.5
1 hr., 45 min.	83	19.3
2 hrs., 24 min.	94	21.6
3 hrs.	near complete	23.0
3 hrs., 45 min.	near complete	23.6
4 hrs., 20 min.	complete	23.8

TABLE 6: WEIGHT GAIN
TUMACACORI PLASTER SAMPLE B
B-72 TREATED; TAP WATER

Elapsed Time	Capillary Rise, mm.	Weight Gain
1 min.		4.3 grams
2 min.		5.8
4 min.		7.0
15 min.		10.8
20 min.		12.1
30 min.		13.4
40 min.		14.8
1 hr.		17.4
1 hr., 30 min.		19.7
2 hrs.		21.8
2 hrs., 30 min.		23.4
3 hrs.		24.3
4 hrs.		25.0
5 hrs.		25.1
Drying		Weight Loss
1 hr.		1.8
2 hrs.		3.8
3 hrs.		5.0
17 hrs.		16.4
21 hrs.		17.7
24 hrs.		18.9

* See sketches, figure 7 for more detailed data on capillary rise.

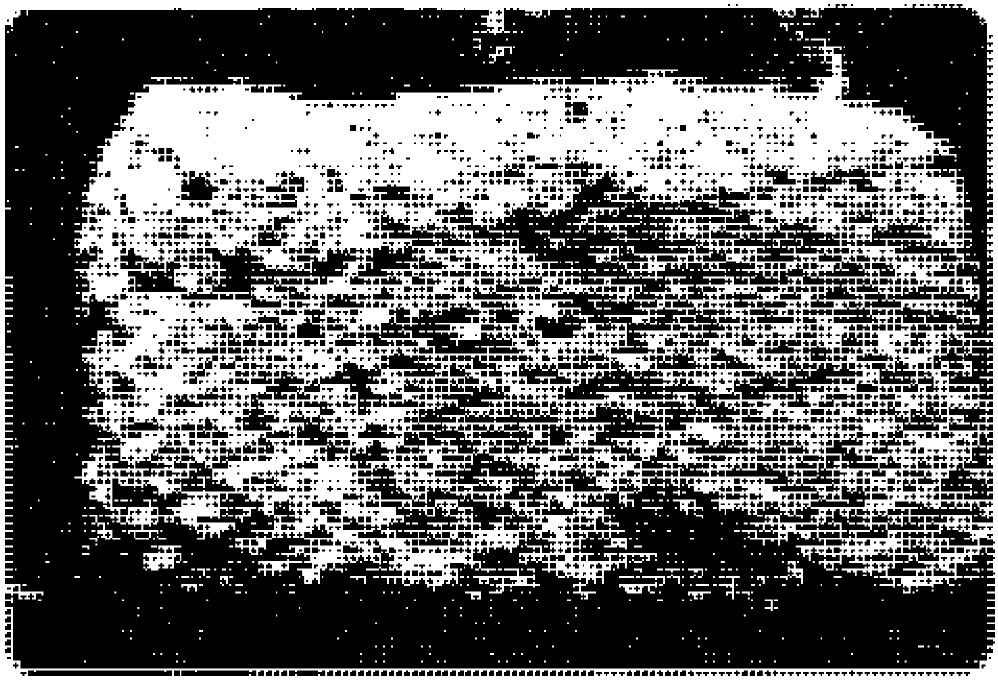


Figure 1a: Rear or unfinished side of Sample 8 after the drying associated with test 3. Three-treatment area is on the upper right and the one-treatment area is below it. Scale: approximately actual size.

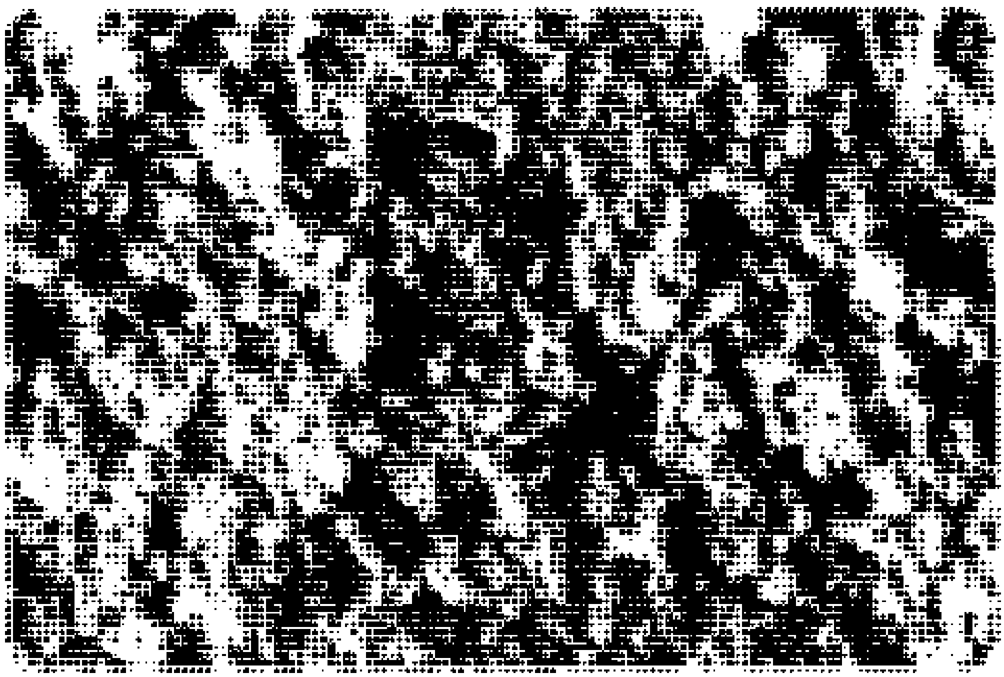


Figure 1b: Detail of Figure 1a showing heavy efflorescence. Scale: approximately three times actual size.

Figure 2: Front or finished side of plaster Sample B showing efflorescence which formed in associated with test 5 drying. Treatment areas are at the upper and lower right. Scale: actual size.

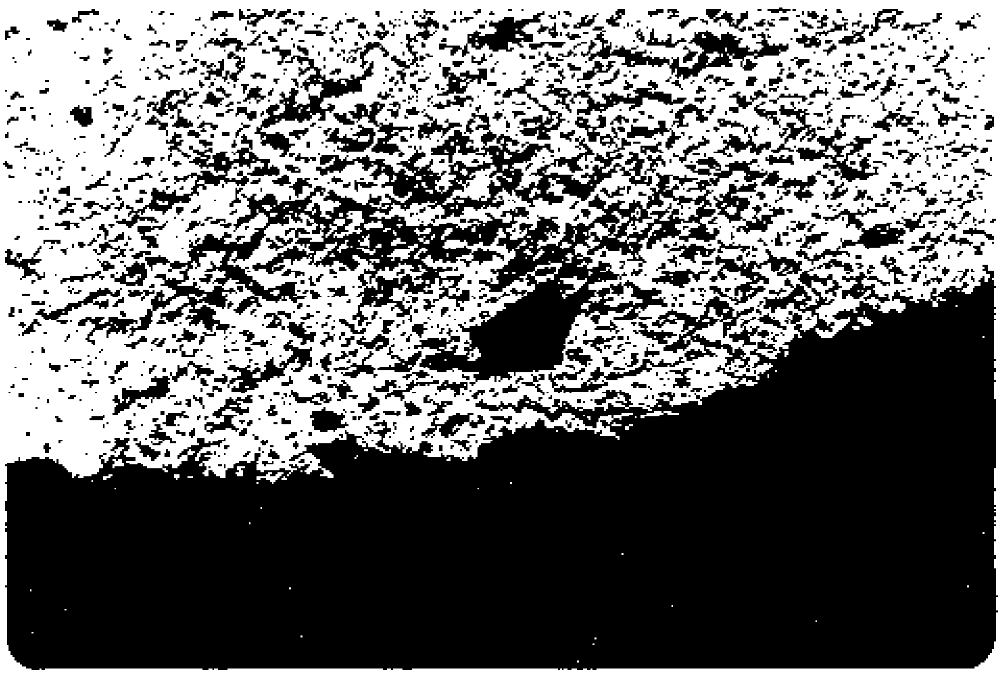


Figure 3: Detail of plaster Sample B showing edge fractures. Scale: approximately five times actual size.

Figure 4a: Surface deterioration of plaster Sample B. Scale: actual size.

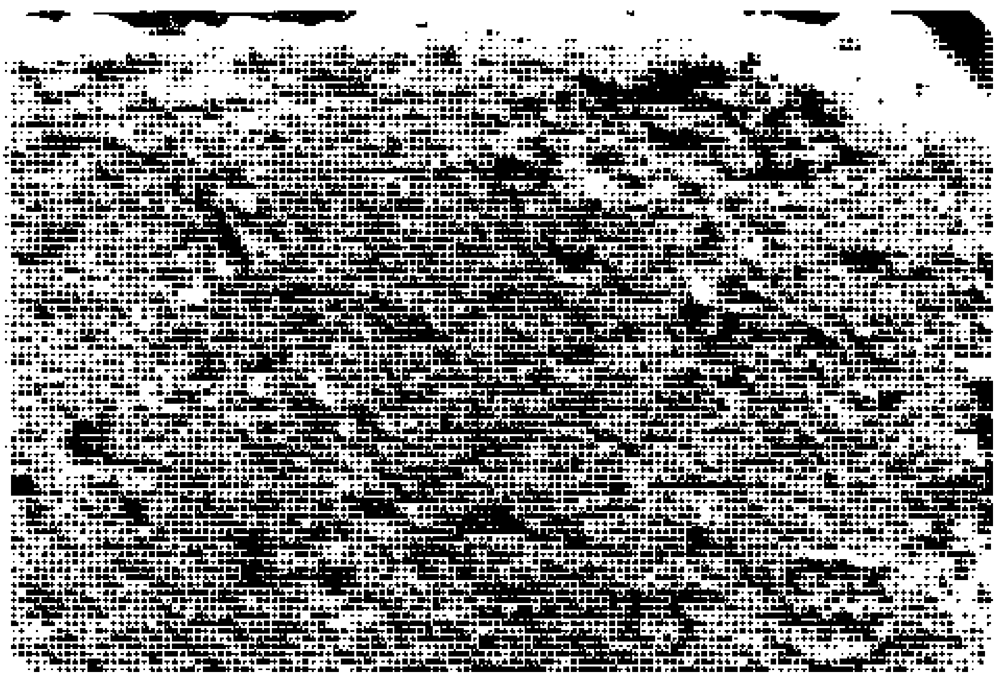


Figure 4b: Detail of Figure 4a. Scale: approximately two times actual size.

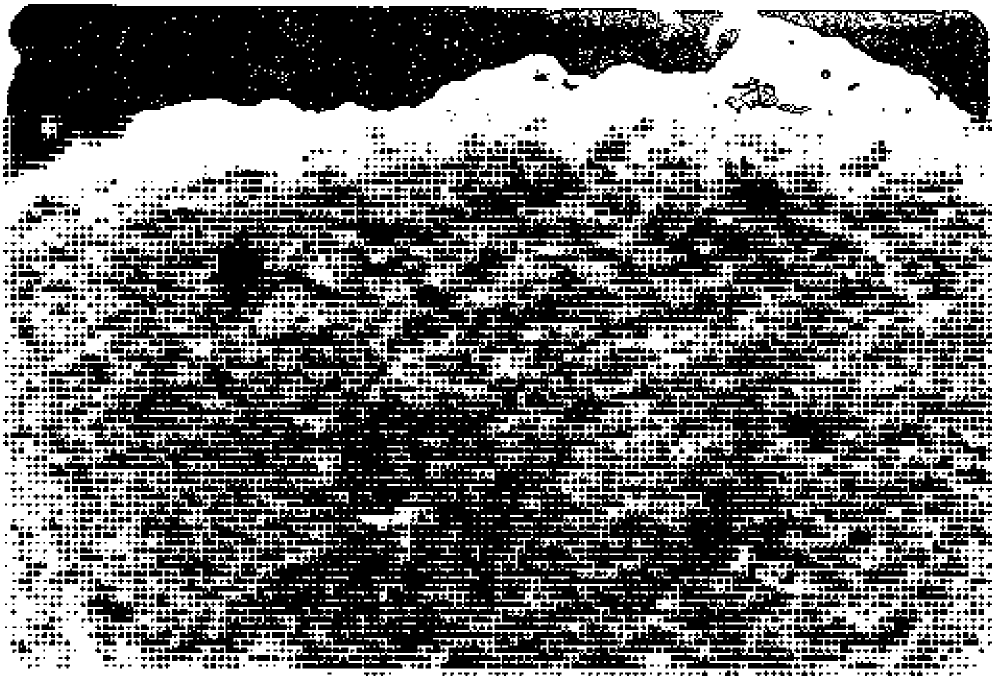


Figure 5: Detail of the upper right of plaster Sample B where small sections have lifted from the finished surface. Scale: approximately four times actual size.

Figure 6: Detail of the center right portion of plaster Sample B showing the remains of some Acryloid B-72 which remained on the surface. Scale: approximately four times actual size.

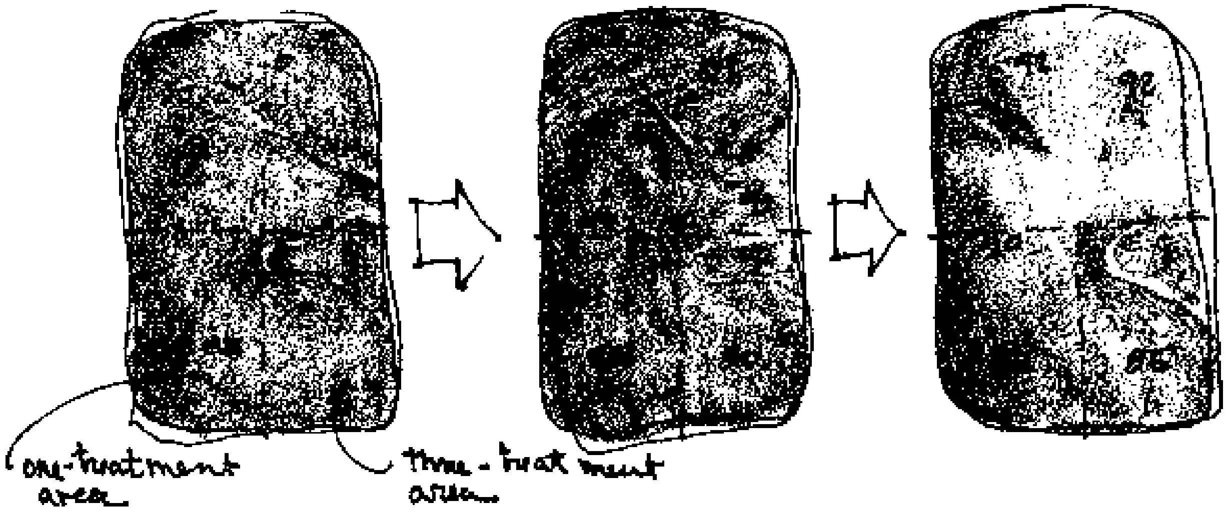


Figure 7: Back side of plaster Sample B showing visable capillary rise and relative surface moisture readings after 1 1/2, 2 1/2, and 4 hours, respectively. The blue areas are those which appear to be wet.

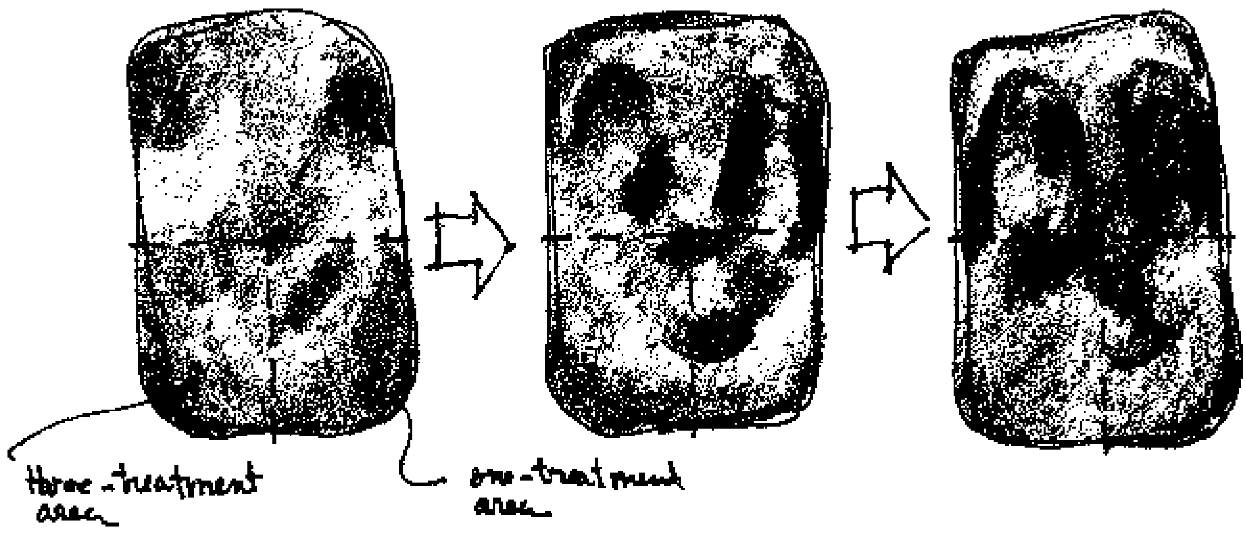


Figure 8: Front side, or finished surface of plaster Sample B showing the formation of efflorescence after 2, 3, and 18 hours respectively. The intensity of the gray areas represents the amount of efflorescence.

E: RECOMMENDED TREATMENTS IN THE 1978 HISTORIC STRUCTURE REPORT FOR TUMACACORI

The following recommended treatment indicates the basic direction of the current project and as well as all the stabilization efforts at Tumacacori since the National Park Service began its initial relationship as the caretaker of this nationally significant site in 1919. Although there doubtlessly were grand schemes for the total restoration of the complex, or at the very least, the total and complete restoration of the church in the minds of individuals associated with Tumacacori over the past half century, there has never been but one viable treatment.

1. Preservation Treatment

   This is the recommended treatment.

Preservation of what was the Mission of San Jose de Tumacacori means specifically the preservation of that portion of the original features, architectural elements, and material which still remain. It does not mean the preservation of the post mission period materials. However, within this preservation direction many post period attritions have become a significant part of the overall desired experience at Tumacacori and unless they are contributing to the actual deterioration of the original fabric they should also be afforded the same concern for their continued existence.

The reconstructed semi-circular pediment which completes the front facade of the church, the 60 feet of reconstructed Campo Santo wall, the late 19th and early 20th century alterations to the extant portion of the convent and the corridor are now an integral part of the site and should remain. The same is true of the nave roof and it, in addition, provides significantly to the preservation of the church. Other somewhat less dramatic additions, such as upper portions of walls, replaced lintels, and other basically stabilization oriented work also belong.

However, there are many other additions which either contribute to the deterioration or detract from the significant part of the resource. These additions should be removed or replaced. Included in this category are the interior and exterior cement stucco and soil cement coating and veneers, the roofs constructed over the granary and the corridor, the building constructed over the extant convento, and the concrete pulpit in the northeast corner of the nave.

2. No Treatment

This alternative calls for no significant action other than routine maintenance. It will not contribute to the preservation of the complex. Basically this treatment is considered to be the neglect of a significant resource. This alternative is not recommended.

C. EVALUATION OF EFFECT OF THE ALTERNATIVES FOR TREATMENT

1. No Treatment Alternative

a. No Effect

The neglect of the resource will have an effect.

b. Adverse Effect

The neglect of the resource will have an adverse effect. The structures as they currently stand will continue to deteriorate at an accelerated rate since they simply cannot be maintained.

2. Preservation Treatment

a. No Effect

The recommended treatment will have an effect on the resource.

b. No Adverse Effect

The overall project will have a beneficial effect on the historic resource.

D. GENERAL STEPS TOWARD RECOMMENDED TREATMENT

The general steps for the preservation treatment are divided into three categories. The first category contains the work to be undertaken and completed this summer. There will most likely be some variation depending on additional information which will come to light as the work gets underway. Consequently, some of this work could perhaps continue on into the fall or some of the work scheduled for the late fall could be undertaken during the summer work.

The second category is the work anticipated during the fall and the third is the work currently anticipated for the spring and early summer of 1979.

All work should be done under the supervision of a preservation specialist.

1. Action To Be Undertaken This Summer (1978)

a. Remove Cement Stucco

The most appropriate method will be determined by the work supervisor and the project architect. In some extremely critical areas, such as the north exterior of the church, the exact determination of what is to be removed will be made during the actual removal process. It may not be possible to remove all the cement stucco without causing an unacceptable amount of damage to the original plaster. The location of the cement plaster which will be removed will be designated in construction drawings and shall include

the entire exterior of the west nave and sanctuary wall

selected areas on the north, south and east sides of the Bell tower

the base or lower portion along the south side and selected areas on the north and east side of the sacristy all the cement stucco and concrete on the campo santo wall

all the cement stucco along the base of the corridor

all the cement stucco and concrete on the mortuary chapel

selected areas on the south side of the church

limited portions of the granary

b. After Removal of Cement Stucco and Concrete, Fill Voids (discussion on page 117)

This will be accomplished with natural adobes and adobe batts, fired brick batts, and mud and lime mortar. The goal is to eliminate the direct access of rainwater to the wall interior and to prepare the wall for later plastering. Consequently, the exterior wall plane will not need to be brought back out to the original plane except at a junction or wall and original plaster. Construction drawings will be provided by the project architect.

c. Remove Soil Cement Adobes from Church Interior

It may be necessary to remove the material by sections to eliminate the loss of original adobes which are shown. The actual method of removal will be determined by the work supervisor and the project architect. There are several critical areas where the removal method may vary. One of these is near the south side altar, west nave wall. The areas involved are on either side of the nave and the south jam of the opening to the baptistry.

d. Replace Soil Cement Adobes

The voids will be filled with natural adobes and mud mortar. All loose friable material in the voids should be brushed clean. The selection of the soil for the mud mortar will be the responsibility of the soils laboratory at the Western Archeological Center in consultation with the project architect.

e. Partially Fill Hole in Sanctuary North Wall (recommended in Tumacacori Preliminary Report, Crosby, 1976, page 130)

The primary reason for this action is to support the original adobes above. A secondary benefit will be the partial elimination of a source of dust which accumulates in the fragile painted plaster.

f. Remove Mud Fill in Holes in Original Lime Plaster

If voids exist behind the plaster, they should be filled with lime grout. The holes themselves should be filled with lime plaster. Specific formula mixes to be supplied by the project architect.

g. Rebuild Bases of Piers

This will be done using natural adobes and mud mortar with the exception of number (3). The three areas are (1) the front or south door, (2) the large pier on the south end of the nave, west side, and (3) campo santo gate piers, with fired bricks.

This will be accomplished with a lime grout. The formula to be supplied by the project architect. The two major areas are (a) the north side of the church, and (b) the west wall of the granary.

j. Remove Campo Santo Wall Cap and Replace

This should be done in conjunction with the removal of the cement stucco on this wall. Details to be provided by the project architect.

k. Acquire Molded Fired Brick for Later Use

This will be necessary for work to be done in the fall or the next spring when replacement of cyma recta cornice brick: Either contract with a supplier or produce locally.

1. Repair Done Temporarily

This will be in association with the continued investigation of the dome's exterior. Lime plaster or grout to be used.

m. Provide Temporary Repair for Lower Portion of Canales

n. Eliminate Insect and Rodent Access to Structures

A vigorous maintenance program should be initiated immediately by the park to discourage the habitation of insects and rodents in the structures. (Discussion on page 100.)

o. Replaster with Mud and Lime Plaster

2. Action To Be Undertaken in the Fall 1978

a. Replace Wood Lintels

This will involve the replacement of some of the wood members in the church and the restoration of others. It may be necessary to undertake this action on some of the exterior lintels when the cement stucco is removed. It also may be necessary to replace some of the interior lintels earlier if a critical situation develops. Details to be provided by the project architect. (Discussion on pages 20-39).

b. Remove Concrete Blocks from Jesuit Church Foundation

The concrete block foundations are a visual intrusion and should be replaced with stabilized adobes. The adobes should weather but at a slower rate than natural adobes. Details to be provided by the project architect.

c. Replace Soil Cement Adobe Wall

This wall was reconstructed in 1970 to replace a wall reconstructed by Pinkley. It extends from the southwest corner of the granary to the corridor. It is a visual intrusion and should be replaced with natural adobes.

d. Replaster Interior of Cisterns

The existing should be removed as should any cement stucco and replaced with lime plaster.

e. Remove Concrete from Drain Located Northeast of Cisterns

f. Remove Metal Structure Over Corridor

The metal structure is a visual intrusion and is also adversely affecting the sacristy to which it is attached. The remaining walls of the corridor can be preserved by cyclic maintenance.

g. Restore Original Canales on North Side of Church

The restoration work is necessary for the preservation of the canales. Details to be provided by the project architect.

3. Action to Be Undertaken in the Spring 1979

a. Drainage System

The construction of a subsurface drainage system is an anticipated action based on the results of the subsurface investigation. It should be designed to incorporate any future drainage needs which can be anticipated. This work element seems logically to be a contract job. Also to include regarding.

b. Dome and Vault Repair

This will be based on further investigation but will include major redesign of the drainage at the exterior base of the dome. It should be undertaken in conjunction with the repair of the ledge around the church and the parapet wall, probably by the same contractor.

c. Ledge Repair

The upper portion of the ledge should be removed down to original adobes or earlier fired brick and replaced with a totally impervious flashing after reconstructed up to its original height.

d. Reconstruct Upper Portions of Nave Walls

This work to be done in conjunction with nave roof repair. (For discussion of upper wall condition see the Tumacacori Preliminary Report).

e. Repair Nave Roof

The details of this work are pending on further investigation of structural and functional needs. It will incorporate a redesign or alteration of the present roof drainage system.

f. Repair and Replace Brick Cornice

This should be done in conjunction with the upper wall repair and the rehabilitation of the nave roof. It also includes the repair of the exterior brick cornice of the sanctuary done in conjunction with the dome repair.

g. Canale Replacement or Repair

This too should be done in conjunction with the repair of the upper nave walls and the roof.

h. Remove Metal Structure Over Granary

The metal building is a visual intrusion which distracts from the resource it is supposed to protect. What remains of the original material can be preserved with a cyclic maintenance program.

i. Remove Building Over Extant Convento

Of the three structures built over portions of the original convento, this one is the most intrusive and contributes most to the deterioration of the resource. Compare figure 40 with figure 44. The removal of the building will not constitute neglect of the resource since it can be preserved through a cyclic maintenance program.

j. Replace Asphalt Walks

A trail system is necessary for practical reasons for the handicapped and during inclement weather. However, the current material is visually intrusive and should be replaced with stabilized soil. Also, the current trails are oriented to the existence of the structures which cover the convento buildings to some extent. The change in this situation will dictate a change in the trail system. A comparison between the visual impact of the asphalt trails and a more desirable situation can be appreciated when comparing the trails located to the east of the church with the lack of a trail along the west of the church.

F: RECOMMENDATIONS FOR FURTHER RESEARCH IN THE 1978 HISTORIC STRUCTURE REPORT FOR TUMACACORI

A. CONSERVATION OF PAINTED PLASTER

In conjunction with the conservation work to be done on the removed painted pendentive it will be appropriate to include the cleaning and evaluation of the painted plaster in the sanctuary. The contractor will be monitored and advised by the project architect.

B. SUBSURFACE INVESTIGATION

An additional subsurface investigation is necessary to determine the subtleties of the subsurface capillary moisture source. The overall investigation should be planned and undertaken by the Division of Cultural Properties Conservation (WAC), with the consultation of the project architect, who is responsible for the coordination of the overall project.

C. ARCHEOLOGY

The only archeological work will be undertaken in response to an anticipated subsurface disturbance related to further subsurface investigation, minor alteration of the existing grade, the installation of a subsurface drainage system, and any other preservation related investigation or activity which would potentially affect any subsurface resources.

D. NEW OR REPLACEMENT MATERIALS

The optimum materials and methods for the preservation will continue to be studied on site until the specific repair is undertaken. Some variations of the methods currently proposed could be appropriate if the removal of much of the extraneous materials such as the cement stucco reveals extraordinary conditions.

E. ENGINEERING STUDY OF TUMAÇACORI'S RESPONSE TO SEISMIC ACTIVITY

This study will be of a basic nature and consist of the comparison of available seismic data with the structure's theoretical and anticipated actual structural integrity. Much information is currently available, consequently a more thorough specific study is not thought necessary. (See pages 7-19 for discussion).

F. INVESTIGATION OF UPPER WALL VOIDS

During the initial phase of architectural investigation several voids were located along the upper nave walls of the church. It will be necessary to gather more definitive information on this condition before actual repair is undertaken and if possible, the extent of voids will be determined nondestructively by a microwave scan.

APPENDIX G

United States Department of the Interior

NATIONAL PARK SERVICE

DENVER SERVICE CENTER
755 Parfet Street
P.O. Box 25287
Denver, Colorado 80225

IN REPLY REFER TO:

December 6, 1982

H30 (TWE-DSC)

Memorandum

To: Regional Director, Western Regional Office

From: Assistant Manager, Alaska/Pacific Northwest/Western Team, DSC

Reference: Tumacacori, Pkg. No. 122, Mission Church Stabilization

Subject: Summary of Paint Conservation at Tumacacori and Estimate of Work Required to Complete the Project

At the October 1982 Work Session we agreed to submit a short summary report on the conservation work carried out at Tumacacori this past summer and to present in this report an appraisal of additional work required, along with a cost estimate to carry the project to completion. The enclosed report, prepared by Tony Crosby, presents this information. Although Mr. Crosby's report is well illustrated and informative, it is an interim report only, and should not be considered a final report on the work.

Kenneth Raithel, Jr.

Enclosure

cc:
Supt., Tumacacori, w/enc.
Chief, WACC-Ms. Martin, w/enc.
Gen. Supt., SOAR, w/enc.

TUMACACORI CONSERVATION: A PROPOSAL FOR THE COMPLETION OF THE WORK

During this past summer a conservation team composed of service personnel and painting conservators from the International Center for the Study of the Preservation and Restoration of Cultural Property (ICCROM) collaborated on the conservation of paint and plaster in the sanctuary interior at Tumacacori National Monument. It was anticipated that this effort would complete this last major portion of the Tumacacori preservation project. The estimate of the time required was included in the project design, "Tumacacori Conservation Report: The Condition of the Paint and Plaster and a Proposal for its Treatment". However, the amount of time allotted was not adequate. Approximately 60% of the work was completed leaving 40% unfinished. The primary and most important work was in the sanctuary, but some work was planned for the nave as well.

Report on the Completed Conservation Work

The major items of completed work consisted of; (1) cleaning, (2) infilling of deteriorated plaster, (3) stabilization and consolidation of the plaster, (4) reattachment of paint, and (5) reattachment of plaster to the adobe substrate. Some of this work, specifically the reattachment of the paint film to the plaster, went much faster than anticipated. Other work, such as cleaning the south side of the dome, and some plaster infilling went much slower. In addition, a great deal of time was required to remove concrete and putty used inappropriately during previous preservation work. Conservation work completed, with minor exceptions, from the top of the dome down to the elevation of the window sills (figure 1).

Polyvinyl and acrylic resins were used as consolidents and adhesives to some extent when appropriate, but the majority of the work was completed using unamended lime plaster, plain water, and tissue. A basically conservative approach to resolving the conservation problems was the principal consideration throughout the project.

Visual comparisions provide the best information about the extent of the work, and its overall effect. Figures 2a and 2b show a before-and-after-treatment comparison of the lower portion of the west surface of the dome.

Figures 3a and 3b show the condition of the painted volute on the upper portion of the painted retablo on the north wall in 1976, in 1982 prior to treatment, and after treatment. The last comparison, Figures 4a and 4b shows the entire dome area before and after treatment.

The stabilization of friable plaster edges, the infilling of large cracks and holes, and the reattachment of a loose friable paint film resulted in two beneficial effects. One effect is a visual consistency that allows for a greater appreciation of the remaining original paint and plaster. The second effect is a material soundness which will ensure the continued existence of the original fabric into the future.

During this work several additional problems were uncovered, and one previously identified problem was not completely resolved. One new problem is the complete lack of structural integrity of the interior window lintels - a condition that will not allow them to support the original wall plaster attached to their surface. The physical condition of the wood was identified earlier in the preservation project, but it was not known until recently that this portion of the original paint and plaster was dependent on the lintel for support. The problem probably can be resolved by consolidation of the lintel with epoxy and reattachment of the plaster to the structurally sound lintel which would result. Another problem was the need for some plaster consolidation and reattachment in several areas on the exterior of the building.

The previously identified problem of the reattachment of lime plaster to mud brick walls was resolved to some extent by using polyvinyl acetate (PVA) as an adhesive. The PVA was injected behind the plaster, between it and the adobe wall. The other cases such as will likely occur in the nave, this system may not work and an alternative system using nylon screws may be more successful. This latter system is new, but has been used successfully on mural paintings in Italy.

The success of the conservation work was dependent to a large extent upon the specific conditions at Tumacacori and the effectiveness of specific techniques which had been developed elsewhere. However, another important reason for the success was the skills of the conservators from ICCROM and the dedication and hard work by the park service conservators. As the work progressed, the service employees began to develop skills and a great deal of sensitivity, which made the work proceed more quickly and with better results than when they first began.

This part of the conservation work involved three ICCROM conservators and seven park service people. Four of the park service people were on training assignments, with their offices paying their salaries. The other three park service people were from the Denver Service Center and the Western Archeological and Conservation Center. Their salaries were also paid by their home offices. The arrangement between National Park Service and ICCROM specified that ICCROM would pay the salaries of their employees and the National Park Service would pay all travel expenses. Consequently, the cost of the project to Tumacacori, mainly in travel expenses was slightly less than $20,000.

<u>Proposal for Future Treatment</u>

The proposal for the remaining conservation work is based upon the results of the initial testing and the success of the work this past summer. A third important aspect of the proposal is that if the remaining work can be undertaken in a timely fashion, many of the same participants will likely be available thus saving the cost of breaking in inexperienced people. The components of the conservation work are generally the same as outlined at the beginning of the conservation project. One exception is that most, if not all, of the reattachment of the friable paint film with water and tissue paper has been completed. Another exception is the addition of epoxy wood lintel consolidation in the sanctuary.

The general components of the remaining conservation work are listed below:

1. Consolidate and reattach paint and plaster.

2. Clean plaster surface as appropriate.

3. Reconstruct missing plaster as appropriate.

4. Replace cement bead in lower plaster edge.

The extent of the remaining plaster consolidation work on the lower sanctuary walls, in the sacristy and nave is limited. A much more critical situation exists on original plaster on the exterior north and south of the church.

The cleaning of the plaster will also be limited, but a minimal amount will be done in the sanctuary nave, and baptistry. As was pointed out in the "Tumacacori Conservation Report..." the decision on whether or not to clean the dark sacristy walls is primarily an interpretive decision, as it is not necessary from a conservation standpoint.

The reconstruction of missing plaster will also be less extensive then was necessary this past summer, but some is needed on the original plaster at specific locations on both the interior and exterior of the building.

The replacement of the cement bead has also been planned for this past summer, but it was not begun. It will be necessary along the lower edge of all original interior plaster.

The following is a specific priority listing of the remaining conservation work:

1. Complete the sanctuary work including the critical wood lintel consolidation treatment.

2. Consolidate original exterior plaster on the north sanctuary wall and the south facade.

3. Reattach delaminated plaster and repair edges and fill holes in the important original painted plaster existing on the entrados, or underside of the main arched doorway opening.

4. Consolidate plaster where necessary and reattach to the adobe walls.

5. Replace cement bead on the lower edges of original plaster in sacristy and nave.

6. Clean walls where necessary.

The cleaning of the sacristy walls is included as a part of No. 6 but probably should be considered of even lower priority.

Priority No. 5 is very important work, but is not listed as a higher priority as it could be done by the Tumacacori maintenance staff with some supervision.

This work could best be accomplished by two conservators who would direct the work and make the technical decisions and recommendations, assisted by four additional less experienced conservators. The total of six is preferable over the number of nine and ten used during the previous summer's work. Assuming a crew of six people with previous conservation experience at Tumacacori the remaining work can be completed in approximately six weeks. The approximate cost for this work will be considerably greater then this past summer since salaries will have to be included this year.

The cost estimate for the completion of all work excepting the cleaning of sacristy walls follows:

Travel (includes all travel related expenses such as air and ground transportation and per diem).	$12,000
Material costs	1,000
Salaries	24,500
Total Estiamted Cost	$37,500

The salary costs could vary considerably, depending on the base salaries or grades of the individuals and their organizations. A more detailed and accurate estimate will have to be prepared when the make up of the team is known.

Recommendation

It is specifically recommended that the National Park Service contact ICCROM as soon as possible to request their participation in the continuation of the project. It is also recommended that those National Park Service employees who participated previously be contacted to begin specific plans for putting together a team to undertake the work at a time acceptable to the Superintendent at Tumacacori, the Region and ICCROM.

December 8, 1982

United States Department of the Interior

NATIONAL PARK SERVICE
WESTERN REGION
450 GOLDEN GATE AVENUE, BOX 36063
SAN FRANCISCO, CALIFORNIA 94102

IN REPLY REFER TO:
H30
(WR)RC

May 25, 1977

Memorandum

To: Chief, Western Archeological Center
General Superintendent, Southern Arizona Group
Superintendent, Tumacacori

From: Acting Chief, Division of Cultural Resource Management, Western Region

Subject: Section 106 Compliance, Tumacacori Church - Research and Preservation

Enclosed are the comments of the Advisory Council on Historic Preservation, dated May 24, 1977, which completes the compliance action.

Also enclosed are copies of the letter of May 23, 1977, to the Advisory Council from the Acting Regional Director, Western Region, and the teletype message of May 23, 1977, from the State Historic Preservation Officer with her comments.

The enclosures should be added to the letter of May 17, 1977, to the State Historic Preservation Officer from the Regional Director, Western Region, copies of which were previously sent to your offices. This will then represent all of the compliance documentation on the undertaking.

SIGNED Thomas D. Mulhern, Jr.

Thomas D. Mulhern, Jr.

Enclosures

cc:
WASO-560, Cultural Resources Management Division
DSC-TWE, Manager, Denver Service Center
Attention: Assistant Manager, Pacific Northwest/Western Team
DSC-QE, Manager, Denver Service Center
Attention: Quality Control and Compliance Division
DSC-MH, Manager, Denver Service Center
Attention: Historic Preservation Division

Advisory Council on
Historic Preservation
1522 K Street N.W.
Washington, D.C. 20005

May 24, 1977

Mr. Bruce M. Kilgore
Acting Regional Director
Western Region
National Park Service
450 Golden Gate Avenue, Box 36063
San Francisco, California 94102

Dear Mr. Kilgore:

On May 24, 1977, the Council received a determination from the National Park Service that preservation research and related actions designed to preserve the Tumacacori Church and related historic structures at Tumacacori National Monument, Arizona, would not adversely affect that property which is included in the National Register of Historic Places. The Executive Director notes no objection to your determination.

A copy of your determination of no adverse effect, along with supporting documentation and this concurrence, should be included in any assessment or statement prepared for this undertaking in compliance with the National Environmental Policy Act and should be kept in your records as evidence of your compliance with Section 106 of the National Historic Preservation Act of 1966 (16 U.S.C. 470f, as amended, 90 Stat. 1320).

Your continued cooperation is appreciated.

Sincerely yours,

for Robert M. Utley
Deputy Executive Director

United States Department of the Interior

NATIONAL PARK SERVICE
WESTERN REGION
450 GOLDEN GATE AVENUE, BOX 36063
SAN FRANCISCO, CALIFORNIA 94102

IN REPLY REFER TO:
H30
(WR)RC

May 23, 1977

Mr. Louis S. Wall
Assistant Director
Office of Review and Compliance
Advisory Council on Historic Preservation
P.O. Box 25085
Denver, Colorado 80225

Dear Mr. Wall:

The Western Region proposes to approve preservation research and related actions designed to preserve the Tumacacori Church and related historic structures at Tumacacori National Monument, a property on the National Register.

In accordance with the procedures of the Advisory Council on Historic Preservation we have obtained the comments of the State Historic Preservation Officer, copy enclosed, which indicates that the undertaking will not have an adverse effect on cultural resources.

A copy of the letter to the State Historic Preservation Officer, May 17, 1977 has been previously supplied your office. We will appreciate your prompt review and comment on this proposed action for this week personnel are coming from Washington to aid in the installation of some of the monitoring equipment. We will appreciate your office sending a copy of your comments by magafax to both:

Western Archeological Center 762-6553
Western Regional Office 556-2793

We would like to thank your office in advance for the extra efforts by your staff in promptly considering the undertaking.

Sincerely,

Bruce M. Kilgore
Act. Regional Director
Western Region

Enclosure

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PMS HOVARD A CRAPMAN, REGIONAL DIRECTOR, NATIONAL PARK SERVICA,

WESTERN REGION, FONE

450 GOLDEN GATE AVA

SAN FRANCISCO CA 94102

REFERENCA YOUR LETTER MAY 17 1977 CONCARNING PRESERVATION PROGRAM AT

TUMACACORI NATIONAL MONUMENT ARIZONA. PROCEDURES OUTLINED IN

ENCLOSURE WILL NOT HAVE AN ADVERSE EFFECT ON THE CULTURAL RESOURCES

DOROTHY H HALL STATE HIUTORIC PRESERVATION OFFICER

NNNN

H30
(WR)RC

May 17, 1977

Ms. Dorothy Hall
State Historic Preservation Officer
Arizona State Parks
1688 West Adams
Phoenix, Arizona 85007

Dear Ms. Hall:

The National Park Service, Western Region, proposes to approve preservation research and related actions designed to preserve the Tumacacori Church and related historic structures at Tumacacori National Monument—a property listed on the National Register of Historic Places.

In accordance with the Advisory Council on Historic Preservation's "Procedures" (36 CFR 800), we request your comments on these actions.

A need for a comprehensive preservation program at Tumacacori was recognized several years ago. However, it was not until the church was closed to the public for a short period of time during the winter of 1974-75 that funding to undertake the project became available. The preservation project began in the Fall of 1975 and is expected to continue through 1979. The goal of the project is to first, determine the specific causes and extent of the deterioration and second, to take action that will ultimately halt or control the deterioration of the resource. The preservation research and related activities are all designed to achieve these goals for preservation of Tumacacori National Monument.

Many activities, such as the removal of material samples, the addition of temporary supports, the placement of visible instrumentation, emergency repair, the replacement of non-historic materials, a subsurface drainage system which helps control moisture problems, minor regrading, the construction of walls to test solutions, and subsurface investigation, all have an effect on the resource. However, each results in conditions or knowledge that are directly beneficial to the structural and decorative integrity of the building without altering the desired effect on the visiting public. All monitoring equipment and construction activities are temporary by design and will be removed when no longer required to identify and test the efficacy of preservation techniques.

The temporary presence of monitoring equipment and test facilities provide an additional and ancillary benefit to the public by making them aware of some of the activities necessary for the continued preservation of the resource. A copy of the proposed handout, "Tumacacori Stabilization Project," is enclosed for your information and comment.

A discussion of the work contemplated at this time is included in the above mentioned enclosure. A more detailed discussion of the project is provided in the paper, "Preservation Research" (Enclosure #2). If you have any questions on the undertaking, or if there are other concerns that you believe should be addressed, we would appreciate your contacting Tony Crosby, Project Architect, (602) 792-6501.

In accordance with Section 106 of the National Historic Preservation Act of 1966, and the Procedures of the Advisory Council on Historic Preservation, we have applied the Criteria of Effect and find that there will be an effect on the historic resource at Tumacacori National Monument. However, in applying the criteria of Adverse Effect, we find the above described preservation activities—implemented in accordance with the conditions set forth in "Preservation Research"—will avoid any adverse effect upon those qualities for which Tumacacori National Monument is nationally significant. To the contrary, they are necessary to arrest the deterioration now affecting the Mission and assure its preservation.

If you concur with the above determination, please sign in the place provided below and return the letter to this Office. If no response is received within forty-five days, we shall assume you have no comment. A copy of this letter is enclosed for your files.

Sincerely yours,

Howard H. Chapman
Regional Director,
Western Region

In duplicate

Enclosures 3

I concur with the determination stated that the proposed preservation research and related actions for the preservation project at Tumacacori National Monument will have no adverse effect.

Dorothy H. Hall — 5-23-77

State Historic Preservation Officer — Date

cc:

Office of Review and Compliance, Advisory Council on Historic Preservation, Western Office, P.O. Box 25085, Denver, Colorado 80225

WASO-560, Cultural Resources Management Division

DSC-TWE, Manager, Denver Service Center
  Attention: Assistant Manager, Pacific Northwest/Western Team

DSC-QE, Manager, Denver Service Center
  Attention: Quality Control and Compliance Division

DSC-MH, Manager, Denver Service Center
  Attention: Historic Preservation Division

Chief, Western Archeological Center

General Superintendent, Southern Arizona Group

Superintendent, Tumacacori

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1973 "Salt Action on Stone in Urban Buildings." Application of Science in Examination of works of Art. Edited by William J. Young. Proceedings of the Seminar June 15-19, 1970. Boston, MA: Museum of Fine Arts.

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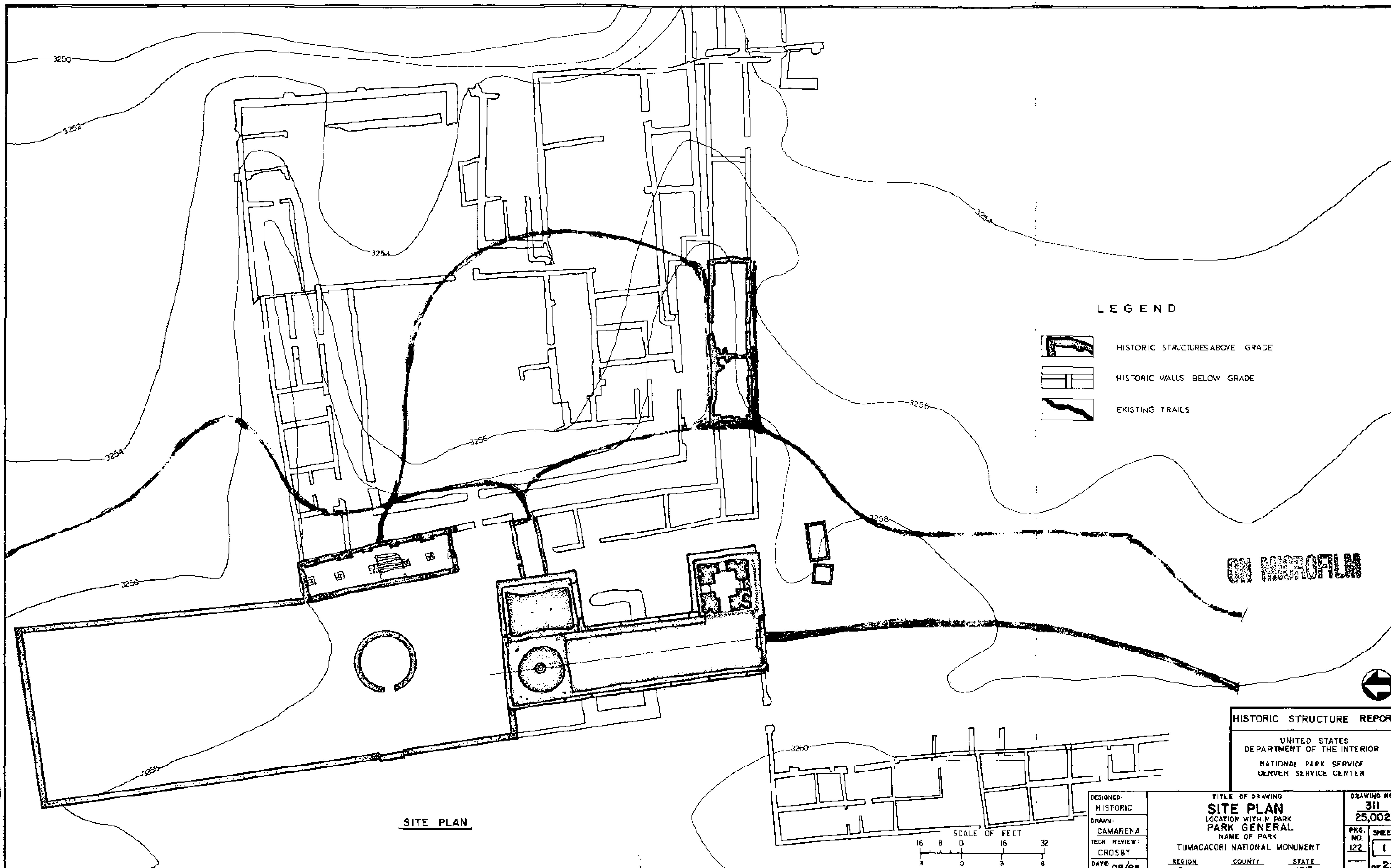
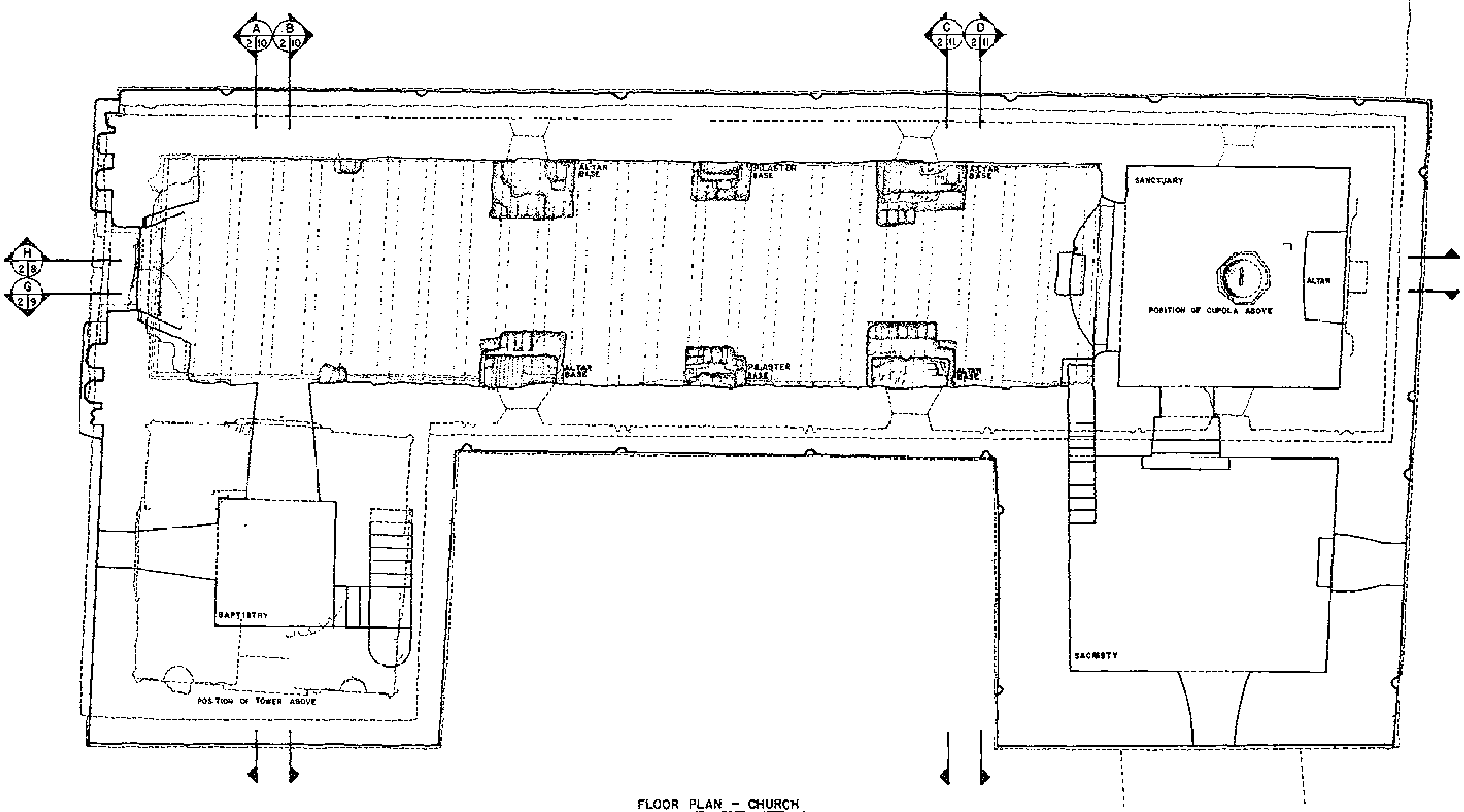
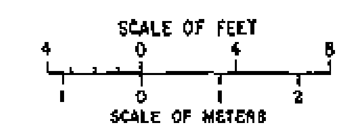
GPO 848-307


LEGEND
HISTORIC STRUCTURES ABOVE GRADE
HISTORIC WALLS BELOW GRADE
EXISTING TRAILS
SITE PLAN
SCALE OF FEET
16 8 0 16 32
SCALE OF METERS
HISTORIC STRUCTURE REPORT
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
DENVER SERVICE CENTER
DESIGNED: HISTORIC
DRAWN: CAMARENA
TECH REVIEW: CROSBY
DATE: 09/85
TITLE OF DRAWING
SITE PLAN
LOCATION WITHIN PARK
PARK GENERAL
NAME OF PARK
TUMACACORI NATIONAL MONUMENT
REGION SW
COUNTY
STATE ARIZ.
DRAWING NO. 311 25,002
PKG. NO. 122
SHEET 1 OF 22



FLOOR PLAN – CHURCH



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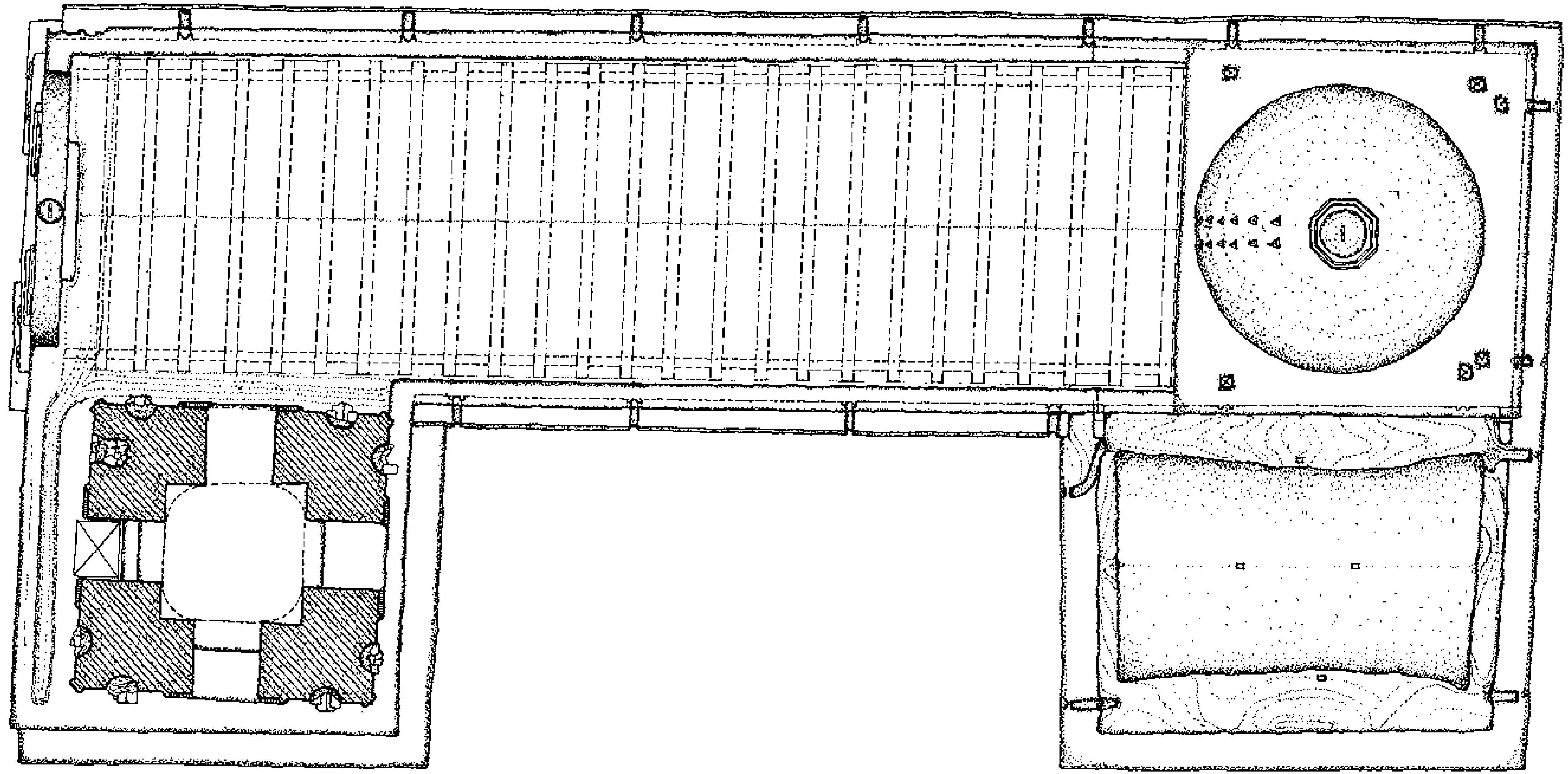
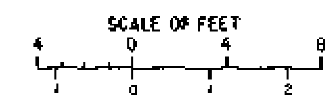
DRAWN: HABS		FLOOR PLAN	PKG. NO. 122
TECH. REVIEW: CROSBY		CHURCH	SHEET 2 OF 22
DATE: /			

BASE DATA: DRAWING BASE REPRODUCED FROM H.A.B.S. DRAWINGS BY OHIO STATE UNIVERSITY DEC. 1973

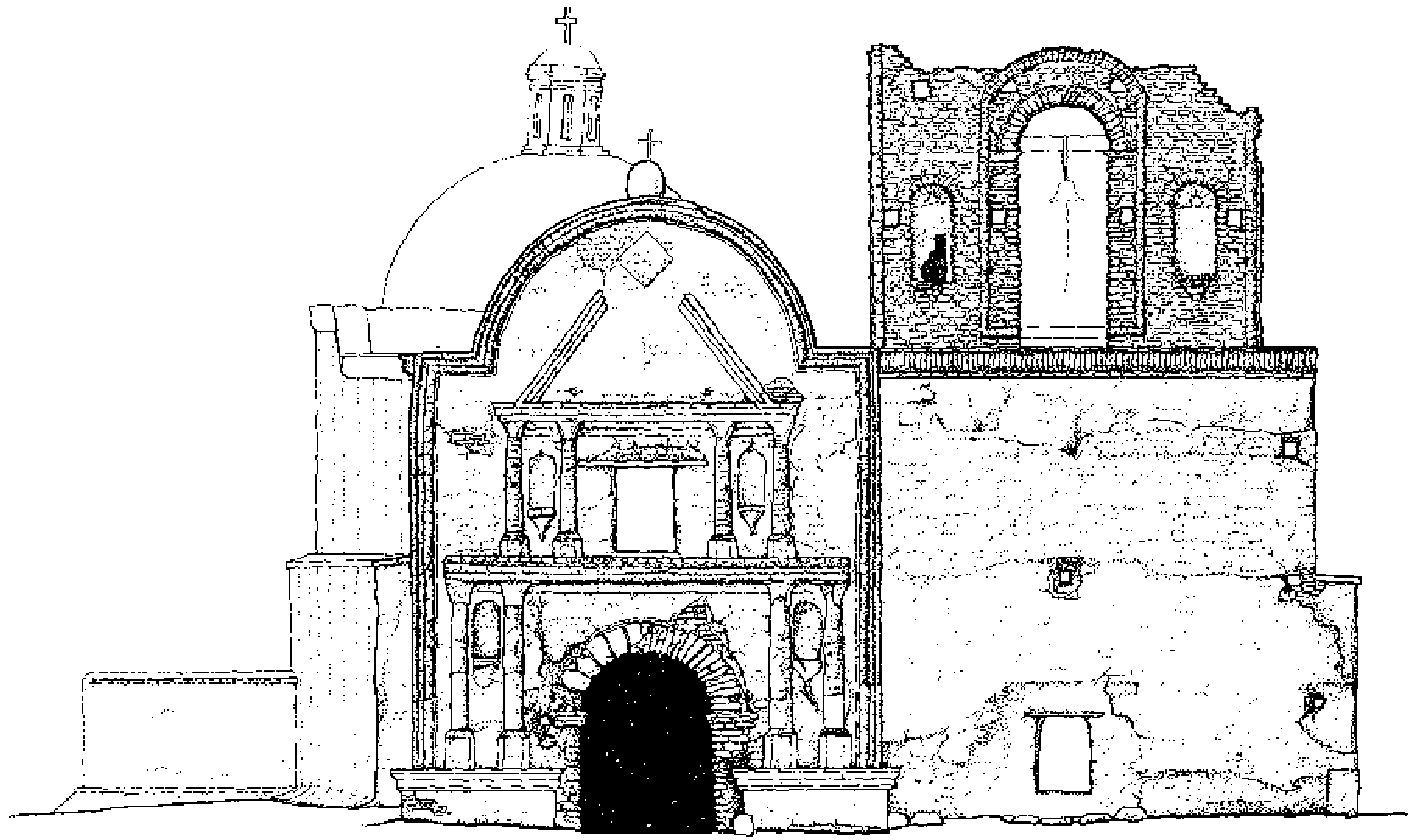


ROOF PLAN — CHURCH



DESIGNED: HISTORIC	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO. 311 / 25,002
DRAWN: CAMARENA		ROOF PLAN	PKG. NO.
TECH REVIEW: CROSBY		CHURCH	SHEET 3 OF 22
DATE: /			

BASE DATA: DRAWING GENERATED FROM 1957 H.A.B.S. ROOF PLAN
COORDINATED WITH 1976 OHIO STATE PLAN ELEVATIONS. FIELD VERIFIED 1976.



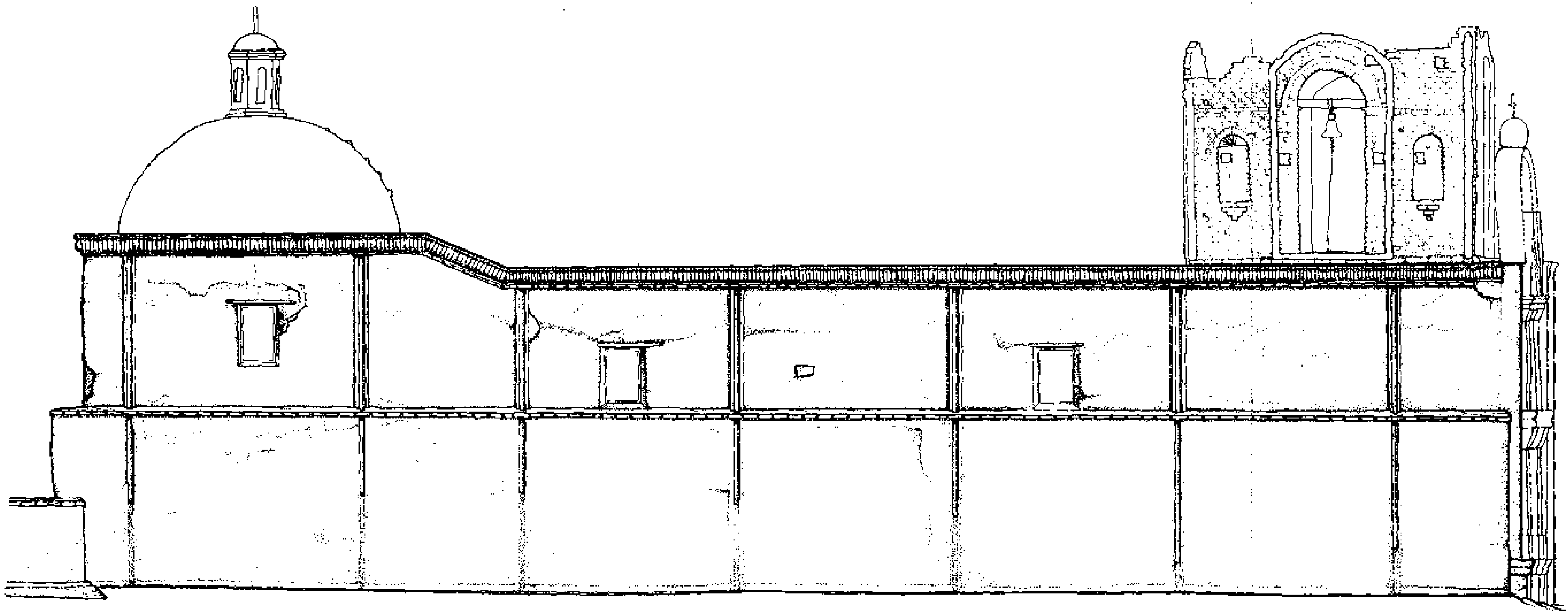
SOUTH (FRONT) ELEVATION – CHURCH

ON MICROFILM

SCALE OF FEET
4 0 4 8
1 0 1 2
SCALE OF METERS

DESIGNED: HISTORIC	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO.
DRAWN: HABS		SOUTH (FRONT) ELEVATION	311 / 25,002
TECH REVIEW: CROSBY		CHURCH	PKG NO. 122 · SHEET 4
DATE: /			OF 22

BASE DATA: DRAWING BASE REPRODUCED FROM
H.A.B.S. DRAWINGS BY OHIO STATE UNIVERSITY DEC. 1975



WEST ELEVATION ~ CHURCH

ON MICROFILM

SCALE OF FEET
4 0 4 8
1 0 1 2
SCALE OF METERS

DESIGNED: HISTORIC	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO. 311 25,002
DRAWN: HABS		WEST ELEVATION	PKG. NO. 122
TECH. REVIEW: CROSBY		CHURCH	SHEET 5
DATE: /			OF 22

BASE DATA: DRAWING BASE REPRODUCED FROM
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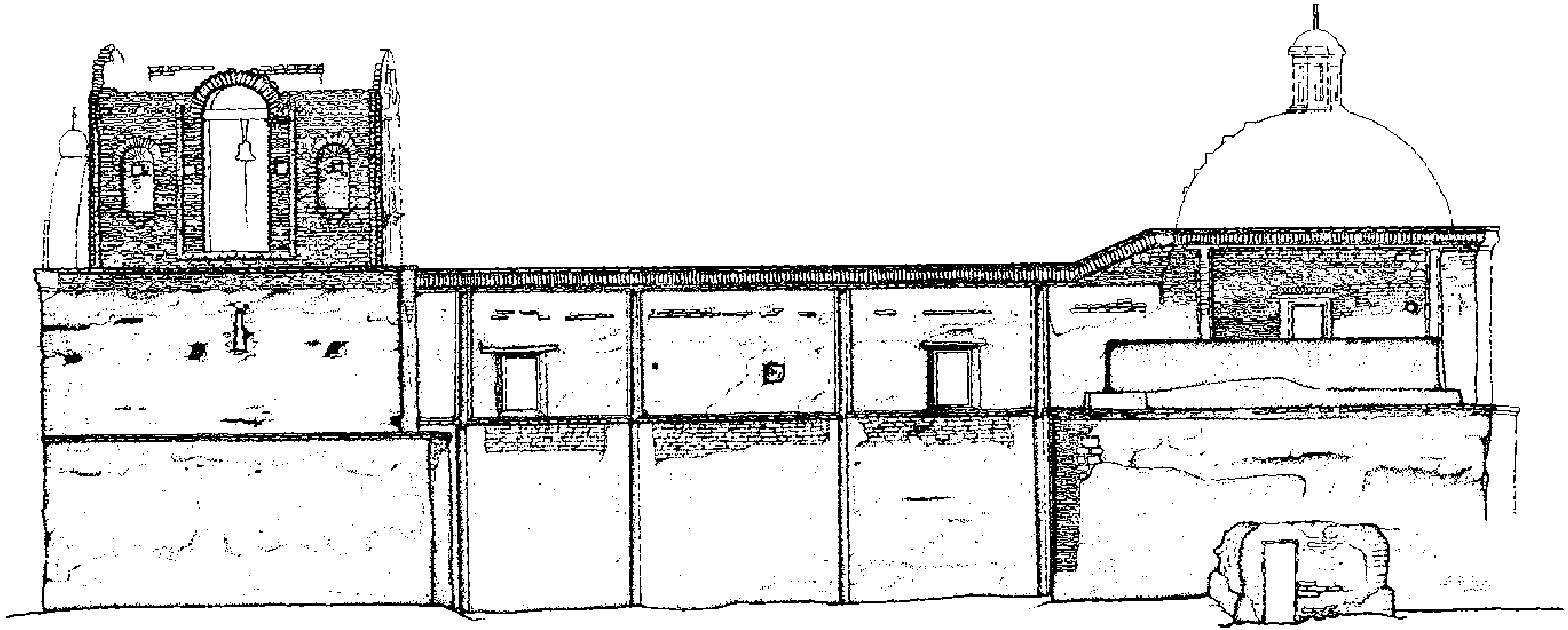


EAST ELEVATION — CHURCH

SCALE OF FEET

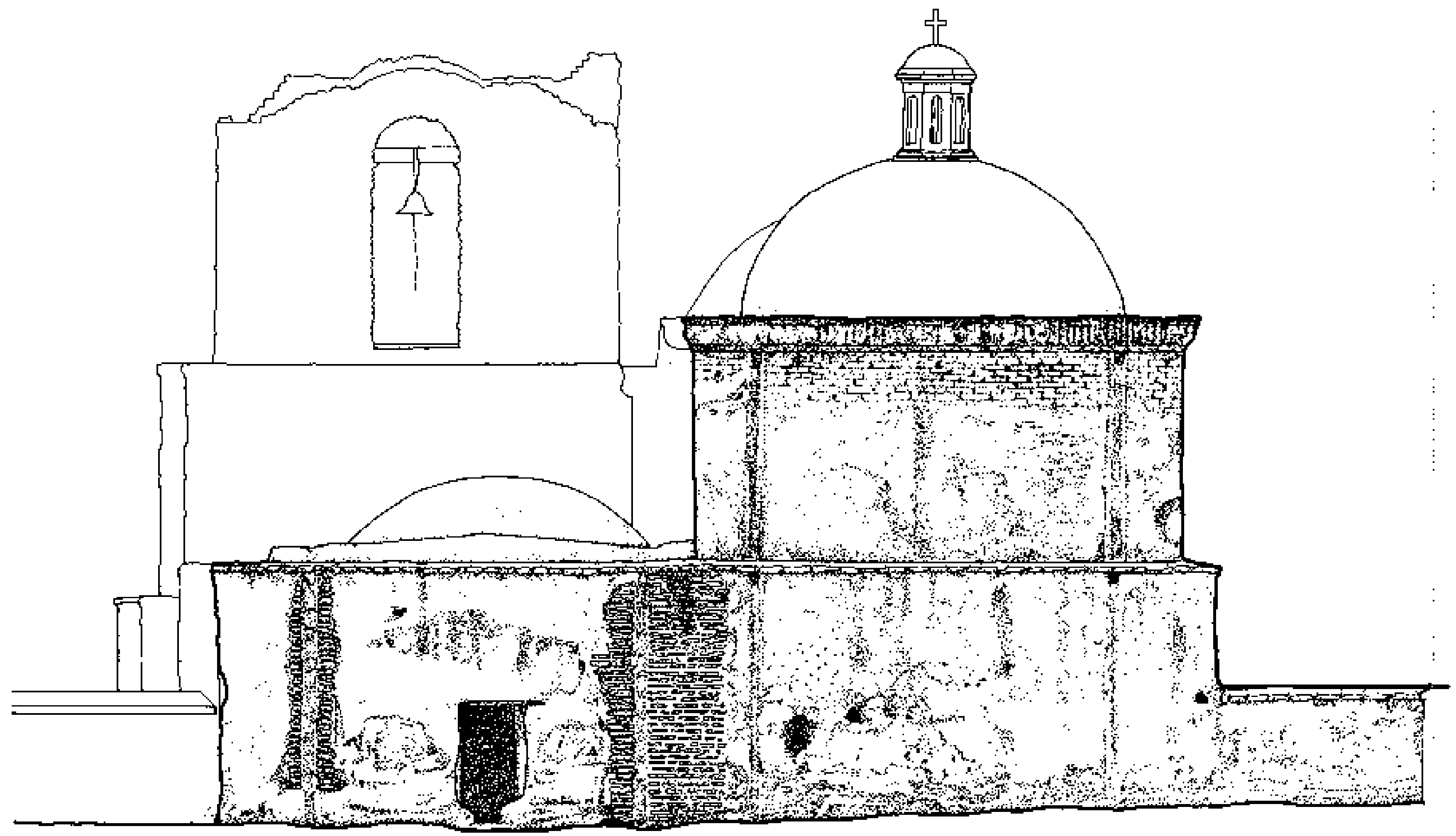
4 0 4 8

1 0 1 2

SCALE OF METERS

DESIGNED: HISTORIC DRAWN: HABS TECH. REVIEW: CROSBY DATE: /	SUB SHEET NO.	TITLE OF SHEET EAST ELEVATION CHURCH	DRAWING NO. 311 / 25,008 PKG. NO. 122 SHEET 6 OF 22

BASE DATA: DRAWING BASE REPRODUCED FROM H.A.B.S DRAWINGS BY OHIO STATE UNIVERSITY DEC. 1975



NORTH ELEVATION (LOOKING SOUTH) – CHURCH

SCALE OF FEET

4 0 4 8

1 0 1 2

SCALE OF METERS

DESIGNED: HISTORIC	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO. 311 25,002
DRAWN: HABS		NORTH ELEVATION	PKG. NO. 122
TECH. REVIEW: CROSBY		CHURCH	SHEET 7
DATE: /			OF 22

BASE DATA: DRAWING BASE REPRODUCED FROM
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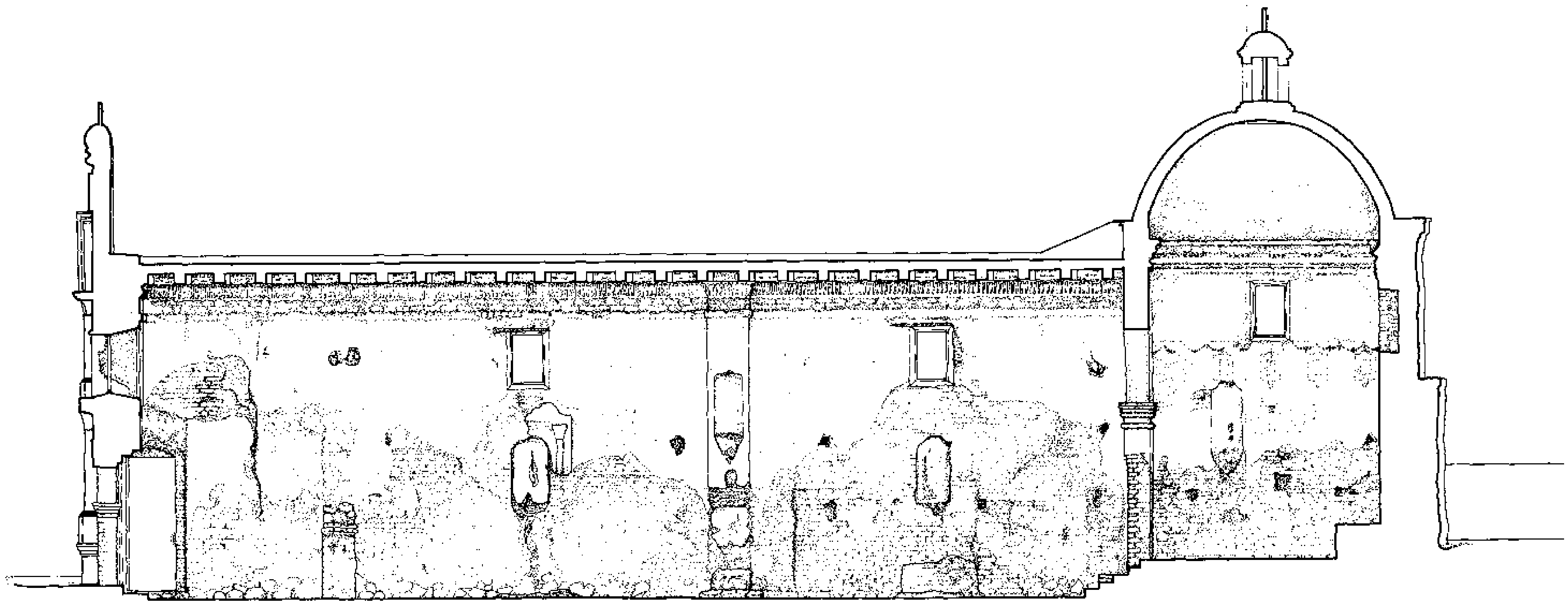
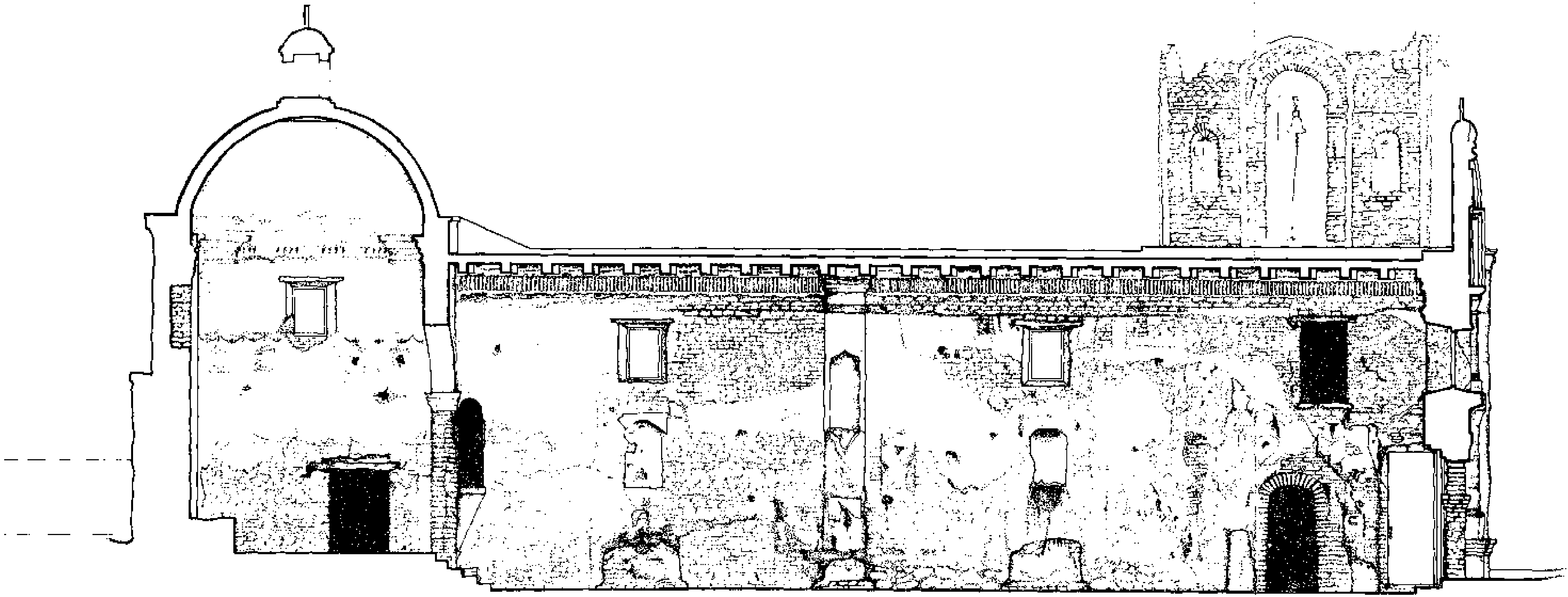


LONGITUDINAL SECTION THROUGH NAVE (LOOKING WEST) H 2|8

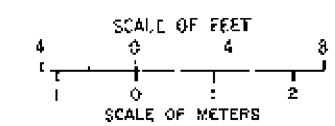
SCALE OF FEET
4 0 4 8
1 0 1 2
SCALE OF METERS

DESIGNED: HISTORICAL DRAWN: HABS TECH. REVIEW: CROSBY DATE: /	SUB SHEET NO.	TITLE OF SHEET **SECTION** CHURCH	DRAWING NO. 311 / 25,002 PKG. NO. 122 SHEET 8 OF 22



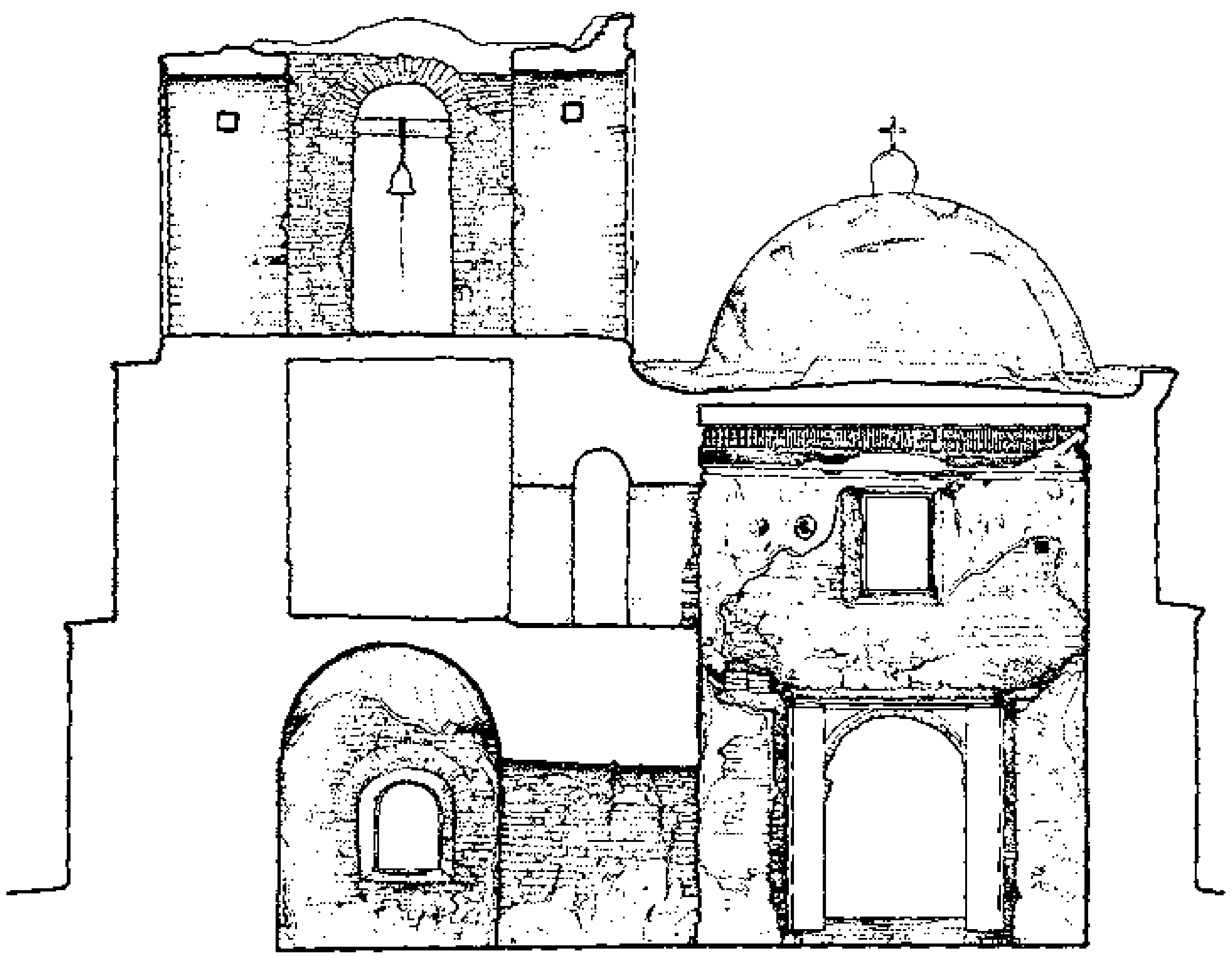
LONGITUDINAL SECTION THROUGH NAVE (LOOKING EAST) G/2 9

ON MICROFILM

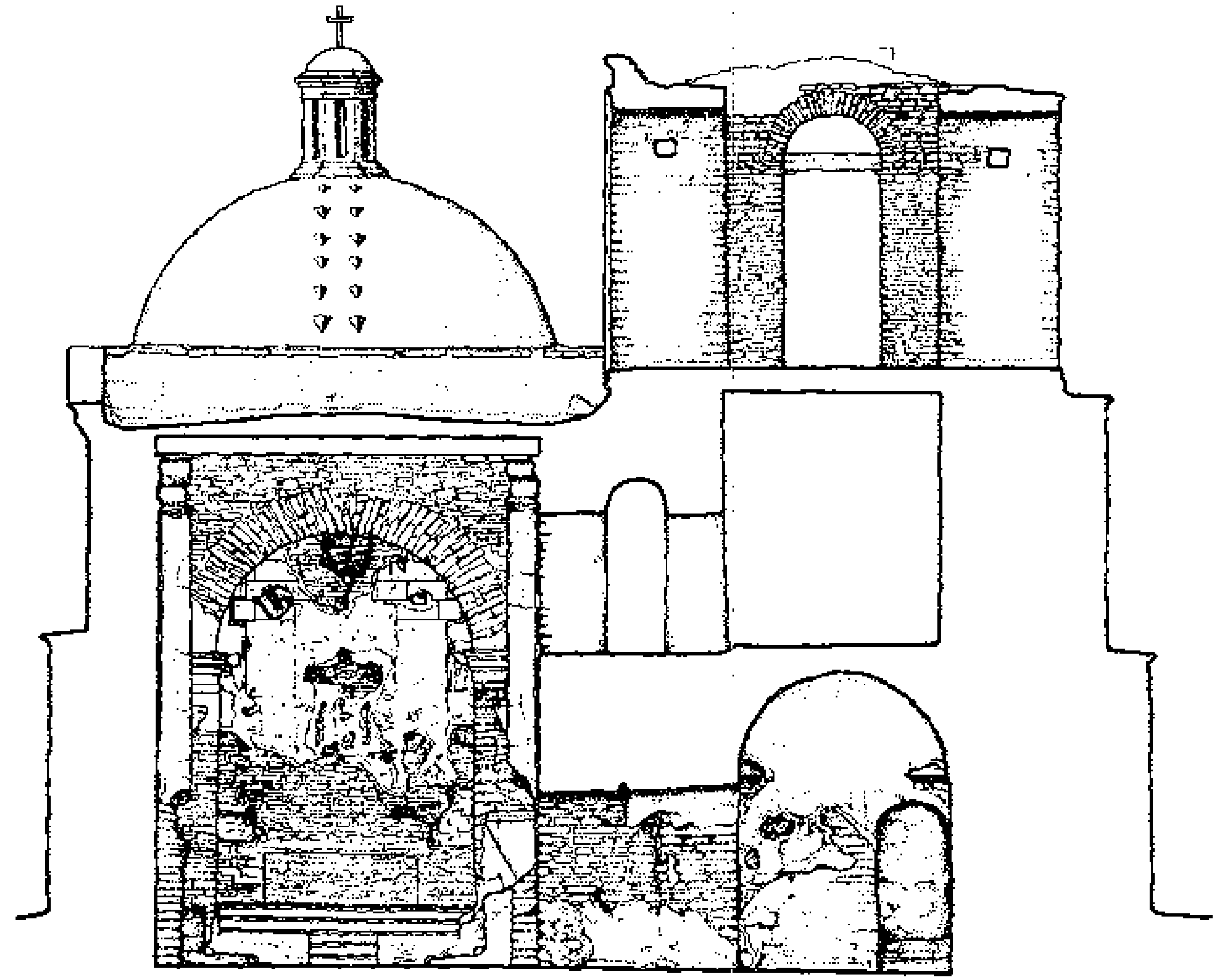


DESIGNED: HISTORIC	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO. 311 / 25,002
DRAWN: HABS		SECTION	
TECH. REVIEW: CROSBY		CHURCH	PKG. NO. 122 — SHEET 9 OF 22
DATE: /			

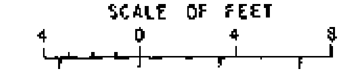
BASE DATA: DRAWING BASE REPRODUCED FROM H.A.B.S. DRAWINGS BY OHIO STATE UNIVERSITY JUNE 1976



SECTION THROUGH NAVE AND BAPTISTRY (LOOKING SOUTH) A 2/10



SECTION THROUGH NAVE AND BAPTISTRY (LOOKING NORTH) B 2/10



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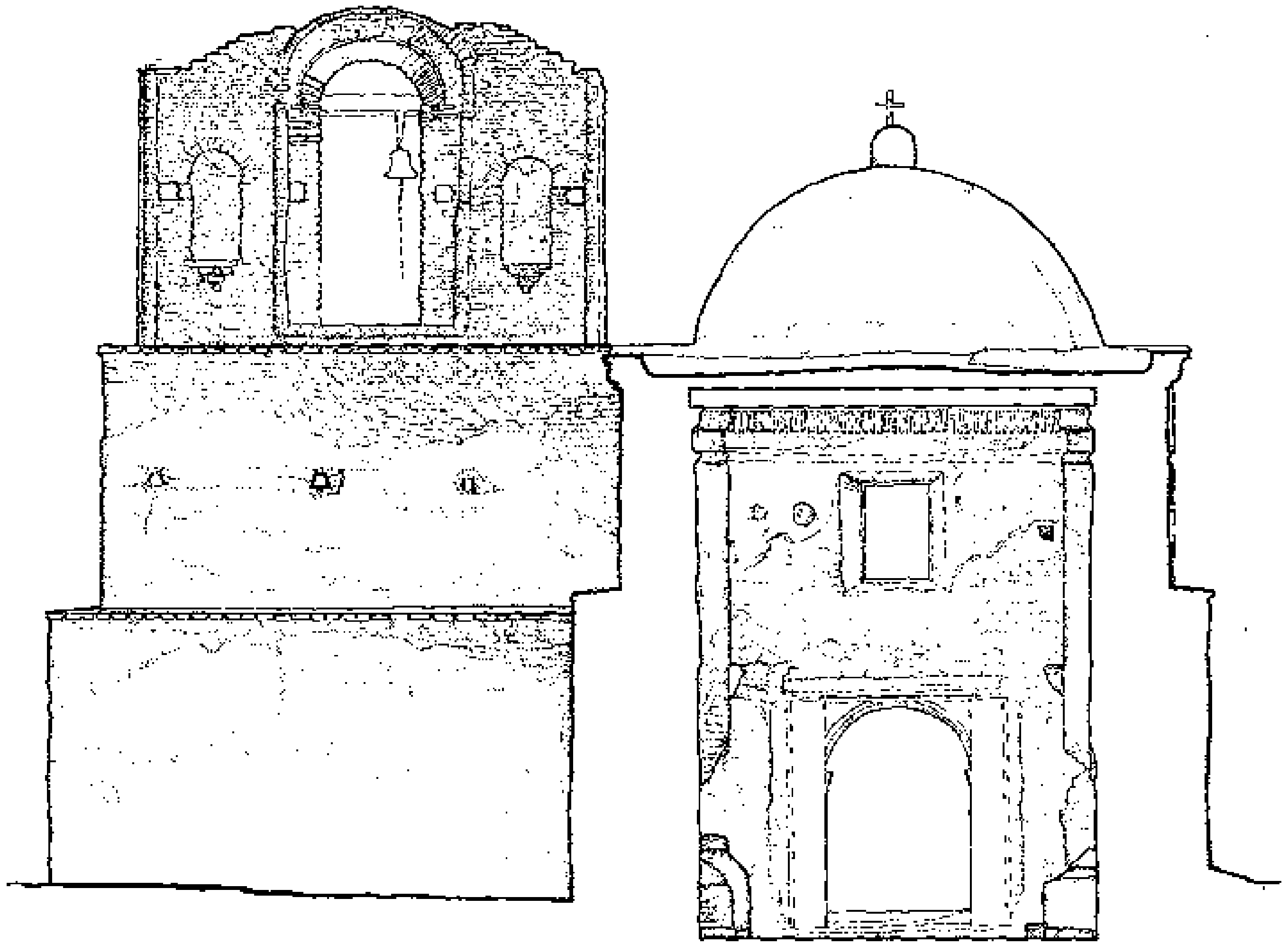
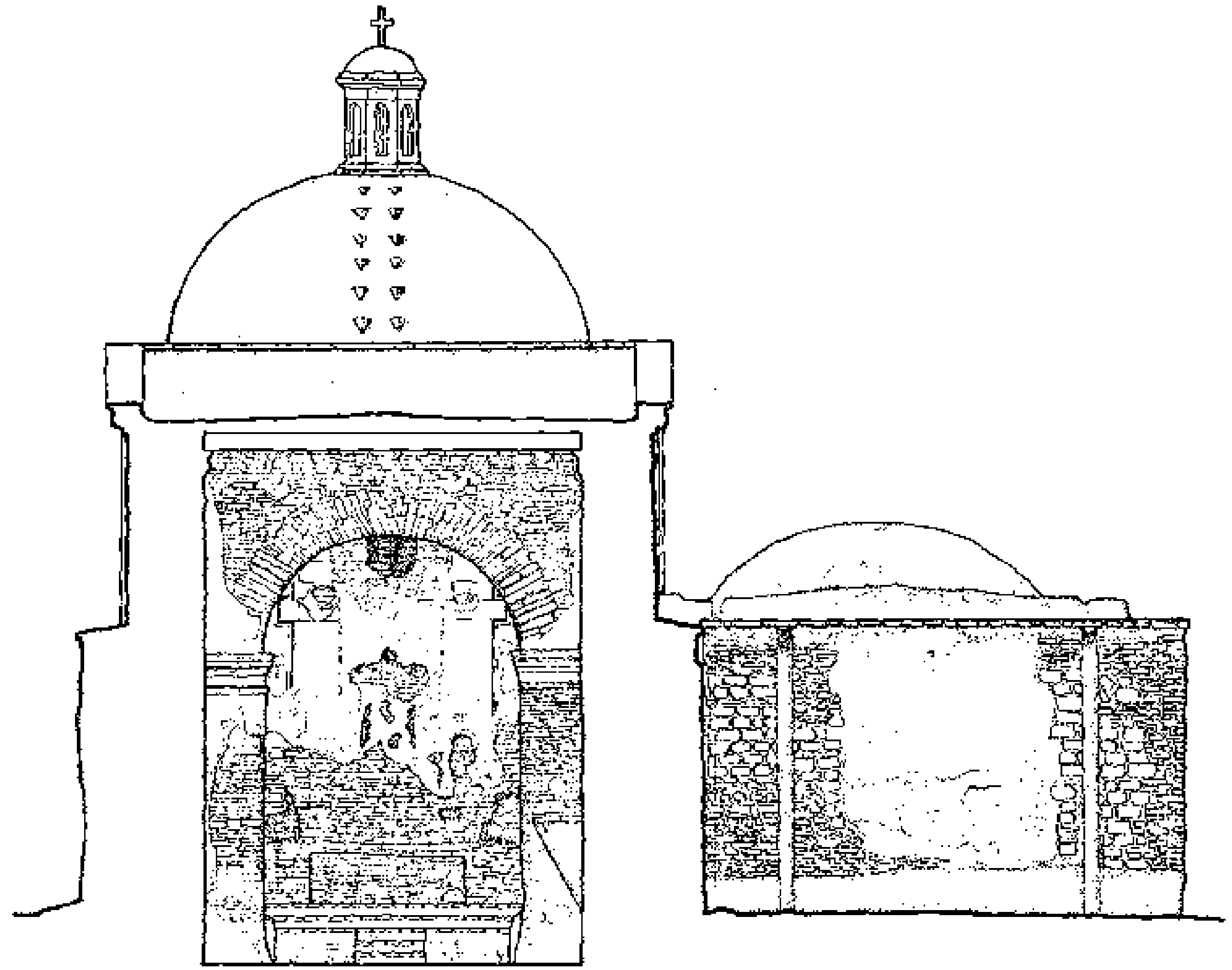
BASE DATA: DRAWING BASE REPRODUCED FROM H.A.B.S. DRAWINGS BY OHIO STATE UNIVERSITY JUNE 1976



SECTION THROUGH NAVE (LOOKING SOUTH) C 2 | 11

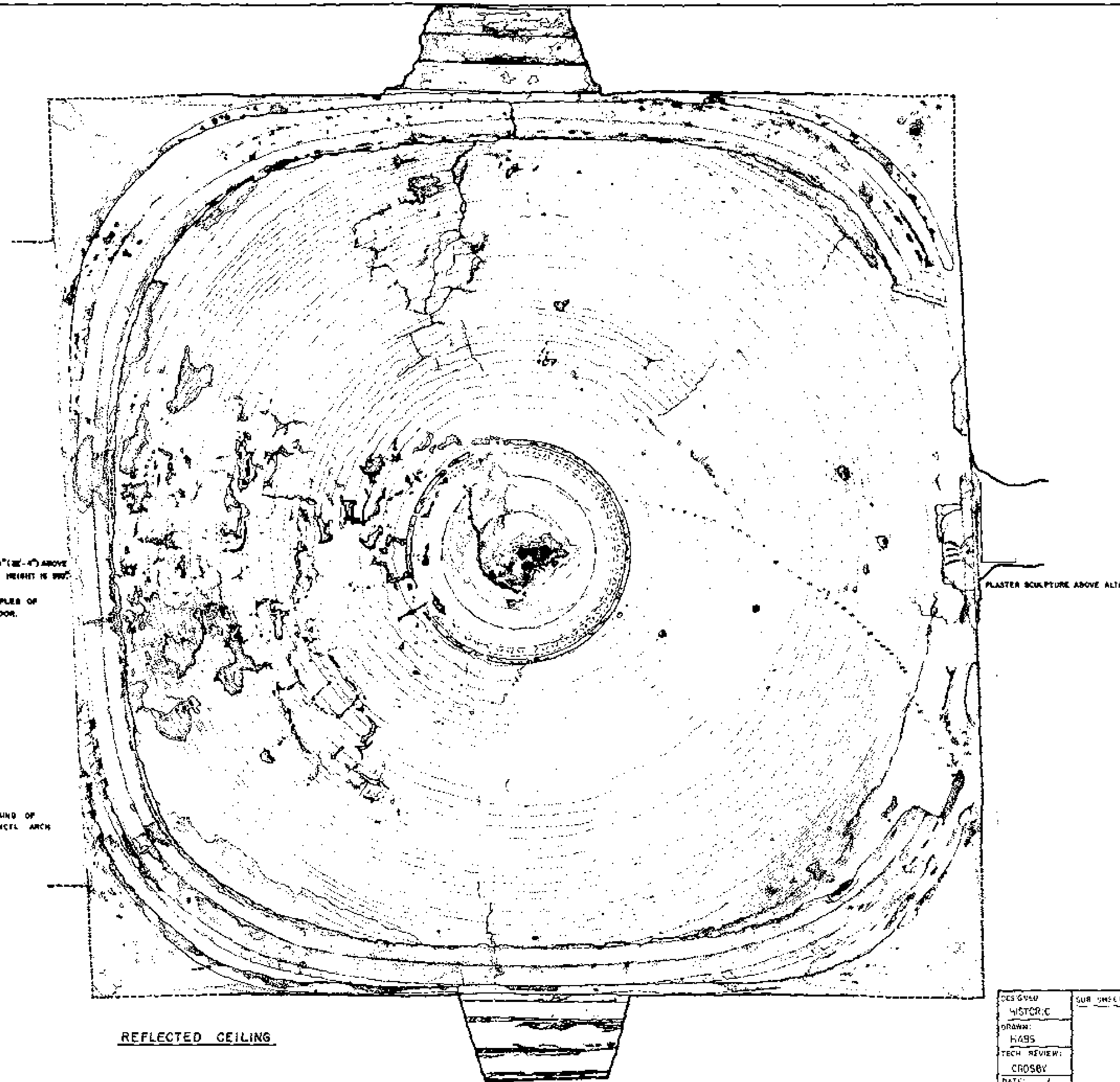


SECTION THROUGH NAVE (LOOKING NORTH) D 2 | 11

SCALE OF FEET
4 0 4 8
1 0 1 2
SCALE OF METERS

DESIGNED: HISTORIC DRAWN: HABS TECH. REVIEW: CROSBY DATE: 7	SUB SHEET NO.	TITLE OF SHEET SECTION C AND D CHURCH	DRAWING NO. 311 25,002 PKG NO. 122 SHEET 11 OF 22

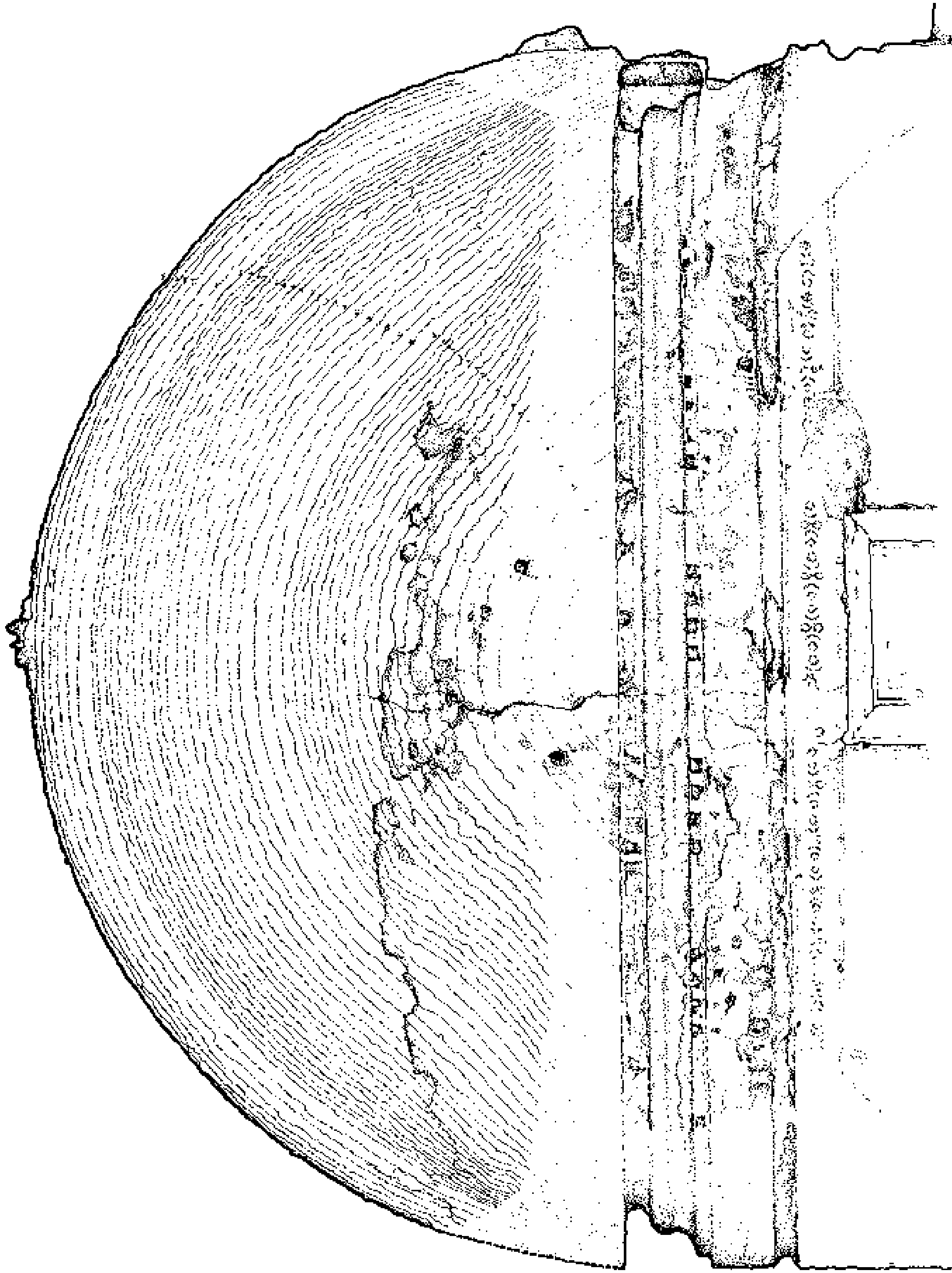
BASE DATA: DRAWING BASE REPRODUCED FROM H.A.B.S.
DRAWINGS BY OHIO STATE UNIVERSITY DEC. 1975



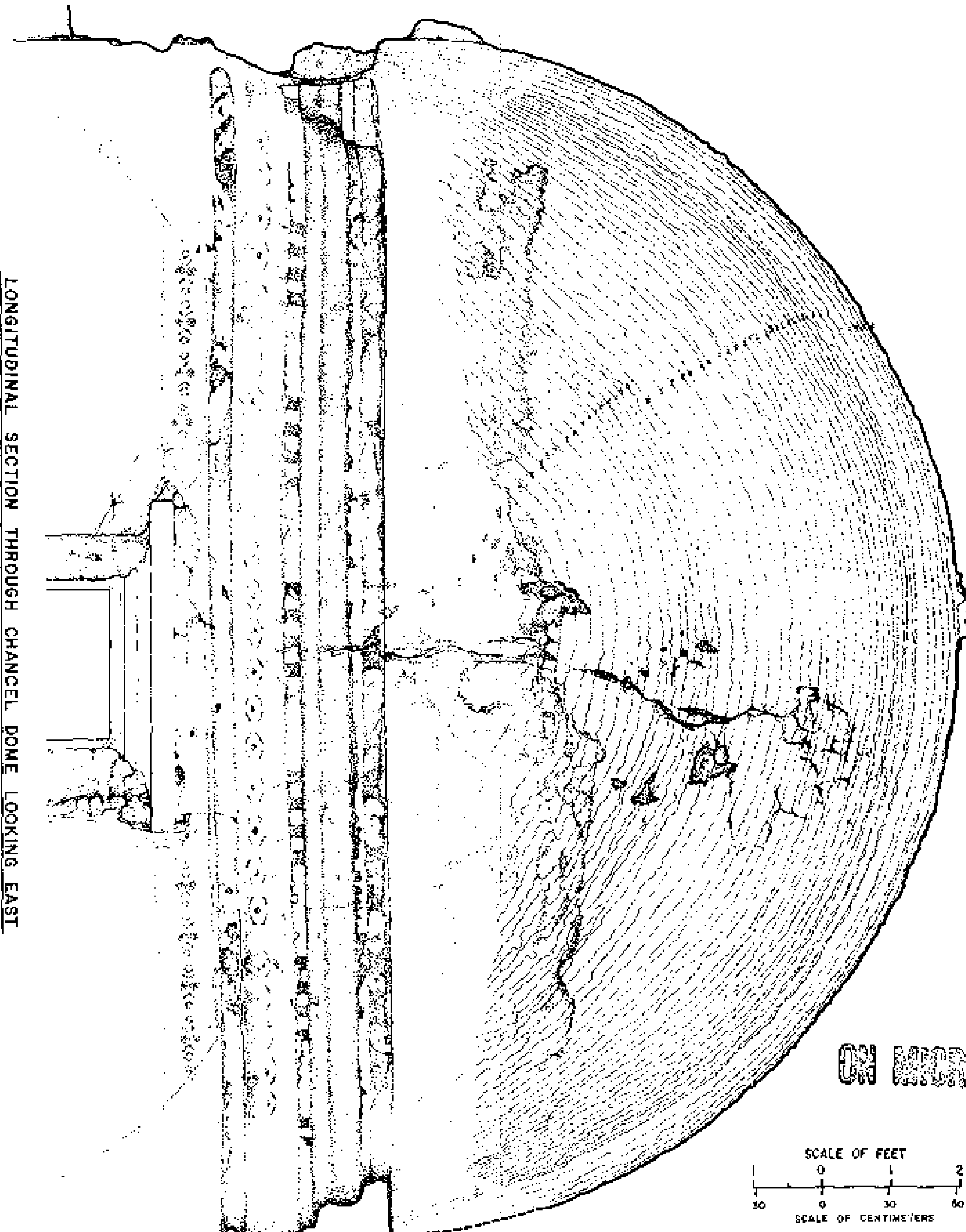
REFLECTED CEILING

SCALE OF FEET
1 0 1 2
0.3 0 0.3 0.6
SCALE OF METERS

DESIGNED: HISTORIC DRAWN: HABS TECH REVIEW: CROSBY DATE: /	SUB SHEET NO.	TITLE OF SHEET REFLECTED CEILING CHURCH	DRAWING NO. 311 / 25,002 PKG. NO. 122 SHEET 12 OF 22



LONGITUDINAL SECTION THROUGH CHANCEL DOME LOOKING WEST

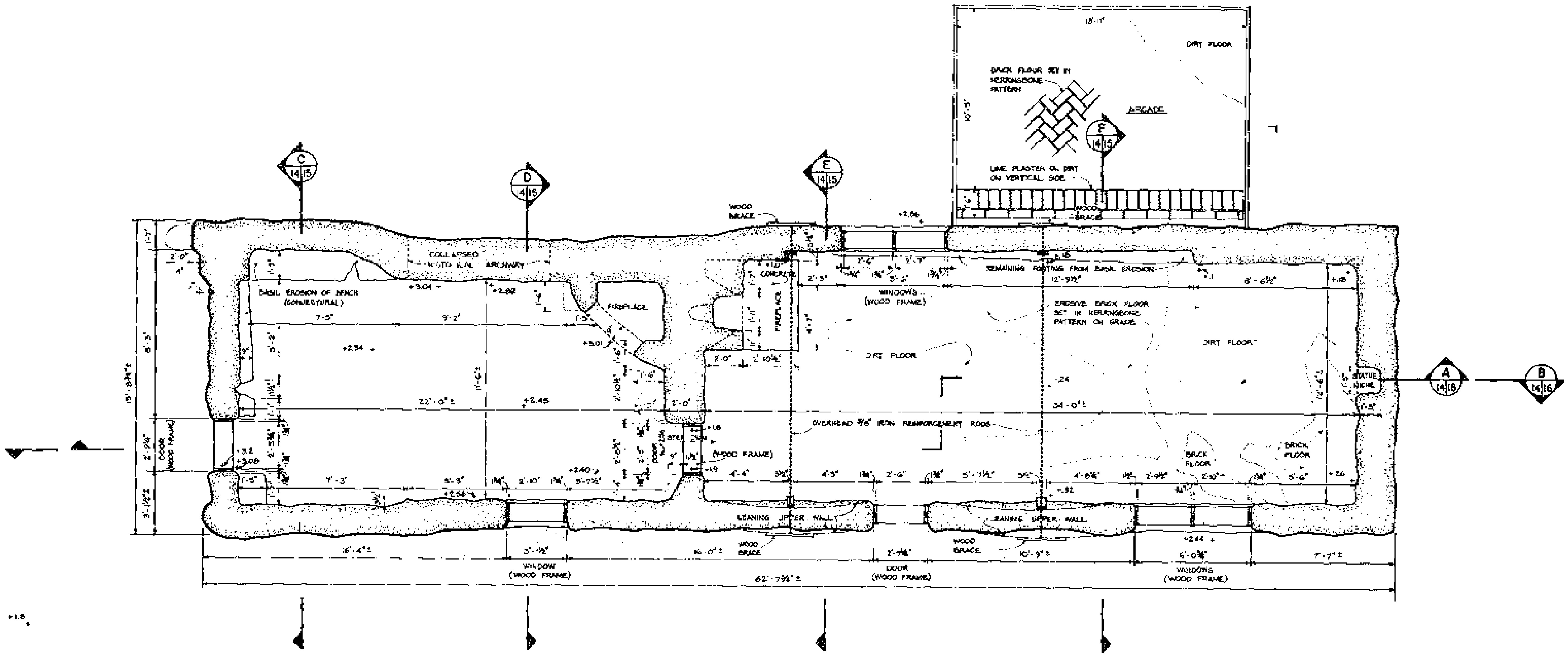


LONGITUDINAL SECTION THROUGH CHANCEL DOME LOOKING EAST

SCALE OF FEET
1 0 1 2
30 0 30 60
SCALE OF CENTIMETERS

VERTICAL SLICES ARE IN INCHES AND MULTIPLES OF INCHES STARTING WITH 0 AT WALL ABOVE WESTERN WINDOW AND CONTINUING TO 200.5" AT WALL ABOVE EASTERN WINDOW.

DESIGNED: HISTORIC DRAWN: HABS TECH. REVIEW: CROSBY DATE: /	SUB SHEET NO	TITLE OF SHEET SECTIONS CHURCH	DRAWING NO 311 / 25,002 PKG. NO. 122 SHEET 13 OF 22

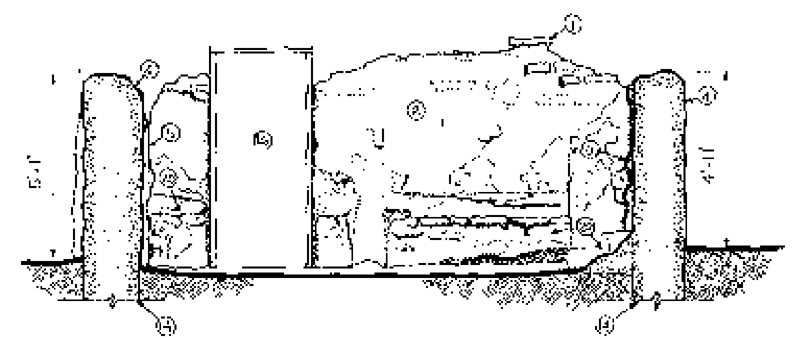


FLOOR PLAN — EXTANT CONVENTO

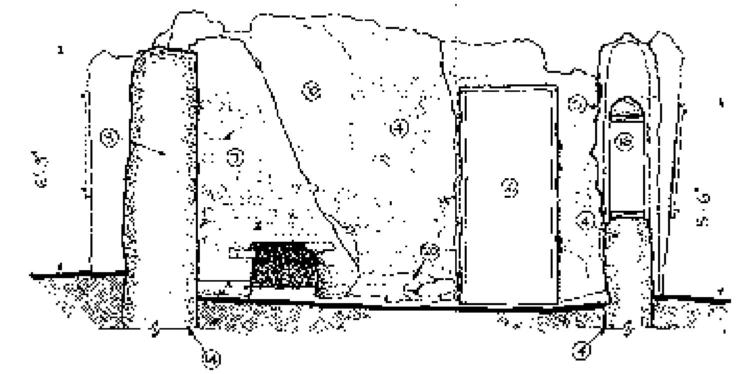
SCALE OF FEET
4 0 4 8
0 1 2
SCALE OF METERS

DESIGNED: HISTORIC	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO. 311 25,002
DRAWN: ATES		FLOOR PLAN	PKG. NO. 122
TECH. REVIEW: CROSBY		EXTANT CONVENTO	SHEET 14
DATE: /			OF 22

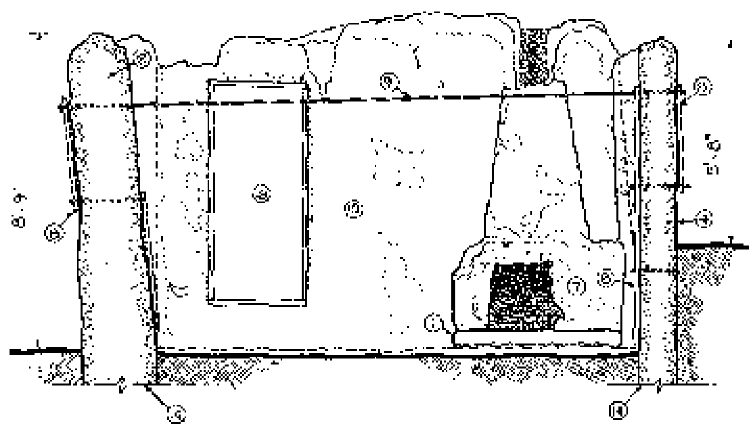
BASE DATA: DRAWING BASE REPRODUCED FROM H.A.B.S. DRAWINGS BY OHIO STATE UNIVERSITY DEC. 1975



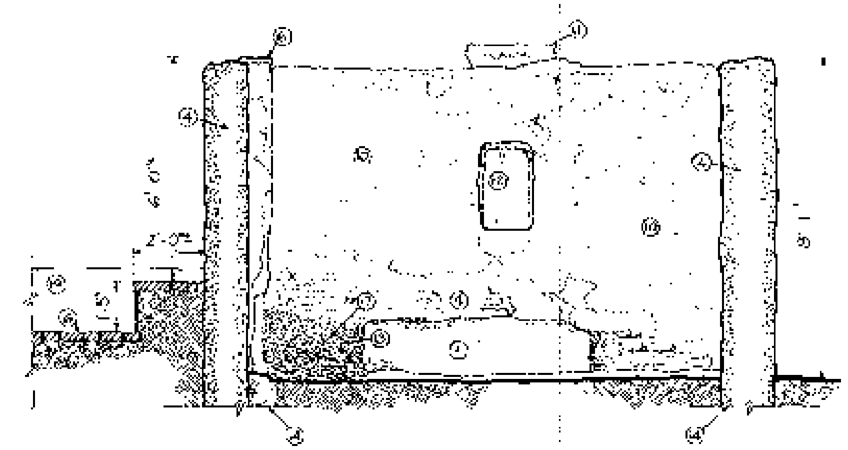
SECTION C (14|15)



SECTION D (14|15)

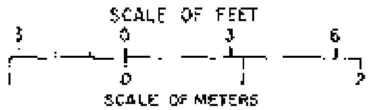


SECTION E (14|15)

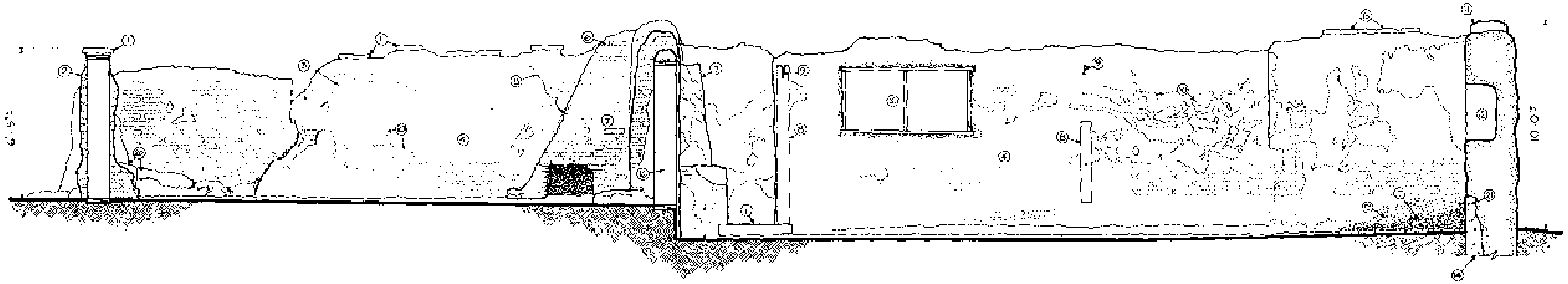


SECTION F (14,15)

ON MICROFILM



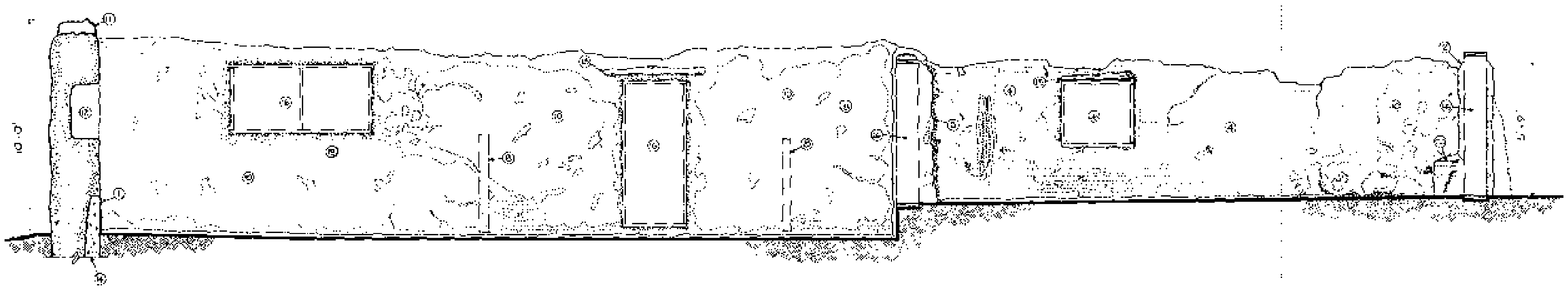
DESIGNED: HISTORIC DRAWN: ATES TECH. REVIEW: CROSBY DATE: /	SUB SHEET NO	TITLE OF SHEET SECTIONS EXTANT CONVENTO	DRAWING NO. 311 / 25,002 PKG. NO. 22 SHEET 15 OF 22



SECTION (A / 14 | 16)

NOTES:

1. CONCRETE
2. NON HISTORICAL WALL
3. FILL OF HISTORICAL ARCH
4. ADOBE BRICK WALL
5. CRACK IN WALL
6. FIREBRICKS
7. NON-HISTORICAL FIREPLACE
8. 1941 REINFORCEMENT
9. REINFORCEMENT ROD
10. ORIGINAL LIME PLASTER
11. LINE CEMENT MORTAR WITH FIREBRICKS
12. STATUE NICHE
13. DISCERNABLE MOISTURE
14. ACTUAL DEPTH OF FOUNDATION UNKNOWN
15. OLDER COTTONWOOD LINTEL
16. ALL OF THE PRESENT OPENINGS ARE APPARENTLY POST SPANISH COLONIAL OR POST MEXICAN
17. AREA OF SOIL SAMPLE
18. LEANING UPPER WALL
19. ARCADE (COVERED PASSAGE WAY)
20. BENCH FOOTING
21. CONCRETE REMOVED IN 19[illegible]

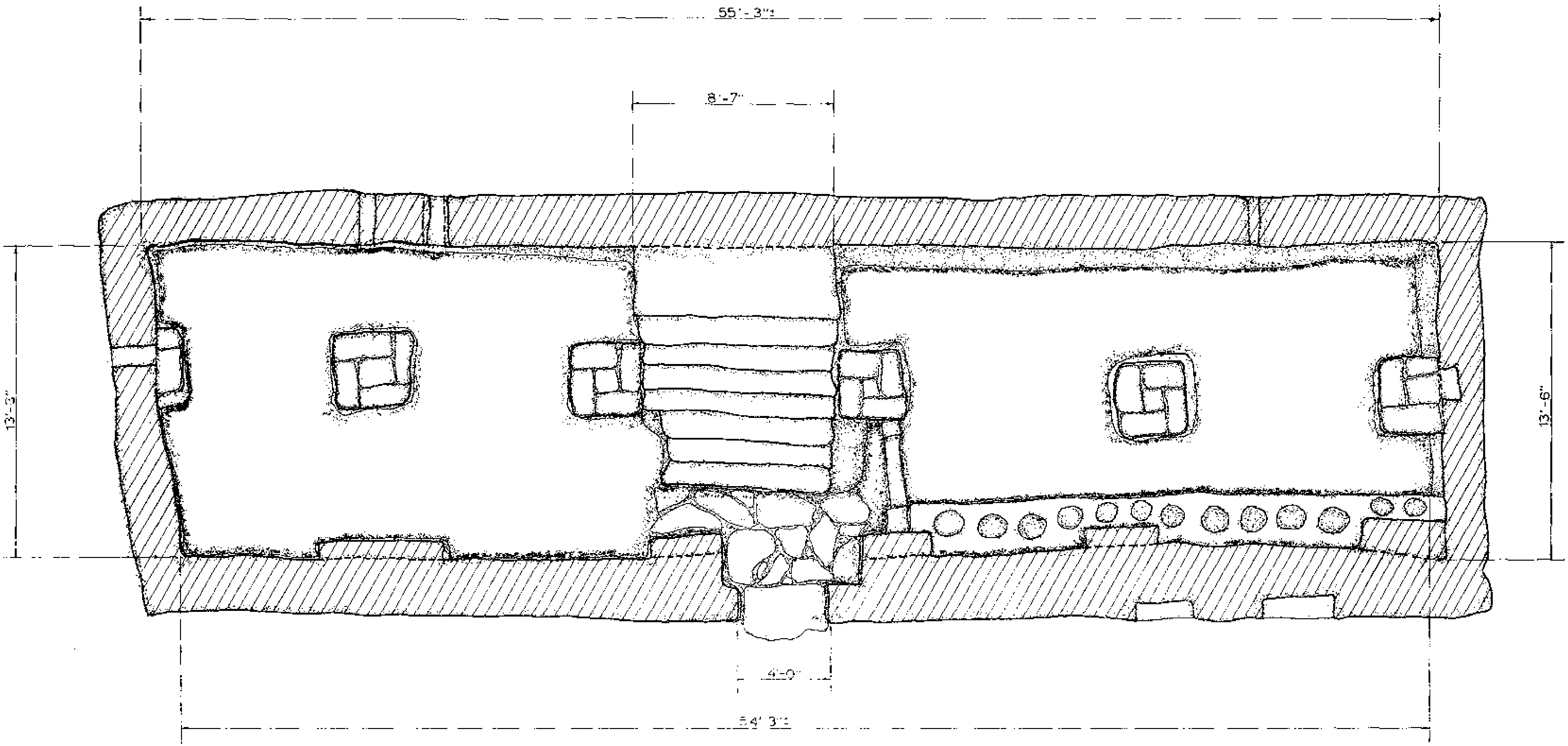


SECTION (B / 14 | 16)

SCALE OF FEET: 2 0 2 4 6

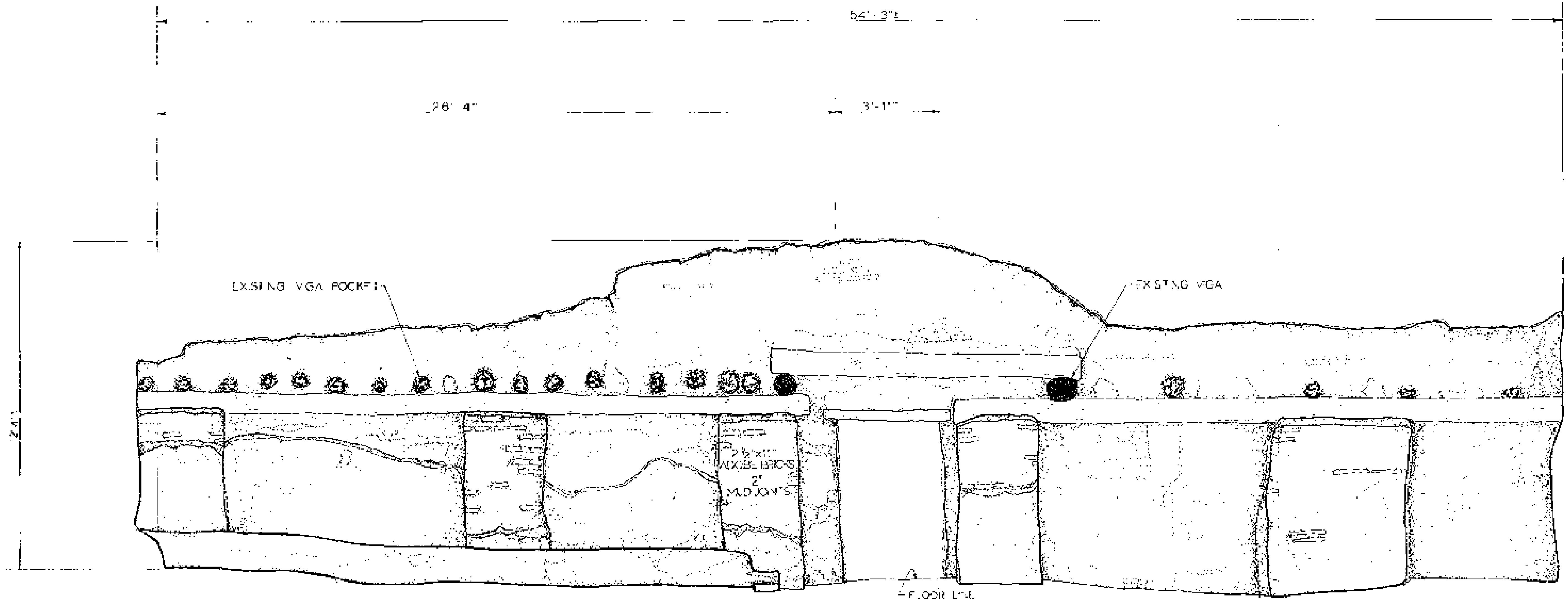
SCALE OF METERS: 1 0 1 2

DESIGNED: HISTORIC	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO. 311 / 25,002
DRAWN: ATES		**SECTIONS**	PKG. NO. 122
TECH. REVIEW: CROSBY		EXTANT CONVENTO	SHEET 16 OF 22
DATE: /			



PLAN – GRANARY

DESIGNED: HISTORIC	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO.
DRAWN: CAMARENA		PLAN	311 / 25,002
TECH. REVIEW: CROSBY		GRANARY	PKG. NO. 122 — SHEET 17 OF 22
DATE: /		ON MICROFILM	

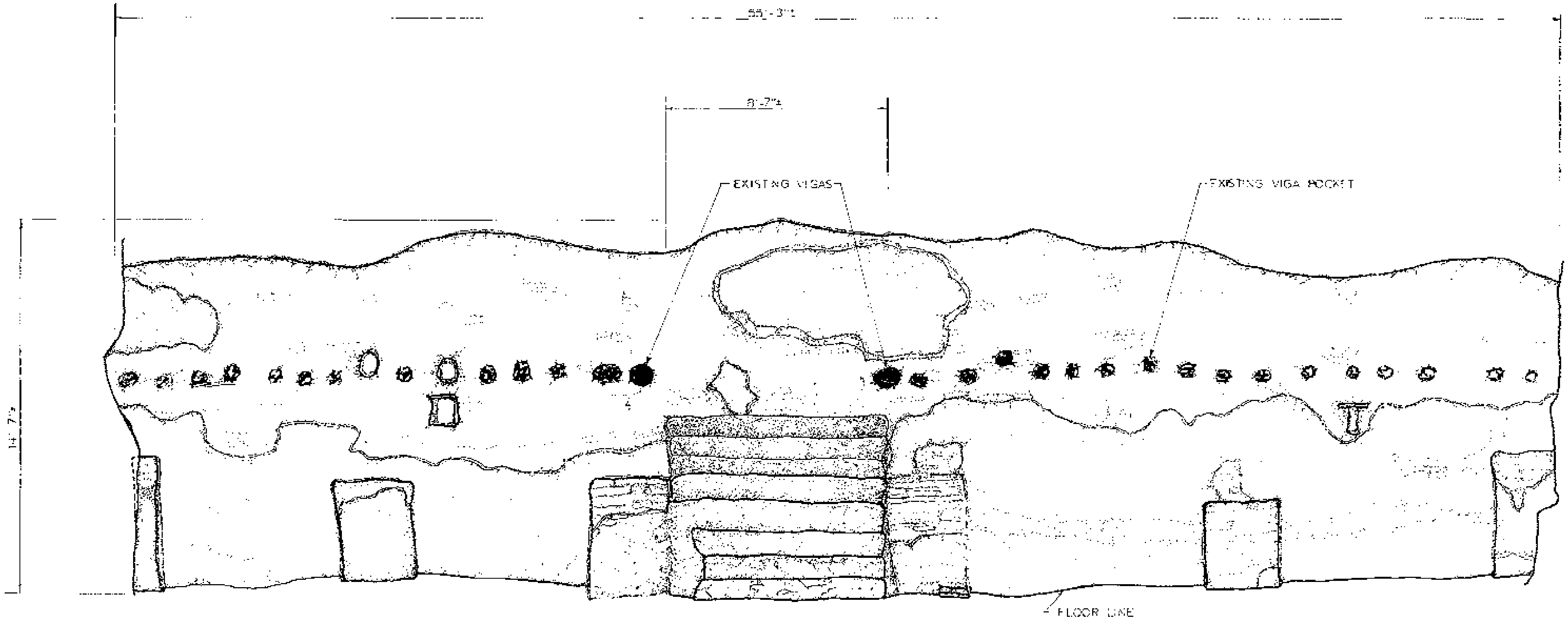


EAST ELEVATION

SCALE OF FEET

SCALE OF METERS

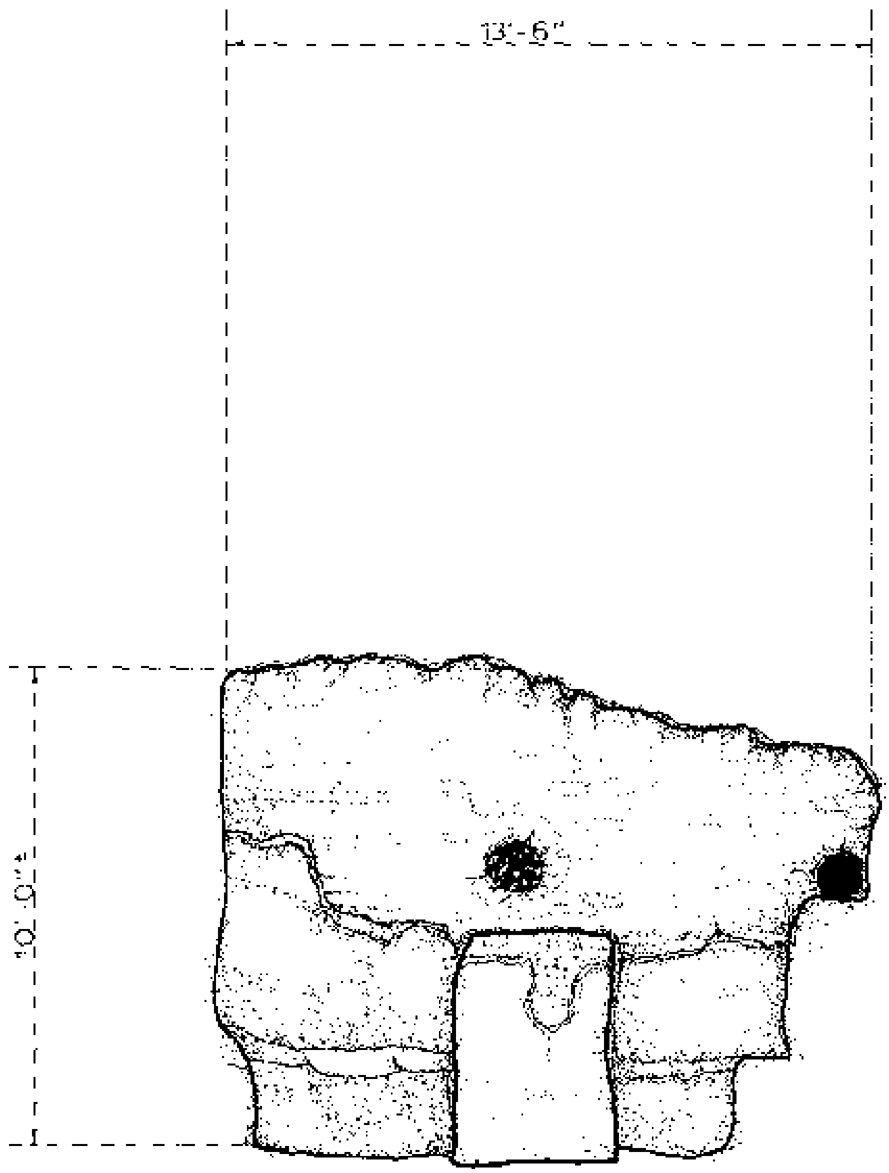
DESIGNED	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO.
HISTORIC		EAST ELEVATION	311 25,002
DRAWN SAMARENA		GRANARY	PKG. NO. 122 / SHEET 18 OF 22
TECH. REVIEW CROSBY			
DATE			



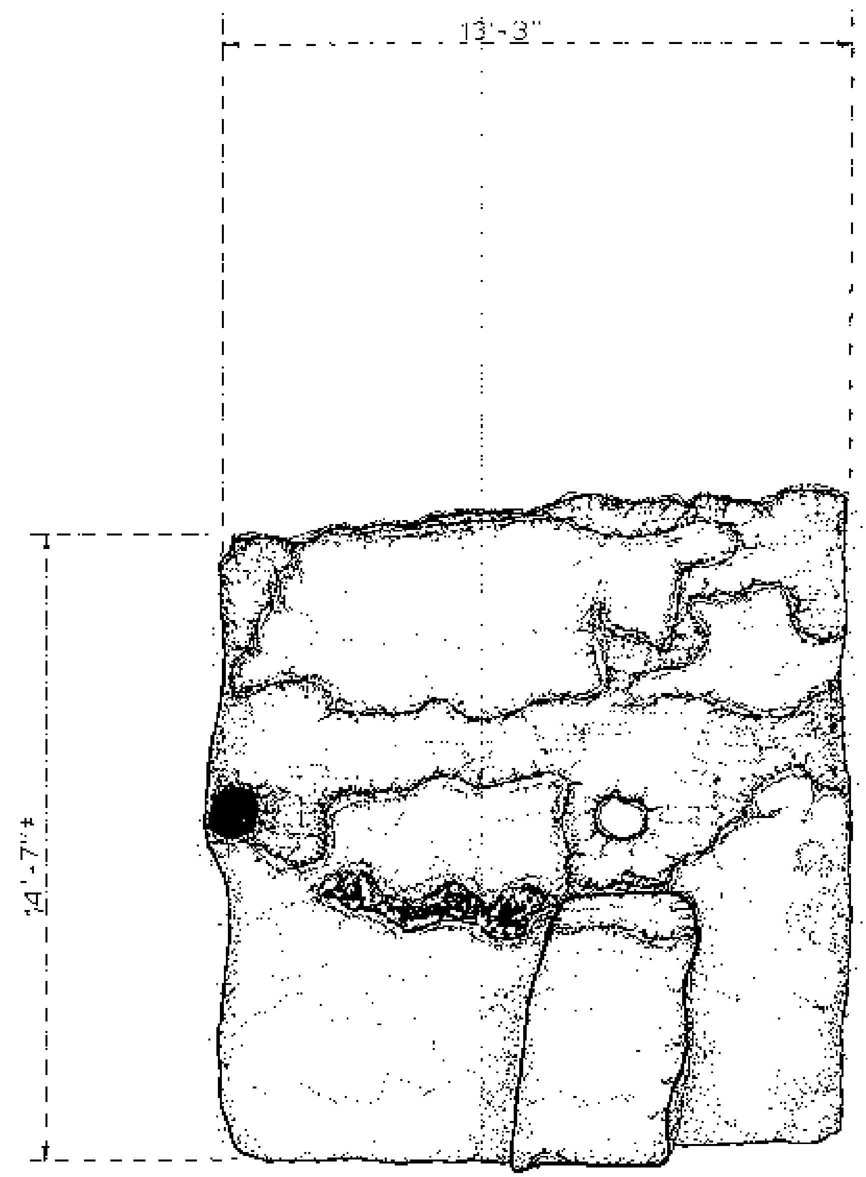
WEST ELEVATION - GRANARY

SCALE OF FEET
4 0 2 4
0
SCALE OF METERS

DESIGNED: HISTORIC	SUB SHEET NO.	TITLE OF SHEET	DRAWING NO. 311 25,002
DRAWN: CAMARENA		WEST ELEVATION	PKG. NO. 122
TECH. REVIEW: CROSBY		GRANARY	SHEET 19 OF 22
DATE: /			



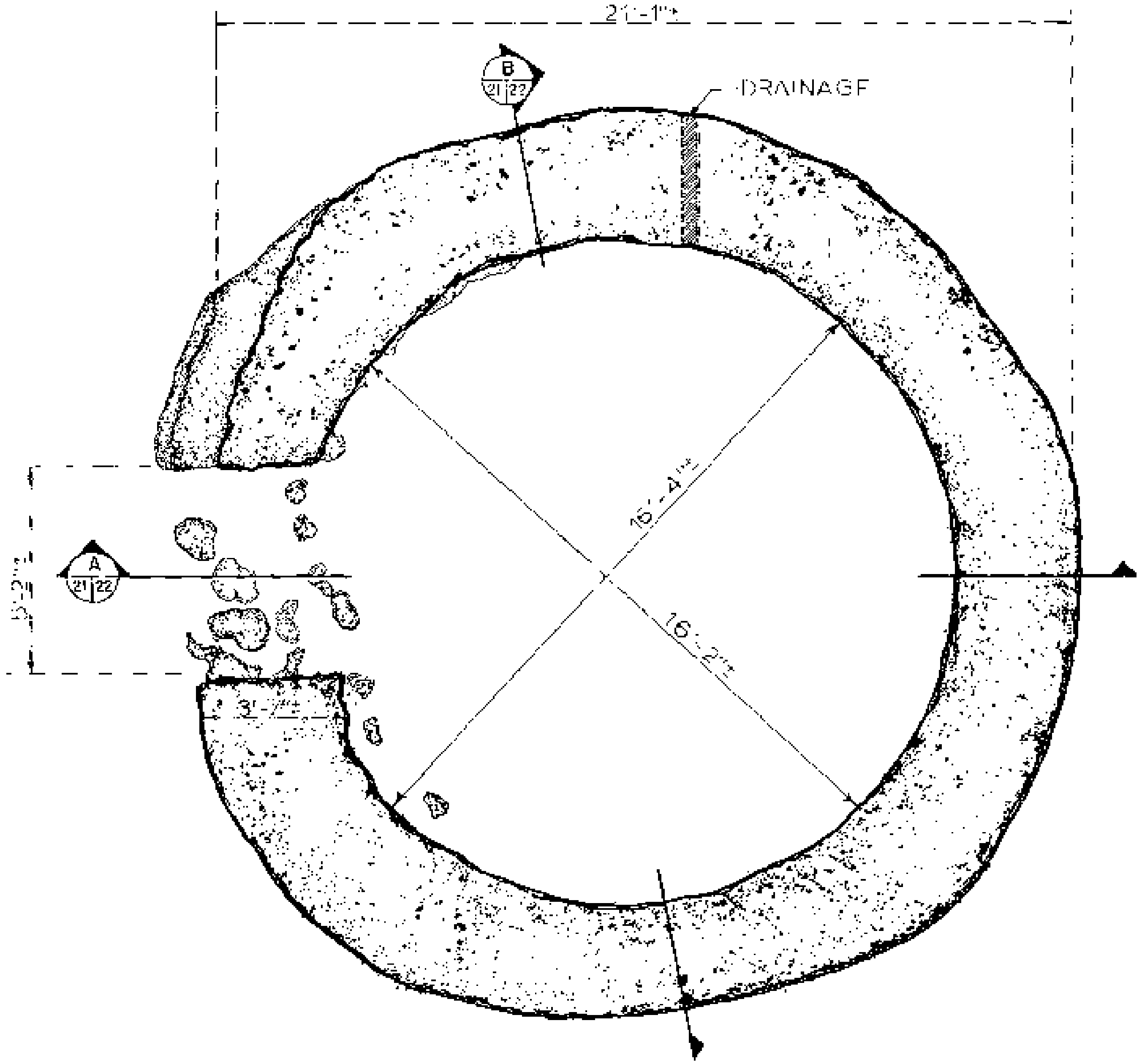
NORTH ELEVATION — GRANARY



SOUTH ELEVATION — GRANARY

SCALE OF FEET
4 0 2 4
0
SCALE OF METERS

DESIGNED: HISTORIC DRAWN: CAMARENA TECH. REVIEW: CROSBY DATE: /	SUB SHEET NO.	TITLE OF SHEET NORTH AND SOUTH ELEVATIONS GRANARY	DRAWING NO. 311 / 25,002 PKG. NO. 122 SHEET 20 of 22

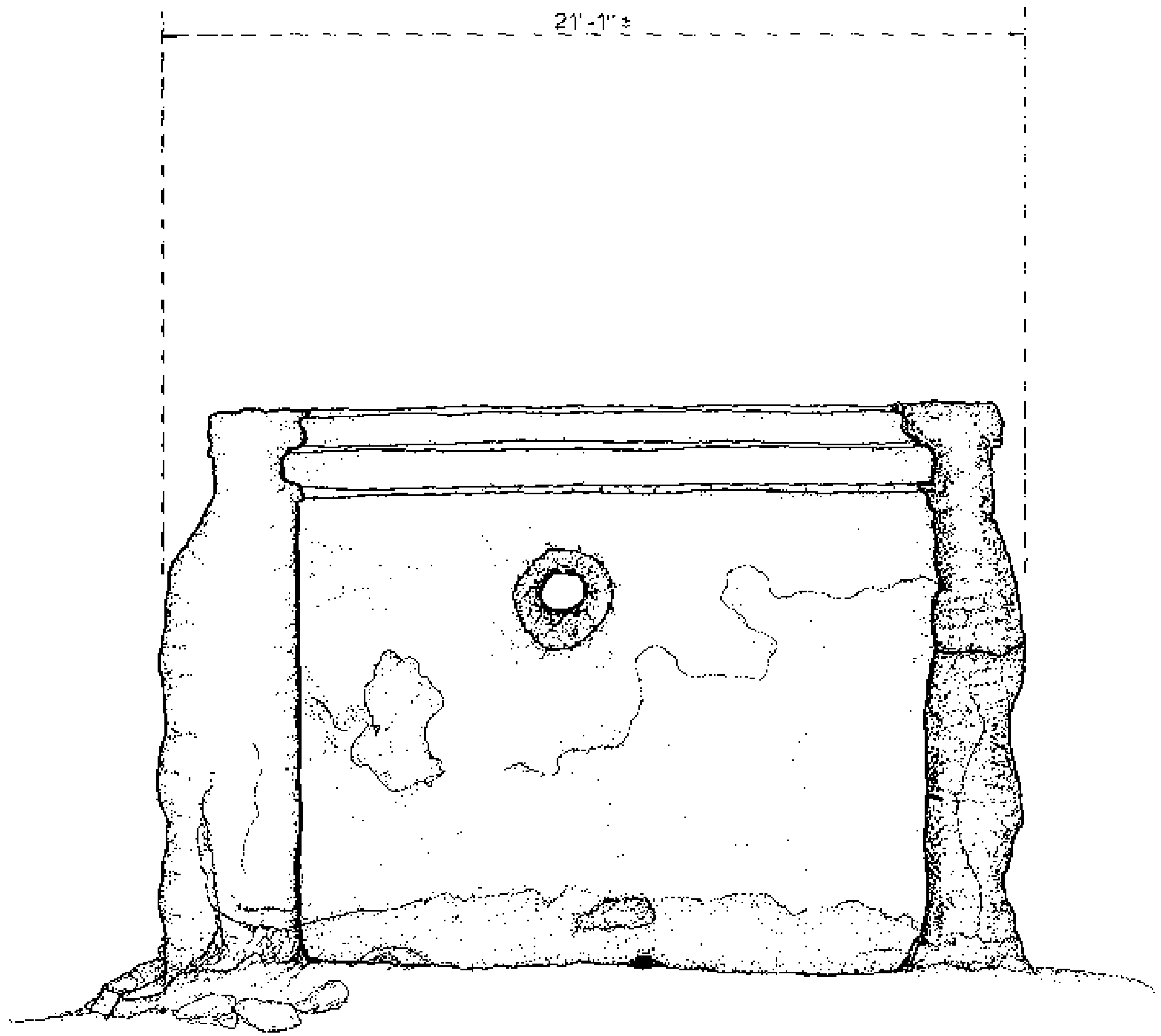


FLOOR PLAN

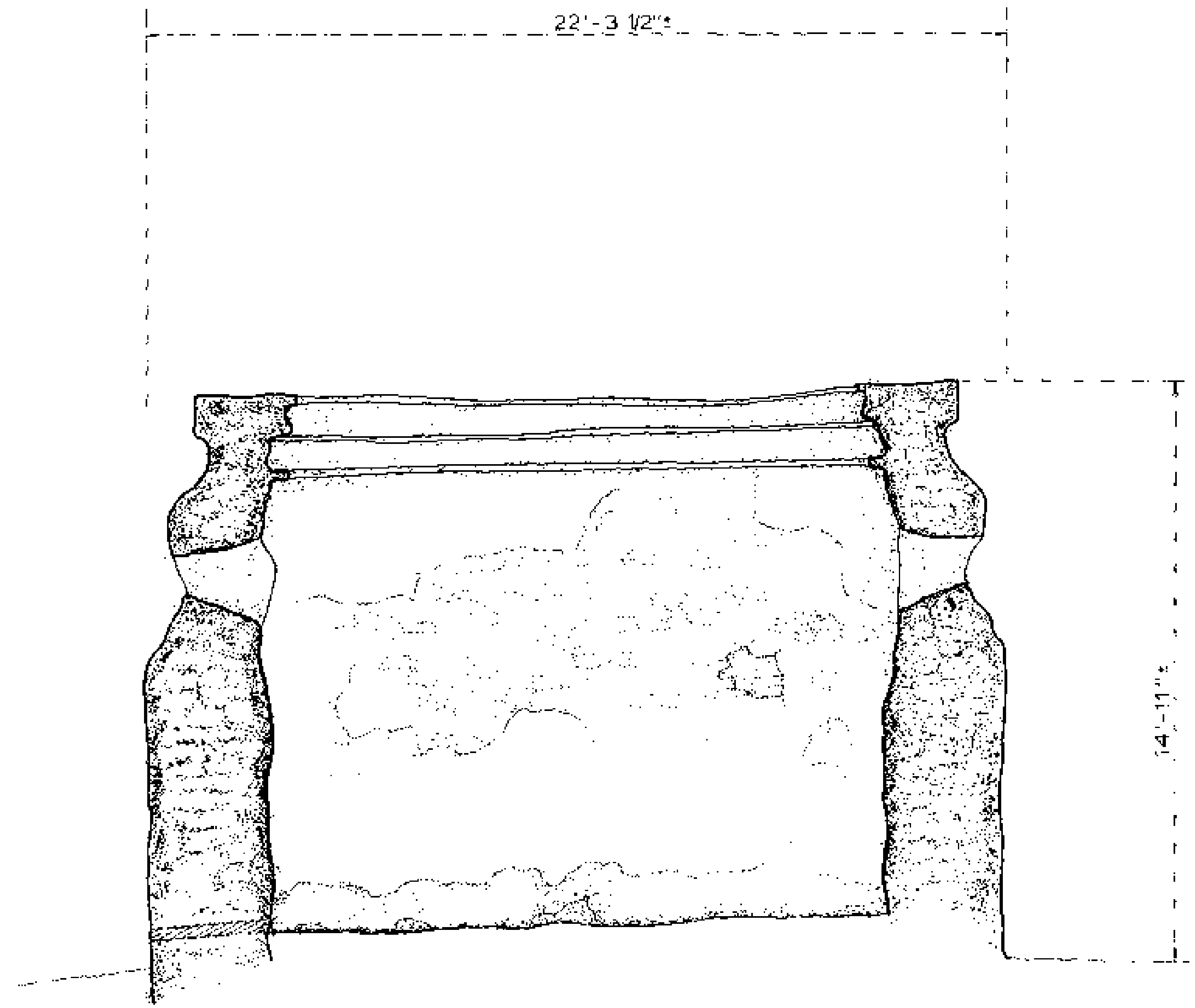
SCALE OF FEET

SCALE OF METERS

DESIGNED: HISTORIC DRAWN: CAMARENA TECH. REVIEW: CROSBY DATE: /	SUB SHEET NO.	TITLE OF SHEET FLOOR PLAN MORTUARY CHAPEL	DRAWING NO. 311 / 25,002 PKG NO. 122 SHEET 21 OF 22



SECTION (LOOKING NORTH) A 21/22



SECTION (LOOKING EAST) B 21/22

SCALE OF FEET 4 0 2 4
SCALE OF METERS 0

DESIGNED: HISTORIC DRAWN: CAMARENA TECH. REVIEW: CROSBY DATE: /	SUB SHEET NO.	TITLE OF SHEET SECTIONS MORTUARY CHAPEL	DRAWING NO. 311 25,002 PKG. NO. 122 SHEET 22 OF 22

As the nation's principal conservation agency, the Department of the Interior has basic responsibilities to protect and conserve our land and water, energy and minerals, fish and wildlife, parks and recreation areas, and to ensure the wise use of all these resources. The department also has major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Publication services were provided by the graphic and editorial staffs of the Denver Service Center. NPS D-15 September 1985