



January 1999

Lessons from the Great House: Condition and treatment history as prologue to site conservation and management at Casa Grande Ruins National Monument

Frank G. Matero

University of Pennsylvania, FGMATERO@design.UPENN.EDU

Follow this and additional works at: http://repository.upenn.edu/hp_papers

Matero, Frank G., "Lessons from the Great House: Condition and treatment history as prologue to site conservation and management at Casa Grande Ruins National Monument" (1999). *Departmental Papers (Historic Preservation)*. 3.
http://repository.upenn.edu/hp_papers/3

Copyright 1999 Maney. Reproduced from *Conservation and Management of Archaeological Sites*, Volume 3, Issue 4, 1999, pages 205-224.
Publisher URL: www.maney.co.uk/journals/cma (article homepage) <http://www.ingentaconnect.com/content/maney/cma> (journal home page).

This paper is posted at ScholarlyCommons. http://repository.upenn.edu/hp_papers/3
For more information, please contact libraryrepository@pobox.upenn.edu.

Lessons from the Great House: Condition and treatment history as prologue to site conservation and management at Casa Grande Ruins National Monument

Abstract

As the first federally designated and protected archaeological preserve in the United States (1889-92), the site of Casa Grande Ruins National Monument in Arizona, USA, provides an excellent opportunity to examine the effects of past site conservation and management policies. Renewed investigation and analysis of the caliche building material and wall conditions of the Casa Grande using new techniques of field, laboratory and digital recording have allowed a reassessment of the structure in an effort to explain recent phenomena of alteration and deterioration, and make recommendations for structural and surface monitoring and treatment. The focus on the development of a detailed condition survey of the earthen structure has also promoted the creation of a standard graphic lexicon of earthen building conditions for use at other sites.

Comments

Copyright 1999 Maney. Reproduced from *Conservation and Management of Archaeological Sites*, Volume 3, Issue 4, 1999, pages 205-224.

Publisher URL: www.maney.co.uk/journals/cma (article homepage) <http://www.ingentaconnect.com/content/maney/cma> (journal home page).

CONSERVATION AND MANAGEMENT OF ARCHAEOLOGICAL SITES

EDITOR:

Nicholas Stanley-Price

REGIONAL EDITOR (USA):

Frank G. Matero

CONTENTS IN BRIEF

(FULL TITLES ON BACK COVER)

EDITORIAL



ARTICLES

Creative preservation:

The development of an artistic approach to the preservation and presentation of the past

Ran Morin

Lessons from the Great House: Condition and treatment history as prologue to site conservation and management at Casa Grande Ruins National Monument

Frank Matero

Plants and mudbrick: preserving the Midas Tumulus at Gordion, Turkey

Naomi F. Miller and Kurt Bluemel



Book reviews

Recent publications of interest

Article and author index for Vol 3



JAMES & JAMES
(SCIENCE PUBLISHERS) LTD

ISSN 1350-5033

ARTICLE

Lessons from the Great House

Condition and treatment history as prologue to site conservation and management at Casa Grande Ruins National Monument

FRANK MATERO

ABSTRACT

As the first federally designated and protected archaeological preserve in the United States (1889-92), the site of Casa Grande Ruins National Monument in Arizona, USA, provides an excellent opportunity to examine the effects of past site conservation and management policies. Renewed investigation and analysis of the caliche building material and wall conditions of the Casa Grande using new techniques of field, laboratory and digital recording have allowed a reassessment of the structure in an effort to explain recent phenomena of alteration and deterioration, and make recommendations for structural and surface monitoring and treatment. The focus on the development of a detailed condition survey of the earthen structure has also promoted the creation of a standard graphic lexicon of earthen building conditions for use at other sites.

That night, in the full moonlight, the Casa Grande assumed a soft, poetic beauty, with its ruddy surface flooded with radiance that threw the shadows of its deep recesses into a rich mysterious obscurity – a transformation from the aspect of the ruins in the broad glare of daylight. While we lay in our tent, gazing dreamingly at the beautiful picture, Mr Cushing told us in his charming and inimitable manner one of the Zuni folk-tales about the 'Priests' of the House' – a tale whose full significance was not clear to him until he came to this region and found the ruins of the 'Great Houses'. As we listened, the ancient walls before us seemed to be repeopled with the venerable old priests, and it would have required little imagination to have heard the weird, fascinating chants of the worshippers. [1]

INTRODUCTION

Cited by Cosmos Mindeleff over a century ago as 'perhaps the best known specimen of aboriginal architecture in the United States' [9: 295, the ruin known as Casa Grande, located in south central Arizona, midway between Tucson and Phoenix, remains unique among ancestral Native American structures in North America. Several principal reasons can be cited for its early and current significance. As the most conspicuous structure of a large prehistoric settlement now partially contained within the boundaries of Casa Grande Ruins National Monument, the Great House is the largest surviving prehistoric non-mound earthen building in the United States. Moreover, it is the only surviving example of Classic Period Hohokam

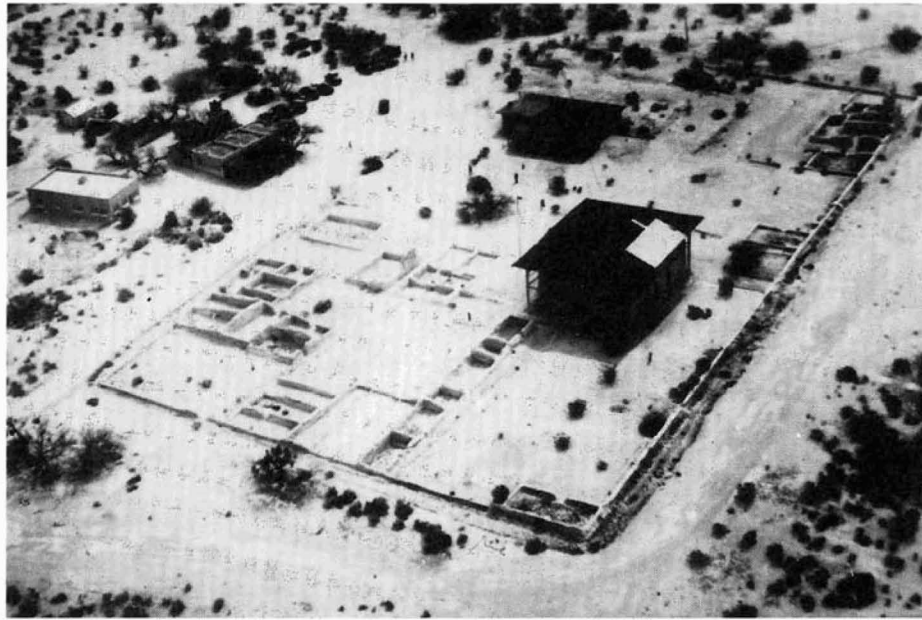


Figure 1. Aerial view of Compound A and the Casa Grande with its 1903 shelter, c. 1930 (CAGR/NPS).

Great House architecture and exists in an immediate village context not preserved elsewhere (Fig. 1). Despite its age (1300–1450 AD), the structure remains one of the most complete and intact free-standing aboriginal structures and certainly the best preserved of any such earthen buildings in North America, displaying a high degree of physical integrity. It therefore affords an unparalleled opportunity to study the architectural and technological knowledge and organizational skills that were required by the Hohokam to construct so large and complex a structure.

The site is equally distinguished as the first federally designated and protected archaeological preserve (1889–92) in the United States and possesses one of the earliest (1932) and largest twentieth-century shelters erected over a single structure to date (Fig. 2). These two aspects of preservation consciousness, one legislative, the other technological, have had a profound impact on the state of conservation of the structure today. The site is also important to the history of the National Park Service (NPS) as the headquarters of the Southwestern National Monu-

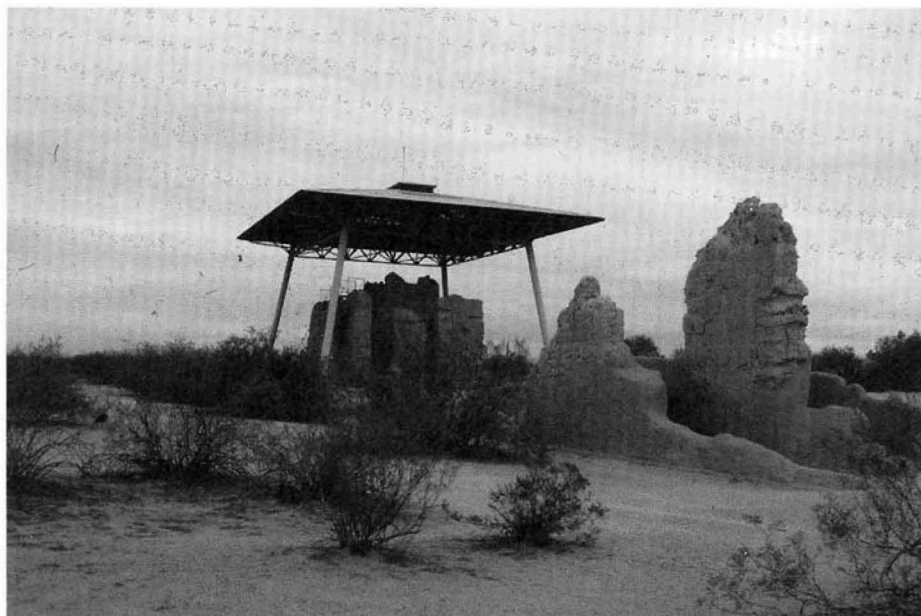


Figure 2. View of the Casa Grande with Olmsted shelter, 1997 (ACL).

ments, directed by Frank 'Boss' Pmkley, from 1923 to the 1940s.

Despite the acknowledged importance and early preservation of the Casa Grande, limited information exists about the composition and physical condition of its earthen walls: the mechanisms and rates of deterioration, aspects of its physico-chemical weathering and structural stability. The erection of the first wood and iron roof shelter in 1903 and its subsequent steel canopy in 1932 have certainly had a beneficial effect by reducing climatic deterioration. Yet recent material analysis and a detailed comparative survey of past and existing conditions have revealed a range of macro- and micro-scaled material alterations and degradation. These changes, when considered in the context of dynamic environmental conditions including diurnal and seasonal climatic change, groundwater withdrawal and seismic activity, present a potentially dangerous situation for the future preservation and survival of the structure.

According to the monument's current management plans [11:2], the prime resources at Casa Grande Ruins are the prehistoric structures, which were the initial justification for designation and protection of the site in 1892 and adoption into the National Park Service in 1918. Currently the whole monument is listed on the National Register and is a National Historic Landmark, and all the prehistoric structures are on the NPS List of Classified Structures (LCS) as they are considered to be of national archaeological and architectural significance. Yet the Great House remains the primary and publicly recognised resource. This is due to its conspicuous size and the fact that over 90% of the site's known archaeological remains are buried and therefore less visible to the public [11:1-17]. However, unlike other exposed walls and features on site that have received numerous preservative treatments involving capping and various types of surface protection, the Great House possesses significant informational value due to its presentation and the absence of direct fabric interventions.

The first scientific documentation and stabilization of the Casa Grande was performed by Cosmos Mindeleff in 1891-2 [9,10] and was continued by Jesse Walter Fewkes during his extensive excavation and preservation work beginning in 1906 [4].ⁱ However, detailed architectural inves-

tigations and architectural recordings of the Casa Grande were first made only in 1976 by Wilcox and Shenk [13] and in 1980 by Wilcox and Sternberg [14], supplemented by photogrammetric recording of the exterior walls by Perry Borchers in 1977. In 1984, an electronic monitoring system was installed to measure crack movement in the Great House walls. Despite an early focus of preservation concern and stabilization, no comprehensive plan currently exists for the site. Preservation has rather been a case of continuing earlier approaches and techniques that have developed over time, based on empirical knowledge as well as limited experimental testing.

In light of the existing documentation of the structure and its previous stabilization history, as well as changes in contemporary conservation methodology, the current programme calls for immediate acquisition of additional baseline information for developing future programmes of cultural resource management for the site.

PROJECT OBJECTIVES AND STRUCTURE

An assessment of the condition and preservation management of the Great House has not occurred since the 1970s.ⁱⁱ To date, a complex array of repairs exists, including the original efforts by Mindeleff from 1891-2. Of these, various treatments are reaching or have reached the end of their serviceable life and need to be replaced or reconsidered. Recent studies, proposals and treatment recommendations made since the 1970s reveal diverse approaches and solutions to the perceived problems at Casa Grande.

Any conservation action must begin with an understanding of the problems through a series of systematic, scientific studies. For the Casa Grande, this must include a detailed survey and assessment of past and existing conditions as baseline information for the design and implementation of a monitoring programme to document and record structural, material and environmental changes. As a result of these identified goals, detailed field- and laboratory-based investigations were developed and begun as Phase I by The Architectural Conservation Laboratory of the Graduate Program in Historic Preservation, University of Pennsylva-

nia from 1997–9 at the request of the Southwest Region Support Office (SRSO) and Casa Grande Ruins National Monument (CAGR). The project was funded by the National Park Service with support from the University of Pennsylvania. iii

The objectives of the conservation programme were generally focused on gaining a better understanding of the existing and potential deterioration problems and to offer options for current and future conservation treatments and management of the Casa Grande. These objectives necessitated the following activities:

- to qualitatively and quantitatively record the past and existing physical conditions of the structure;
- to analyze the material and structural characteristics;
- to explore conservation treatments for the immediate problems of fragment and surface detachment, surface friability and animal activity;
- to document all research results;
to produce a report and proposals for conservation and future phases of research.

Phase I comprised the following components:

- **Documentation and Condition Survey:** detailed field examination and computer-based graphic recording of the condition of the exterior and interior elevations of the earthen walls and associated finishes. Included were annotations of past conditions and interventions as evidenced by earlier photographic and written documentation. This was correlated with the other investigations, and will be essential for planning future diagnoses, monitoring and treatment applications and evaluations.
- **Material Testing and Analysis:** scientific examination, recording, geo-technical testing, and analysis of the earthen building materials and finishes to assess their original formulations, use and alterations and deterioration over time. This is the first step in conjunction with the macro-analysis of structural and environmental conditions to ensure that compatible methods and materials are selected for any conservation work to be implemented.
- **Structural Analysis:** preliminary structural analysis including determination of the stability of

the walls in their original configuration and current condition under their own weight and under wind and seismic loading. In addition, a structural assessment of the existing steel shelter was performed using a Staad III program and a preliminary retrofit design using composite materials was posited.

- **Treatment Testing and Assessment:** detachment of the interior wall surfaces was investigated and several grouting formulations and reattachment methods were evaluated as possible candidates for treatment of unstable areas using facsimile models in a laboratory-testing programme and limited trial field tests.

PAST CONDITION AND CONSERVATION HISTORY OF THE CASA GRANDE

Casa Grande Ruins National Monument holds a seminal position in the development of a preservation consciousness for America's archaeological sites. Long noted as the first prehistoric and cultural site to be established in the United States, 14 years before the passage of the Antiquities (Lacey) Act of 1906 and 24 years before the formation of the National Park Service (1916), the monument also displays a series of early approaches to the physical conservation and presentation of such sites. As part of these efforts of preservation, various written, graphic and photographic descriptions of the existing conditions of the site were recorded. Today these documents serve as useful evidence for charting past and current deterioration and the effects of specific interventions. An interest in the description of the Casa Grande in general is of course much older than the preservation efforts of the past century. Fewkes [4] and Wilcox and Shenk [13] provide the best detailed chronological account of information on its appearance. A more recent administrative history of the monument covering the years of federal management from 1892–1992 has also been prepared [2].

As extensive as these studies are, a review of previous documentation for the purposes of diagnosing earlier conditions in order to understand past and current decay mechanisms and predict future failure has not been conducted. The need for and difficulty with generating such baseline

information was understood as early as 1895, when John Wesley Powell, Director of the Bureau of American Ethnology (Smithsonian Institution), wrote to the Secretary of the Interior regarding the Casa Grande. 'It is impossible to determine, and difficult even to approximate, the rate of destruction quantitatively [of the Casa Grande], especially so since it goes on cumulatively, with constantly increasing rapidity' [9:349]. The following summary of past conditions based on the earlier written and photographic sources is an attempt to provide the foundation for such a baseline comparison with the present condition survey conducted in 1997–9.

Frank Hamilton Cushing – Visit and description of December 31, 1887 to January 4, 1888

As first director of the Hemenway Southwest Archaeological Expedition, F. H. Cushing visited Casa Grande Ruins from December 31, 1887 to January 4, 1888 to conduct a comparative study of the remains of another Great House at the site of Los Muertos, Arizona. Cushing prepared a sketch plan of the site and photographed the structure (see below). He also interviewed a local rancher who reported that the ruin had fallen into rapid decay only within the past ten years due to the removal of beams and lintels (15:603). Cushing believed that earthquakes played a major role in the destruction of the Casa Grande [14:16].

Jesse Walter Fewkes – Visit and description of April 1891

Following Cushing as the new director of the Hemenway Southwest Archaeological Expedition, Fewkes visited Casa Grande Ruins in 1892 for a brief period to make 'a few observations of its present condition', including measured plans indicating standing and fallen wall sections [3:180]. Buried within his text of archaeological description are several important statements regarding the 'as-found' condition. Most important in this regard are his comments on graffiti and the severe undermining of the foundations, especially on the exterior northwest corner, from pothunters and vandals (Fig. 3). According to Fewkes, these below-grade exposures not only revealed the



Figure 3. South elevation of the Casa Grande, c. 1888, published by Fewkes (1892). Note partial wall segment that collapsed by 1891–2.

amount of weathering the exposed exterior had suffered, but created a structurally precarious situation 'afford[ing] an all too good opportunity for additional undermining by the atmosphere, rains, and like agents of erosion' [3: 188]. Two accompanying photographs of the south and northeast exterior elevations taken prior to Mindeleff's 1891–2 stabilization work give a clear, albeit partial, indication of the severe basal erosion of the exterior walls, the undermining from localized excavation, the irregular high level and slope of the immediate grade and the difference in fill level between the exterior and interior.^{iv}

Also visible in these photographs are the three wall segments that subsequently collapsed on the north, east and south elevations around 1891–2. Although Rizer in his completion report documents the loss of the south end of the exterior east wall and a separate section of the south wall during stabilization [10:321–42], it is clear from photographs during and after stabilization that the east end of the north wall also collapsed or was removed at that time. The instability of all these wall sections is clearly evident given the combination of unsupported wall ends on the northeast and southeast corners and their associated vertical construction seams and through-wall cracks, especially defining the fallen section of the south wall (compare Figs 3 and 4). Additional damage to the structure also may have occurred from the Sonoran Earthquake of 3 May 1887 but clearly most of the collapses occurred earlier.

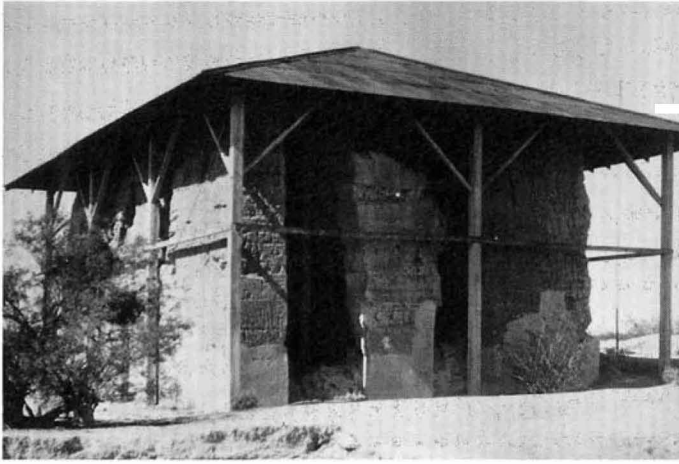


Figure 4. South and west elevations of the Casa Grande with its first 1903 shelter and Mindeleff repairs, c. 1910 (NPS/CAGR).

Cosmos Mindeleff – Documentation of 1891

As a result of the efforts of Mary Hemenway and other influential Bostonians, \$2000 was allocated by the United States Senate for the preservation of the site and expended on documentation and stabilization of the Casa Grande. The work, identified as ‘preservation of the ruin [with] no attempt at restoration’ [9: XXXVII] was prepared and supervised by Cosmos Mindeleff for the Smithsonian Institution from 1891–2 and included excavation and levelling of debris from the exterior and interior, the insertion of metal rods and wooden tie beams to support the south wall, the insertion of brick and plaster infill support of the wall bases and the insertion of wooden lintels in breached openings as needed (Fig. 4). Subsequently, an area of approximately 480 acres including the Casa Grande Ruins was established as a preserve by Executive Order and a custodian was appointed [10].

Mindeleff’s 1891 examination and documentation of the structure prior to stabilization was first reported in the Thirteenth Annual Report of the Bureau of American Ethnology [9]. The stabilization work was subsequently described in detail in the Fifteenth Annual Report of the Bureau of American Ethnology [10]. Despite the division and date of the reports, documentation and preservation were performed as consecutive operations. Mindeleff’s reports are the first detailed descriptions of existing architectural and material conditions of the site and included detailed topographic

site plans and photographs. As such they rank among the earliest professional technical reports on ruin stabilization in the United States.

Like all writers before him, Mindeleff concluded that the Casa Grande was already a ruin by the time of the first Spanish descriptions beginning in 1694. Mindeleff took a great interest in hypothesizing site formational processes in the creation of the mounds; however he took a sceptical view of equating surface erosion and wall loss with original height of walls or the relative age of structures. He did, however, make the astute observation by using earlier photographic evidence that the Casa Grande had changed relatively little in recent times in its gross overall profile or surface texture (compare Figs 3–5).

The surface erosion of a standing wall ... is very slight. Photographs of the Casa Grande ruin, extending over a period of sixteen years ... show that the skyline or silhouette remained essentially unchanged during that period ... It is through sapping or undermining at the ground surface that walls are destroyed. [9: 300]

In his preservation report Mindeleff, like Cushing and Fewkes before him, cited vandalism (digging and timber removal) as the primary agent of destruction of the Casa Grande Ruins. The differential conditions of the exterior walls – the south and east walls being in the worst condition – were attributed to the prevailing storms from the south-east. Conversely, the collapse of the southeast and northeast corners was attributed to weather and

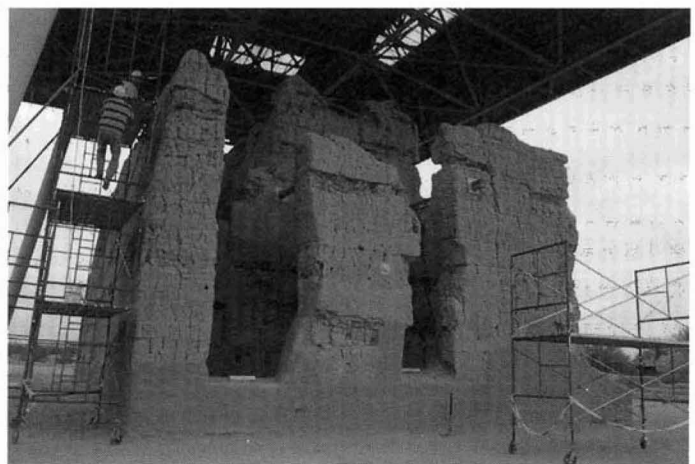


Figure 5. South elevation of the Casa Grande, 1997. Compare with Figs 3 and 4 (ACL (UPENN)).

wall construction defects. In addition to these localized problems, Mindeleff considered wall collapse from basal erosion or 'sapping' to be a serious problem requiring immediate attention. This, he believed, was caused by the mechanical abrasion of wind-driven sand against the lower walls softened by rising damp from the ground and accumulated debris against the wall [9:300-301]. While early pre-stabilization photographs clearly show significant overall basal undercutting, up to one foot deep according to Mindeleff, at the interface of the exposed wall base and adjacent ground level [9: Plate LV, 10: Plate CXVII], it is highly unlikely that mechanical scouring was the culprit (Fig. 3). Water, no doubt, was involved in the process of deterioration; however it is more likely that, given the high water resistance of the caliche (as demonstrated by the recent laboratory tests), salt and possibly frost cycling were probably responsible instead for the chemical and mechanical deterioration of the earthen walls.

This undermining of the walls through basal erosion clearly extended down below the built-up debris as demonstrated by the extent of the brick and plaster infill required once the soil was removed. This type of damage was also noted during the recent condition survey of the interior walls where fallen and accumulated debris once existed as evidenced by Mindeleff's contour maps [9: Fig. 328 and Plate LII] and recorded ground cross-sections [10: Plate CXVIII]. Here loss and friability of the walls were observed in a wide zone below and just above the fill line, clearly indicating deterioration before and/or during debris accumulation. This exists in contrast to intact, originally concealed subgrade walls that were only exposed in 1891 when the original floors were removed (Tiers B and E.) Clearly the zone immediately below and above this relatively loosely packed soil and debris was an active area of wetting and drying, both inside and out, experiencing potentially excessive salt and/or freeze thaw cycling.

Cosmos Mindeleff- Preservation repair work of 1891-2 [10]

As stated in the original report, the \$2000 in funding allocated by Congress was known to be

insufficient to complete the preservation work outlined first by Alexander L. Morrison, then Victor Mindeleff and finally by his brother Cosmos. Nevertheless, interventions deemed necessary on the basis of the above assessment were executed as emergency measures. Debris removal and regrading were first undertaken in a ten-foot area around the main ruin. Specifications called for temporary bracing of the walls before the removal of interior debris 'down to floor level or the original ground level' [10:335]. Undoubtedly this resulted in the removal of the original built-up floor levels in Tiers B and E. Debris and soil removal to at least 12 inches below grade on the exterior exposed the walls for basal insertion of fired brick laid in cement mortar generally two bricks deep [10: Plates CXX and CXXI]. A 1-2 inch recess was created at the surface to allow for the application of a cement-lime plaster flush with the exterior earthen walls. Contrary to current explanation, this infill was not installed strictly as structural underpinning but 'to give a surface capable of effectively resisting atmospheric influences and the destructive action of flying sand, and at the same time would not disfigure the ruin by making the repairs obtrusive' [10:326].

In addition new wooden lintels were inserted in openings where infill of the cavities above was required for structural support. The south wall, due to its unstable fragmented condition, was supported by two metal tie rods and two wooden tie beams running north-south to adjacent east-west walls and fixed at their ends by metal plates. Wood was used in lieu of metal for the longest of the lateral supports, presumably to reduce any thermal expansion stresses the metal might create. Fencing and a protective roof or shelter as originally proposed were not executed at this time. Both Victor and Cosmos Mindeleff opposed the installation of a roofed shelter, insisting on repairs 'so devised that the ruin was not materially disfigured or changed' [10:329]. Cosmos, however, did recommend a reassessment after four years to ascertain whether atmospheric erosion was severe enough to require protection of the ruin. If so, a shelter was to be designed so as to be supported entirely from within the structure.

As recommended, a reassessment of the ruin was made by W. J. McGee in 1895 after field visits and comparison with photographs taken in 1892 before preservation work began. While comparison showed no perceptible change over most of the walls, conditions on the south and east walls were found to have worsened in just three years. He reported: 'the profiles are more extensively modified ... some of the old crevices are widened and deepened, and some new crevices appear; and in some parts it can be seen that the walls are lowered several inches ... destruction is proceeding at a not inconsiderable rate' [10:348]. If accurate, this supports earlier and current observations regarding the severe condition and exposure of the south and east elevations due to the prevailing winds and storms. Eventually, in 1903, with another \$2000 of funding secured by Congress, a redwood and corrugated iron roof shelter was constructed over the Casa Grande closely following the design published earlier by Mindeleff [10: Plate CXXIV] (Fig. 4).

Jesse Walter Fewkes – Excavation, repair and preservation work of 1906–07 and 1907–08 [4]

As part of its commitment to assist government agencies responsible for the protection of archaeological sites, the Bureau of American Ethnology (BAE) began a series of work projects and publications focused on the preservation of selected sites in the southwest, including the Jemez Plateau, Mesa Verde and Casa Grande. Dr J. Walter Fewkes of the BAE was placed in charge of the excavation, repair and preservation of the entire Casa Grande site, continuing the work begun by Mindeleff in 1891–2. A special appropriation of \$8000 was disbursed under the auspices of the BAE, Smithsonian Institution, and an extensive programme of excavation and interpretation was instituted to make the site more accessible and legible to the public [4]. Compound A and the Casa Grande were treated in the first season (1906–07) (Fig. 1). Little work was done specifically to the Casa Grande Ruin although the walls of Compound A and others were excavated, capped with adobes and protected with shelter coats of cement and soil and an open drainage system was installed.

Later maintenance and preservation (1920s to the present day)

Preservation of the site after the major excavation and interpretation program by Fewkes was largely restricted to maintenance and localized repair. The major intervention to occur during this period which would visually affect the structure and site for years to come and influence future arguments regarding all shelters was the construction of the great steel canopy designed by Frederick Law Olmsted, Jr and NPS landscape architect, Thomas Vint (Fig. 2). During the 1940s and later in the 1970s experiments with water repellents and consolidants eventually led to a programme of acrylic-amended mud shelter coats for the protection of the earthen compound walls. Later, reburial was adopted as a method of preservation for fragile walls and features.

CHARACTERIZATION AND ANALYSIS OF THE EARTHEN BUILDING MATERIAL

The earthen material used to construct the Great House at Casa Grande Ruins is a limey soil known as caliche. Caliche refers to accumulations of authigenic carbonates common in soils of arid regions where accumulation forms prominent layers in which the morphology is determined by the impregnating carbonate. Archaeologists speculate that the caliche for the Great House was obtained from borrow areas nearby and then processed or 'puddled' in caliche mixing bowls [6]. By breaking up and working the hard natural caliche, the builders of the Great House were able to augment the natural properties of this particular soil by improving matrix homogeneity and particle contact, reducing voids, and increasing plasticity without additional water, thereby avoiding shrinkage and improving the density and strength of this material for building purposes.

Many speculations regarding the construction techniques for the Great House have been offered since it was first viewed by Europeans beginning in the seventeenth century. Most observers implied the use of formwork to construct the walls; however Wilcox and Shenk [13] proved that no forms were involved and suggested rather that a system of individually placed, hand-shaped units



Figure 6. Lower west wall of the Casa Grande, north end showing area of detachment and loss in 1975 (left) and 1995 (right), 1998 (ACL).

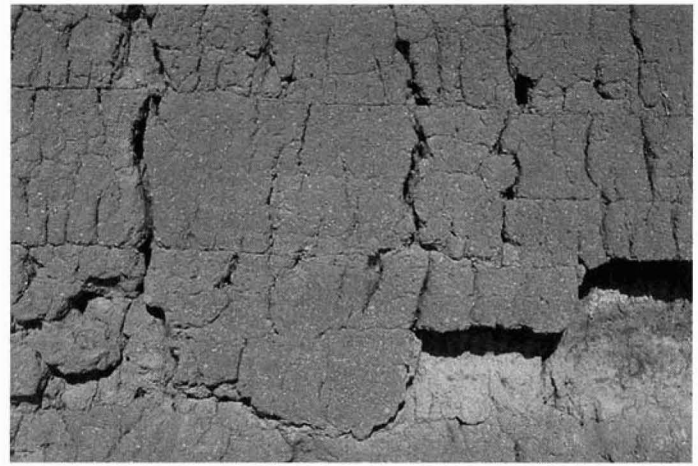


Figure 7. Lower west wall of the Casa Grande, north end adjacent to Fig. 6. Note cracking and detachment cracking indicative of potential future loss (ACL).

similar to 'English cob' was employed. Research conducted during the present study also suggests that more than one system may have been employed to construct the walls in which larger 'dumps' of the puddled caliche may have been used in combination with the smaller hand-moulded units to create the horizontal wall courses. This aspect of construction is important as it may explain the characteristic detachments or spalls of both large and small fragments that have occurred over time as the result of the weathering of the puddled earth of various but prescribed sizes making up the wall cross-section (Figs 6 and 7).

The composition of the caliche from the Great House has been analyzed by numerous researchers beginning in 1879.^v The present characterization and analysis was performed as part of the current research programme using the fragment that fell from the west wall in 1995.^{vi} Analysis included thin section petrography with polarized light microscopy, scanning electron microscopy and x-ray diffraction. Geotechnical tests to assess physical, mechanical and chemical properties included granulometry, Atterberg Limits (liquid limit, plastic limit), volumetric and linear shrinkage, moisture and soluble salt content, compressive strength, modulus of rupture, wet/dry cycling, water resistance, water absorption and acid soluble content.

These analyses and tests suggest that the caliche from the Great House was composed of a naturally occurring combination of gravel, sands, silt

and clay cemented by calcium carbonate. In addition, a high percentage of naturally occurring nodules or concretions of calcium carbonate of various sizes and shapes was found as the main component of the course fraction. Therefore calcium carbonate was present in the caliche in two forms: as a cryptocrystalline binder and as large calcic nodules which probably played a major role in reducing slump and shrinkage in its use as a coursed material for building the walls.

As a result of years of natural weathering from wet-dry cycling, the caliche developed a calcium carbonate-enriched crust on its exposed surface and a corresponding calcium carbonate-depleted zone located immediately behind the surface 20–30 cm deep. Similar surface crusting has been observed for calcareous soils and is related to both the chemical solubility of carbonates in water and water movement in soil. Water, either migrating through the material during drying or from exterior ground sources, alters the cementing media of caliche. Thus the caliche loses some of its calcium carbonate, which, being dissolved, is transported to the surface, and during evaporation is precipitated close to or at the surface. Accordingly, the outer pores are gradually filled with carbonate at the expense of internal depletion and weakening. In this manner an enrichment zone of calcareous matter develops on the exposed surface and varies in thickness.

This phenomenon has been observed on the fragment analyzed from the west wall of the Casa

Grande. The relocation of calcium carbonate from inside outward changes the density, porosity and strength of the caliche. Hence an increment of calcium carbonate content in the form of very fine particles within the capillary tubes of the caliche reduces the diffusivity (water movement) of the material. This reformed caliche exhibits high resistance to water and wet/dry cycling, low water absorption and low shrinkage. Conversely, the inner zone of caliche displaying impoverishment of calcium carbonate shows high porosity, friability and low strength as well as low resistance to water and wet/dry cycling, high water absorption and high shrinkage.

These physical and chemical changes in the caliche of the Great House have resulted in differential weathering of the material. Thus, the calcium carbonate-enriched zone has functioned as a protective skin more resistant to wind and water erosion due to its highly cemented condition and low water absorption. This altered surface caliche has been lost in areas due to mechanical cracking and fragmentation, conditions attributable to other factors including construction flaws, initial shrinkage and seismic shock. On the other hand, interior carbonate-depleted zones have been greatly affected by water (dissolution), freeze-thaw cycling and wind abrasion resulting in active conditions of surface friability and loss.

Differential deterioration is not only due to physico-chemical changes in the caliche. Other intrinsic causes of deterioration are construction-related combined with subsequent damage from timber removal. Extrinsic factors have been responsible for aggravating existing intrinsic problems resulting in the various detachment of fragments and cracking of the Great House. Site observations based on patterns of deterioration, along with results obtained from the wall conditions survey and the present characterization of the caliche have provided additional information on wall construction and construction sequencing of the Great House, thus extending recent investigations of the original construction [13,14]. The integration of such findings has allowed new interpretations of the differential weathering of the structure, especially in relation to the large fragment detachments that have been occurring at various locations (Figs 6 and 7).

In conclusion, a combination of intrinsic factors including preparation techniques of the caliche, construction methods, and physico-chemical transformations of the caliche in combination with natural and human-related activities have been responsible for the past and present condition of the Great House.

CONDITION AS EVIDENCE

Methodology

One of the underlying objectives of the current Casa Grande Phase I conservation Program has been the development of a methodology for the documentation of earthen architecture and related surface finishes. Despite the world-wide occurrence of these materials and their susceptibility to decay, no systematic standardized programme for their recording or study has been developed. The conditions recording and documentation programme developed included the following three components:

- The creation of a universal (and expandable) lexicon of conditions terminology for earthen building materials, complete with written description, photographic and schematic illustration, and coloured graphic symbols for mapping;
- The development of a simple reproducible field-to-lab system of recording using 35mm rectified photography to create base images for graphic field annotation of detailed conditions in the past and present;
- The assembly of existing graphic and database software to digitally manipulate the graphics and textual information in order to record conditions now and in the past, and to assist in conditions diagnosis and interpretation, including the identification of the cause, pattern and cycle or progression of deterioration now and in the future.

Field recording

Prior to conditions surveying, the exterior and interior elevations of the Casa Grande were recorded using 35mm rectified photography to provide literal base images for annotation. Each wall surface was divided into sectors, which

represented the smallest area to be surveyed as a single field sheet. The sectors for each wall were given a unique identifier, a letter and a number. Each sector photograph was printed on a laser printer from a Kodak Photo CD.

The photographs were taken with a 35mm single lens reflex camera fitted with a 28mm wide-angle perspective control (shift) lens. The camera was mounted on a tripod for all photographs, and levelled in two dimensions using a spirit level. The third critical measurement, perpendicularity to the wall, was achieved by using a framing square, or by measuring from two equidistant points on either side of the photo centreline

Conditions annotations

Interior and exterior conditions were recorded by 19 graduate students over a total of four weeks of field time. Pre-established descriptive terminology and graphic symbols were employed as annotations using coloured markers on acetate overlays on the printed photo elevations. Prior to the field recording, earlier photographs were collected from the site library, the Western Archaeological and Conservation Center (WAAC) and the Arizona State Museum, Tucson. These were all used to date and record previous conditions and repairs on the overlays. In addition, each sector was described using an accompanying architectural description form including information on the base image, surveyors, date, wall location, tier, wall orientation, room space, surface finish and loss and treatment ascertained from the historical documentation.

The breakdown of conditions recording into discrete, symptomatic descriptions allows for the possibility of postulating correlation among conditions and with variables such as environment, material composition, building construction and previous repairs and treatments. This has been made all the more possible through the ability to better manipulate digitized data as discrete layered systems with CAD and GIS software (Fig. 8).

Short of long-term monitoring, the careful recording and interpretation of existing conditions affords the opportunity to posit trends and potential cause and effect relationships explaining deterioration phenomena. Instrumental monitoring

provides the quantitative data to understand the subtleties of change over time. However, what, where, how and when monitoring occurs depends first on an understanding of the critical parameters affecting change through an initial reading of the physical evidence.

To this end, a visual 'reading' of the condition and deterioration of Casa Grande was first executed using a conditions glossary developed specifically for the project as a potential universal prototype for earthen architecture (Appendix). Prior to executing the survey, conditions were identified individually by their physical characteristics and grouped according to their overall effect as either subtractive or additive. Building features and previous interventions and repairs constituted separate categories. All conditions were recorded in time present. Past losses were indicated by location as notes only if accurate photodocumentation could pinpoint their occurrence by or between a certain date(s).

Graphic recording systems were developed using colour and symbol to define discrete classes of conditions and subsets within each. Both linear and overall pattern symbols were employed depending on the type of condition. For example, subtractive conditions such as loss, detachment and cracking were represented with linear patterns, while additive conditions such as surface deposits were represented by overall point patterns. Within general condition types, colour and pattern were further refined linking subtypes together and/or reflecting the different levels of severity within a type. For example, all subtypes of loss were represented in red and repairs in blue. In other cases, graphic symbols were further refined so that linked subtypes were expressed as variations on a specific pattern, such as diagonal hatching and cross-hatching for degrees of detachment and solid and dashed lines for cracks of different widths and depths. In this way, a graphically compatible and legible system could be created allowing a fast visual reading both within condition categories (same type) and across condition categories (different types), while at the same time referencing past conditions and previous treatments through notes.^{vii} The result is a graphically meaningful and legible system that takes advantage of colour, graphic symbol and

NOTES

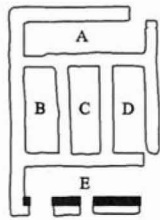
A Loss 1891-1892

B Repairs by Mindelieff 1891-1892

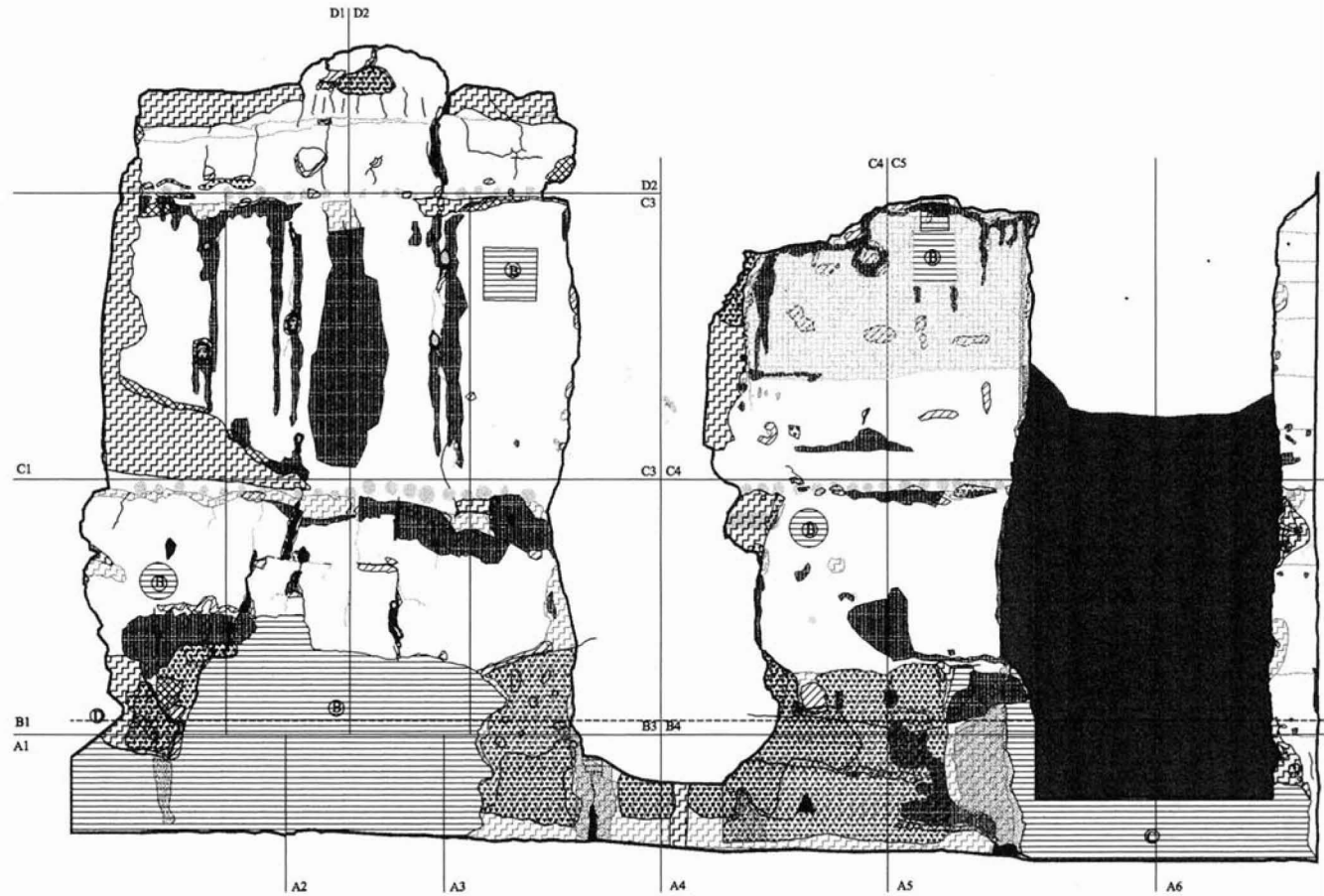
C Embedded original stubb wall fragment

D Original floor level

- Complete loss
- ▨ Major loss > 750 cm sq and ≥ 10 cm depth
- ▧ Moderate loss 1-10 cm depth (interior)
- Erosional loss > 10 cm depth
- ▨ Surface erosion
- ▧ Through-wall cracks
- ▧ Moderate crack > 10 cm depth
- ▧ Moderate crack 5-10 cm depth
- ▧ Moderate crack < 5 cm depth
- ▧ Open crack > 1 mm width (interior)
- ▧ Open crack < 1 mm width (interior)
- ▧ Map cracking
- ▧ Detachment crack
- ▧ Detachment > 5 cm
- ▧ Detachment < 5 cm
- ▧ Surface finish detachment (interior)
- ▧ Displacement > 1 cm
- ▧ Microbubbles
- ▧ Friable surface
- ▧ Animal activity
- ▧ Salt deposits
- ▧ Soil deposits
- ▧ Unexcavated fill
- ▧ Repair, prehistoric
- ▧ Repair, modern (1891-1996)
- ▧ Fill line
- ▧ Construction seam
- ▧ Architectural feature
- ▧ Architectural feature
- ▧ Photo grid



GROUND PLAN



TIER E SOUTH



Figure 8. Representative elevation of wall conditions survey, Tier E, south interior wall, 1997-8 (ACL).

letter-related text, and can be easily studied for visual patterns.

Digital documentation

All field-recorded information was subsequently imported into computer photographic and drawing applications to transfer the field survey into a digital format. The final product is a series of plotted drawings within the traditional architectural format of scaled elevations and plans but with the ability to manipulate complex overlays of annotated conditions and to quantify each condition (Fig. 8). The drawings were also saved digitally on high-capacity Zip disks as Autodesk AutoCAD (r14) drawing files.

Prior to the overlay of conditions, all acetate sheets and their base photographs were scanned to facilitate the location of conditions through tracing. CadOverlay was used as an imaging programme to bring the raster images into AutoCAD. Although with AutoCAD (r14) one can bring digital images directly into the programme itself, there were capabilities with CadOverlay to align and manipulate images that had the potential of adding more flexibility if raster images could be printed underneath the vector line drawings.

All individually entered sectors were then joined to complete each elevation. In the future this joining as a complete montage elevation should occur before the overlay of individual sector conditions so that field recording anomalies (e.g. misalignment, perspective distortion) may be corrected on the base photographs, allowing accurate conditions overlay at any scale (i.e. individual sector or entire elevation). Adjustments to the drawings, hatch scales and layouts were made before final plotting. Twenty-five sheets were produced including 23 elevations, a glossary sheet of definitions and conditions, and a plan sheet documenting wall abutments and discontinuities. Large format and reduced 11" x 17" drawings were produced (Fig. 8).

ASSESSMENT AND DIAGNOSIS

The following observations are a summary of the major conditions recorded during the exterior and interior wall survey of the Casa Grande from

1997–8. When considered in conjunction with other factors such as environment and microclimate, wall orientation and exposure, wall composition, construction technology and previous interventions, these observations suggest obvious and subtle patterns of physical alteration which have resulted in both loss and degradation as well as potential improvements such as surface hardening. The summary observations described below are intended to accompany and supplement the graphic data. By using the CAD digital format, multiple interpretations of conditions can be explored to query and reveal patterns and trends as well as anomalies related to time, location, and condition type. Simultaneously, plotted images as both overall elevations and detailed sectors allow for an effective cyclical assessment of conditions and an evaluation of treatments in the field.

OBSERVATIONS OF PRINCIPAL CONDITIONS

Loss

Loss, whether as wall fragments or wall segments, is the final and ultimate stage of deterioration at the Casa Grande. It is the most extreme condition and obviously non-recoverable; however the careful recording of total and various partial loss categories (major, moderate, erosional and surface) is a useful indicator of past and current trends, especially when dated through earlier documentation. When viewed in conjunction with other factors such as wall configuration and construction details (seams), or accompanying conditions such as friable surfaces or soil deposits, fabric loss can be understood as the result of structural or superficial forces and active or inactive decay mechanisms. At Casa Grande, most complete loss appears to be the result of single event structural collapse, usually in association with structural weaknesses from construction seams or unsupported masonry as in the case of broken wall ends and breached openings. Smaller but no less significant loss can be traced to localized detachment (see below).

Major and moderate losses are usually associated with large surface areas of severe exposure such as parapets, wall tops and bases. Localized loss within the confines of specific construction

courses usually indicates intrinsic material inferiority in those areas. Erosional loss is a specific condition, always in association with deep cracks, ledges or openings causing high volume water channelling and mechanico-chemical dissolution of the clay-lime binder of the earthen material. Surface erosion is a more diffuse condition occurring over a broader area and with less volume of water washing over exposed areas (see below) and may be related to the loss of the calcium carbonate-enriched surface.

At Casa Grande nearly all wall tops exhibit areas of major and moderate loss, presumably from centuries of weather exposure (wetting and drying) prior to the erection of the shelter in 1903. Basal loss, now only visible in the interiors, but formerly on the exterior (before Mindeleff's repairs), was most likely also due to water, however in this case, as the agent for salt and frost attack resulting in the gradual flaking and disintegration of the wetted zone.

Cracking and detachment

Although cracking is the most visible and obvious of conditions observed at Casa Grande, its importance in the overall stability of the structure is no longer critical with the exception of through-wall cracking. The majority of cracks observed on the exterior and to a lesser degree on the interior of Casa Grande are superficial and the result of gradual surface weathering of original shrinkage cracks within individual construction courses. Obvious exceptions to this are cracks whose length, depth and direction of propagation clearly indicate construction anomalies or post-construction failure from settlement, uneven loading, collapse and seismic and vibrational activity.

Most vertical through-wall cracks appear to relate to original construction methods including termination of individual horizontal courses (head joints) and adjacent wall abutments. Where these anomalies occur with other deleterious conditions such as unsupported wall ends or water channelling, collapse can and has occurred in the past. Both structural and non-structural cracks whose depth and width invite insects, birds, and rodents create further complications through the destructive activity associated with these animals.

Detachment cracking, on the other hand, represents a very different problem. Although insignificant in appearance, its association with detachment indicates the potential for large losses of lens-shaped fragments. These have occurred in both isolated and associated areas of the exterior and interior as indicated by several recorded events over the past fifty years and probably even earlier, judging from the presence of tell-tale lens-shaped losses on the surface. This peculiar condition appears to be clue to inherent planes of weakness within the walls caused by the mounding or puddling of large and small units of prepared caliche, especially along the lower courses, often above now unsupported areas (Figs 6–7). Given the blind nature of these failures, incipient detachment can occur for a long period of time undetected, allowing additional damage from animal activity and salt formation such as was observed in association with the most recent spall on the west exterior in 1995, and earlier in 1975.

Surface finish detachment is a unique condition characterized as a loss of bond between the interior finishes and their masonry substrate, occurring either as open or blind separation. Like wall detachment, this condition appears to be largely due to construction technique whereby the smooth, level interior surfaces were created by the application of a separate veneer of puddled earth or layers of earthen plasters. These in turn were subsequently finished with one or more thin layers of red clay washes. Surface finish detachment is almost always located along the lower or upper walls where the wall has been damaged and opened from the removal of beams and the penetration of water.

Microhoodoos, friable surface and soil deposits

These conditions, often found in association with one another, indicate a past and possibly active condition of weathering from wind-driven rain and snow. Although the construction of the first and subsequent shelters in 1903 and 1932 ostensibly halted direct damage from precipitation, wind-driven rain and occasionally snow still reached the exterior and interior walls. This is evidenced by puddled water in the interior and the occasional wetting of walls after a heavy

storm. The presence of rivulets of soil deposits on original walls and post-shelter repairs is further evidence of past and active patterns of water-borne surface erosion. Related to this is the unique occurrence of microhoodoos that indicate the direction of wind-driven rains and storms from their uniform angle of erosion. Such damage is most probably ancient, however. In conjunction with recent soil deposits these signal key locations for possible monitoring and protection.

SUMMARY DIAGNOSES OF CONDITIONS

Based on the above observations of recorded conditions in conjunction with archival documentation on past descriptions of the structure and previous preservation interventions, the following conclusions can be made to guide immediate and future plans for conservation and management, including further study and monitoring and active and passive conservation interventions.

Despite the apparent extreme appearance of the Casa Grande, there is little evidence to suggest that many of the conditions observed and recorded are active, especially those related to surface erosion and cracking. Potentially active sites of weathering from exposure (e.g. microhoodoos and detachment) may exist and need to be studied more closely through quantitative monitoring.

Structural instability of walls and wall sections remains a possible serious threat. Clear evidence exists that large-scale collapse of several sections of wall did occur during remedial stabilization in 1891–2 and possibly earlier. These collapses occurred in vulnerable areas associated with original construction faults and subsequent deterioration such as unsupported broken wall ends. It is important to stress that conditions similar to those associated with these past wall collapses currently exist on all four exterior walls, especially on the north, east and south elevations. Through-wall cracks and wall separation remain a major concern. External forces such as seismic activity, vibrations and wind load have been cited as potential agents that could cause major damage to the current structural disposition of the Casa Grande. Future study and monitoring, both through fieldwork and virtual computer models, is clearly needed and is currently underway.

The current (1995) and repeated loss of large lens-shaped fragments of wall material on the lower exterior and interior walls indicates an active and complex condition requiring further study to ascertain the full extent of the causes and locations at risk. The present condition survey has allowed an initial prediction of potential future spalls by using the specific conditions survey to isolate specific areas for monitoring, closer inspection and possible emergency treatment.

The majority of visible repairs at the Casa Grande are those installed by Mindeleff in 1891–2. These remain largely intact with minor carpentry repairs and brick plaster resurfacing. No evidence exists indicating that these repairs have caused damage to the original fabric of the structure; however a reassessment of their positive contribution to the performance and stability of the structure must be made. This is especially true for the wooden and metal tie rods that could cause damage to the structure in the event of seismic activity.

The interior surface finishes of Casa Grande are among the best preserved of any ancestral Native American structure. As such, any deterioration, no matter how minor, is harmful, compromising its archaeological and aesthetic integrity. Areas of active finish detachment exist and need immediate attention before further loss occurs. Pilot treatments to readhere flaking clay washes with water and various fixatives including gelatin and acrylic emulsion have thus far proved successful.

Earlier excavation of Tiers B and E has created difficult level changes among the tiers and the exterior grade. This in turn has necessitated the insertion of staircases, steps and built-up floor surface treatments on the interior. Methods of visitor access and control should be studied to determine the best strategy for accepting or changing this situation to facilitate interpretation and visitation, improve drainage from within the structure and protect the fabric.

A FRAMEWORK FOR CONSERVATION

Philosophy

Aside from its significance as the only surviving Hohokam Great House and the largest prehistoric (non-mound) earthen structure in the United States,

one of the most significant aspects of Casa Grande is the fact that it has survived stabilization and interpretation with remarkably few material interventions. This conservatism of treatment has not only ensured the high retention of information for archaeological study, but has also inadvertently protected the structure from the often adverse effects of incompatible material interventions. The decision to protect the structure by external means through the erection of a shelter was proposed early on even before the preservation program of 1891–2.^{viii} Victor Mindeleff, the original architect of the proposed preservation program, did not advocate a shelter, citing its negative visual impact on the site. His brother, Cosmos, who replaced him in finalizing and supervising the work, eventually designed a shelter which, owing to lack of funding, was not immediately constructed. Nevertheless, he too recommended monitoring of the structure for a few years before making the decision to install a shelter. Mindeleff's wooden and corrugated metal roof shelter was constructed by 1903, an unsightly tight-fitting structure built within and over the standing ruin. This was eventually replaced in 1932 by the present steel canopy shelter designed by Frederick Law Olmsted Jr and Thomas Vint, itself now a landmark after 67 years and a National Park Service classified historic structure.

The ultimate effect of continuous shelter protection (even during replacement of the 1903 shelter) has been to reduce significantly atmospheric weathering and therefore remove the need for directly applied protective treatments such as consolidation, water repellents and crack and loss repair. This has certainly not been the case for the other standing walls at the site, which have had a long and current practice of surface protection using coats of cementitious- and later acrylic emulsion-bound soils. Although useful in preserving the overall form and configuration of the exposed walls with a reasonable simulation of earth, this technique has diminished the informational value of the walls and may be worsening the condition underneath. Further investigation and assessment of this long-standing technique of preservation for many of the lower compound walls at the site should be conducted in the future.

Although the construction of the shelter has had an undeniably positive effect on the Casa Grande in that the structure has been spared direct fabric interventions over the years, it has also created the problem of an illusion of stability and no change. Based on the present condition survey and the associated diagnoses outlined above, inherited damage and instability dating from before the shelter, particularly in association with external forces such as vibration and seismic movement, remain a primary concern. A review of past proposals for major interventions including laser drilling for the insertion of a metallic and epoxy reinforcement system in the walls [8] and the application of various consolidants and water repellents have all responded to incomplete assessments of the caliche and the walls. That these proposals, some supported by highly technical studies, were all shelved for future consideration, attests to the implicit appreciation and significance of the structure's physical integrity by the National Park Service.

In keeping with the long-standing tradition of conservative approaches and preventive conservation at the Casa Grande, a judicious and cautious policy of intervention has been embraced as the best option, where justifiable through continuous scientific analysis and monitoring. In other words, any proposed treatment should first be proven as providing necessary and beneficial action to the material and structure and guarantee that it will 'do no harm'. Any such physical interventions should also be considered with respect to issues of further archaeological study and cultural appropriateness, established through consultation with affiliated Native American groups. The current condition survey and material characterization studies offer the necessary baseline information to continue to test assumptions and proceed with future plans of immediate and long-range conservation monitoring and site management.

Future considerations

The identification, documentation and explanation of the processes of deterioration of the Great House are a necessary prelude to any conservation and management strategy. Fortunately since the first stabilization efforts of 1891–2 until the

present, continuous protection, care and maintenance have significantly reduced deterioration of the Great House. Continuous efforts to redress the issues of deterioration and possible intervention have resulted in several studies focused on structural problems, namely related to seismic and wind damage [5,7,8]. Proposed methods of stabilization by Kreigh and Sultan [8], inserting steel pipes into vertical holes laser-drilled through the walls, filled with epoxy and the whole tied into a rigid structure of horizontal pipes, was fortunately rejected as too invasive and experimental, compromising the physical and informational integrity of the structure. A second plan was proposed involving the filling of the various beam holes, roof grooves and erosional losses with caliche on the basis that this was needed for structural stabilization [14:42]. Its implementation was rejected by the National Park Service again due to its negative impact on the structure through obfuscation and possible damage to these important architectural features. While it is highly questionable that either of these proposals would have resulted in achieving their stated objectives, and, in the case of the former proposal, would have clearly resulted in irreversible damage, their rejection did not remove the suspected problem of structural instability, especially with respect to seismic activity.

From 1903 with the addition of the first protective shelter until the present, several major processes of deterioration, mainly water-related, have become largely inactive. In some cases, gradual deterioration of the fabric continues, albeit reduced. In other cases, earlier damage resulting in structural instability still remains, not necessarily active but still unaddressed. The most serious immediate deterioration observed at the Great House is related to past and active mechanical failure of individual fragments and former loss of entire wall segments. Exposure of friable material due to gradual localized loss of the protective calcium carbonate-enriched surface is also a problem of smaller magnitude, but no less significant. These problems are intrinsic in that they are related to the natural weathering of the caliche and the original construction of the building. As such they cannot be reversed but rather retarded or mitigated through different methods of stabilization.

Fragment detachment and loss

The cracking, detachment and loss of individual fragments of caliche, some weighing as much as 100 pounds, is both a past and active condition which needs to be further assessed based on the results of the condition survey. Detached fragments not only result in the loss of original fabric but pose health and safety hazards to the public and staff. Areas identified as 'at risk', based on the combination of conditions of detachment, detachment cracking and associated construction seams, should be carefully examined (Fig. 8). The extent of detachment should be evaluated, first using simple and direct methods such as water injection to determine the volume, location and interconnection of voids and planar discontinuities. Where necessary, structural bracing or facing may be required depending on the size of the fragment before any further testing is attempted. Non-destructive evaluation using impact echo, radar or other techniques may prove useful; however further inquiry into their valid application for this situation will be necessary.

Once all detached and potential spall areas are assessed in detail, a pilot treatment programme should be implemented to determine the possibilities and limitations of the proposed techniques. Based on the heterogeneous nature of the caliche and the inclusion of large nodules and internal construction discontinuities and cracks, mechanical pinning should be avoided as unpredictable and dangerous. Grouting with compatible, low viscosity, inorganic grouts such as those based on moderately hydraulic lime, selected aggregates and fillers with acrylic emulsion additives, such as those developed by the Architectural Conservation Laboratory and used extensively at other sites such as Fort Union National Monument, Fort Davis National Monument, Mesa Verde National Park and Çatalhöyük, should be tested. These would provide sufficient readhesion and fill blind and surface voids restricting animal access and potential vandalism.

Animal activity

Based on the results of the condition survey, it is clear that a variety of animals, birds, rodents,

insects and arthropods, have made the larger cracks and crevices of the Casa Grande their home. This activity has resulted in the enlargement of cracks and voids and associated staining. Rodent activity was noted in association with the fragment that fell recently from the lower west wall (1995) suggesting the possible exacerbation of existing damage originally attributed to other causes.

All cracks and voids greater than 10cm in depth should be evaluated for filling, especially those that exhibit active animal activity. Fills could be formulated from caliche and installed below the surface of the loss, thereby identifying them as repairs rather than original material. Further identification for future researchers could be insured by adding dated microtags into the caliche fill material. Where original architectural features require filling due to destructive animal activity, an isolating layer material such as a polyester textile could be installed prior to the insertion of the fill to allow easy removal at a future date. The current method of wire mesh fill, while reversible, is unsightly.

Structural instability of walls

Beginning with the first preservation efforts, wall stability has been a major concern at the Casa Grande. As already discussed, the present structural condition of the walls is the result of a number of factors, including wall material and construction methods, previous vandalism, stabilization and collapse and environmental exposure. These factors in their various combinations and permutations have created a range of conditions. Unlike all other surface and material conditions noted and discussed, structural instability is most serious because it results in total and immediate catastrophic loss and a safety hazard. Past and current studies have shown that of the many potential external factors affecting the structural condition of the Casa Grande, which include earthquake, wind load, aircraft and traffic vibration and water table subsidence, seismic activity remains the major threat. Contrary to previous assessments, seismic activity may well have been responsible for major single event losses to the walls. This is not to diminish the damaging effects

of timber removal, excavation, weathering and salt cycling on the structure, but whereas these agents have ceased or have largely been eradicated, seismic activity remains a major threat according to the calculations and predictions by Gift and Johansen [5] and King [7]. Advanced techniques of modelling and monitoring since the previous studies would allow for a more accurate assessment and prediction of possible future damage.

As a result of these preliminary studies and the above survey and material analysis computer modelling of the walls is underway based on their original configuration and current condition (including the effect of Mindeleff's repairs) using the natural frequency parameters already measured by King for each wall section. In addition, a trial monitoring and stabilization system, termed a 'smart viga', will be installed on the east wall for one year to demonstrate and measure the strengthening and stiffening effects of this form of intervention as a possible method for seismic mitigation. This will involve increasing the overall natural frequencies of the wall from 2.9-4.0z/s to over 6 z/s and thus reduce the susceptibility to collapse from distant seismic activity.

Surface friability and erosion

More than any other building material, the treatment of friable earthen-based materials has been of great concern for professionals. An endless list of various products has been tested and used as consolidants to improve the mechanical properties of the soil and impart water repellence. The long history of the application of these materials to earthen structures has generally resulted in failure; the damage caused by the loss of the treated material has been often greater than that from natural weathering.

Analysis of the Casa Grande caliche has demonstrated that the condition of friability, where it exists, is a function of the loss of the calcium carbonate-enriched crust that naturally forms upon exposure of the material to repetitive wetting and drying cycles. Due to the construction of the protective shelter over the Great House, this natural phenomenon has been interrupted; once the crust is lost (see above), it cannot form again and deterioration of the calcium-depleted zone

beneath can occur, especially if exposed to wind-driven rain and abrasion.

Consolidation of these localized friable surfaces could be achieved at the Casa Grande through the application of limewater (calcium hydroxide) consolidant. This method has received much study and trial use since the 1930s, particularly for carbonate rocks and some lime plasters. Calcium hydroxide, applied as a solution of limewater, evaporates, thereby depositing material within the pores of the material, which expands and hardens upon carbonation. This results in increased particle-to-particle cementation and improved cohesive strength and abrasion resistance. The use of limewater would be extremely suitable at the Casa Grande due to its compatibility with the calcium carbonate content of the caliche. Consolidation using limewater is still widely debated as to its efficacy, largely due to the lack of penetration of the calcium carbonate. Tests run at the Architectural Conservation Laboratory using eighty applications of limewater to consolidate friable historic and feeble replicate lime plasters proved effective, with significant hardening of the surface and good depth of penetration. Before adoption of this technique, laboratory tests to establish the best method of application and its effects would need to be performed in conjunction with a monitored field testing programme. Monitoring in the field could be performed through the installation of ceramic or stainless steel pins surface-mounted in selected areas of treated and untreated friable areas and stable areas for comparative evaluation of the treatment.

CONCLUSIONS

As has been wisely observed, the interpretive potential of the Casa Grande remains limitless [14: 421. As public property whose care and interpretation is entrusted by law to the National Park Service, future research and continued public enjoyment of the Casa Grande must be guaranteed. Given its uniqueness and significance, any conservation measure considered must be evaluated against the physical changes that will result from its implementation, now and in the future. To this end, continued investigation and modelling, monitoring and judicious pilot treatments can be

recommended as the most responsible and appropriate method toward developing, implementing and modifying over time a cultural resource management plan for the last Great House.

Frank Matero is Associate Professor of Architecture and chairs the Graduate Program in Historic Preservation at the Graduate School of Fine Arts, University of Pennsylvania.

Contact address: Graduate Program in Historic Preservation at the Graduate School of Fine Arts, 115 Meyerson Hall, University of Pennsylvania, Philadelphia, PA 19104, USA. Tel: + 1 215 898 3169. Fax: + 1 215 573 6326.

REFERENCES

- 1 Baxter, S. Archaeological camping in Arizona. *The American Architect and Building News* 26 (1889) 121.
- 2 Clemenson, A. B. *Centennial History of the First Prehistoric Reseme 1892. Administrative History, Casa Grande Ruins National Monument, Arizona*. Denver Service Center, United States Department of the Interior, National Park Service, Denver (1992).
- 3 Fewkes, J. W. A report on the present condition of a ruin in Arizona called Casa Grande. *Journal of American Ethnology and Archaeology* 2 (1892) 179-193.
- 4 Fewkes, J. W. *Casa Grande, Arizona. 28th Annual Report of the Bureau of Ethnology, 112 & -07* (1912) 25-179.
- 5 Gift, A. and Johansen, G. E. *Casa Grande, A Preliminary Structural Rariau*. University of Pennsylvania, Department of Engineering (1998). Unpublished report (UPENN).
- 6 Hayden, J. D. Plaster mixing bowls. *American Antiquity* 7 (1942) 405-407.
- 7 King, K. and King, E. *Casa Grande National Monument Vibration Investigation* (1998). Unpublished report. (NPS-CAGR)
- 8 Kreigh, J. D. and Sultan, H. A. *Final Report Feasibility Study in Adobe Preservation, Casa Grande National Monument and Fort Bowie National Historic Site*. University of Arizona College of Engineering (1974). Unpublished report.
- 9 Mindeleff, C. *Casa Grande Ruin. 13th Annual Report of the Bureau of American Ethnology* (1896) 289-316.
- 10 Mindeleff, C. *The Repair of the Casa Grande Ruin, Arieona in 1891. 15th Annual Report of the Bureau of American Ethnology* (1897) 315-349.
- 11 *Statement for Management. Casa Grande Ruins National Monument, Arizona*. National Park Service, United States Department of the Interior (1995).
- 12 Resources Management Plan. Casa Grande Ruins National Monument. National Park Service, United States Department of the Interior (1996).
- 13 Wilcox, D. R. and Shenk, L. O. *The Architecture of the*

- Casa Grande and its Interpretation*. Arizona State Museum Archaeological Series **115** (1977).
- 14 Wilcox, D. R. and Sternberg, C. *Additional Studies of the Architecture of the Casa Grande and its Interpretation*. Arizona State Museum Archaeological Series **146** (1981).
- 15 Wilcox, D. R. and Hensley, C. M. A Hemenway portfolio: Voices and views from the Hemenway Archaeological Expedition, 1886-1889. *Journal of the Southwest*. (1995) 521-624

ENDNOTES

- i The site was visited and recorded earlier by Adolf Bandelier in May 1883 during his five-year trip through New Mexico and Arizona for Lewis Henry Morgan and the Archaeological Institute of America (reported in Bandelier, A. F., *Final Report of Investigations Among the Indians of the Southwestern United States, Carried on Mainly in the Years 1880-1885, Part I* Cambridge. John Wiley [1892] 1405, 453, 458, 461). As for other sites he visited, Bandelier produced coloured measured plans and sections of the site and the Great House.
- ii During the 1970s, Dennis B. Fenn initiated a test wall research program at Casa Grande and other sites in the southwest, focused on evaluating existing and proposed chemical stabilization treatments for adobe and related earthen building materials.
- iii The project team included Frank Matero, project director; G. Eric Johansen, engineer and architect; Elisa del Bono and Kecia L. Fong, graduate conservation researchers; Guy R. Munsch and Nicholas L. Stapp, graduate coordinators for documentation; Andrea Gift, undergraduate engineering researcher, and Toni Loiacano, graduate engineering researcher. In addition 19 graduate students generously contributed many hours of field and computer laboratory time to record and document existing field conditions. Catherine Dewey was responsible for the final production of the digitized computer drawings. The project's work programme was formulated in conjunction with professional staff from the Southwest Region Support Office. Associated supervising National Park Service project personnel included Jake Barrow, project manager and Robert Hartzler, field supervisor. Ann Brackin Oliver and Kate Dowdy assisted in the preparation of baseline photographs for the conditions survey. Valuable input was also provided by James Rancier, former archaeologist, Southern Arizona Group Office (SOAR), David Evans, exhibit specialist (SOAR), James Trott, archaeologist (Architectural Conservation Projects Program, Santa Fe Support Office, Intermountain Region) and Don Spencer, CAGR Superintendent. Given the complexity of the conservation problems, consultation was sought from numerous specialists in the university and elsewhere including Gomaa Omar, geologist, and Arthur Johnson, soil scientist, Department of Geology and Environmental Science (UPENN); and Alex Radine, research engineer, Laboratory for Research on the Structure of Matter (UPENN). Ken King,

- geophysical engineer, also provided valuable information on the issues of potential vibration damage to the structure as an independent consultant to NPS.
- iv These photographs are credited as being 'loaned by Mrs. Hemenway, to whom [they were] presented by Mr Frank H. Cushing'. [3] Presumably Cushing took these photographs during his visit to the site from December 31, 1887-January 4, 1888 or during a second visit in late January 1888.
- v Based on current research executed as part of this conservation programme by Elisa del Bono as a MSc thesis on the characterization and analysis of the caliche walls of the 'Great House' at Casa Grande Ruins National Monument, Arizona, 1999.
- vi Since then scientific studies of the material have been carried out periodically. Cook first analyzed the material followed later by Littnan (1967), Vick (1973), Kreigh and Sultan (1974), Wilcox and Shenk (1977), and Roy (1980).
- vii This system was first created and perfected for the recording of architectural surface finishes at Mesa Verde National Park by the author, beginning in 1994.
- viii As early as 1878, local opinion promoted the idea of protecting the structure from the weather and vandalism with an enclosure.

APPENDIX

GLOSSARY OF CONDITIONS TERMINOLOGY FOR EARTHEN MATERIALS

Animal activity

The presence of birds, rodents, spiders, insects, and other desert-dwellers as evidenced by guano, spider webs, debris and burrow-tunnels.

Architectural features

Major building features such as wall profiles, openings, beam pockets, floor scars, and observation holes, etc.

Complete loss

Gross loss of wall fabric as per past photographic documentation, relative to the present; not loss of completeness of form.

Construction seams

COURSE BOUNDARIES

Horizontal construction seams of variable length and width marking the upper and lower bed faces of individual construction courses.

HEAD JOINTS

vertical construction seams marking the end or interruption of horizontal construction courses. Joints may span one or more courses and are generally straighter and more planar than subsequent vertical cracks.

Cracks

Linear discontinuities in the walls, either in the earthen substrate, the applied earthen finish layers or both. Cracks in the substrate are usually vertical, while those in the finish layers are more random in orientation. Five categories of cracks are defined:

THROUGH-WALL CRACKS

Major vertical cracks that extend all the way through from exterior to interior surfaces and are more or less perpendicular to the wall surfaces. Also included are wall juncture separations resulting from butt wall detachment.

MODERATE CRACKS

Irregular cracks of predominately vertical orientation and variable depth (1 to >10cm) Three types of moderate cracks are differentiated:

- Cracks greater than 10cm in depth
- Cracks 5-10cm in depth
- Cracks less than 5cm in depth

SURFACE CRACKS

Two types of superficial cracks restricted to the applied surface finishes of the interior and differentiated by width:

- Cracks greater than 1mm in width
- Cracks less than 1mm in width

MAP CRACKING

A patterned network of fine superficial cracks occurring in the finish layers and exposed earthen substrate, usually associated with exposure.

DETACHMENT CRACK

Cracking associated with areas of incipient detachment (see below).

Detachment

Planar discontinuities resulting in lens-like fragments of wall material that have become partially separated from the underlying earthen substrate. The detachment is detected visually and audibly by sounding, and by inserting a probe behind the fragment. The angle of the separation, indicated by the probe, must be 0-60 degrees, measured from the plane of the wall face. Two categories of detachment are differentiated:

- Detached fragments greater than 5cm thick
- Detached fragments less than 5cm thick

Detachment boundaries not otherwise marked as cracks or construction seams, are also noted.

Displacement

Movement and cracking of the wall, resulting in the shifting of the wall surface more than 1cm out of plane.

Erosional loss

Distinctive patterns of loss, often in association with vertical cracks, where the depth is greater than the width and at least 10cm in depth.

Fillline

Former level of accumulated interior aeolian deposits (wind-blown earth and debris) and earthen material from collapse and rainwater washing of the standing walls.

Friable surface

Surfaces that display active disaggregation of individual nodules or flakes which disintegrate under finger pressure.

Major loss

Loss of earthen material where the loss is greater than 750cm² and at least 10cm in depth, as

measured from the present plane of the wall surface.

Microhoodoos

Small protruding stalks of earthen wall material formed by differential erosion of the surface from wind-driven precipitation. These microhoodoos are oriented parallel to the prevailing wind, and usually support erosion-resistant aggregate at the tip.

Moderate loss

Loss of earthen material where the loss is 1–10 cm in depth, as measured from the plane of the present wall surface. (Recorded only on interior surfaces.)

Photo grid

Demarcation of the area recorded by the individual rectified photographs of the interior and exterior wall elevations.

Repair

All actions, ancient and modern, executed to maintain, repair, and preserve the fabric of the structure.

PREHISTORIC REPAIR

All observed repairs made during and after construction by native inhabitants, including, mud patching and stick stitching of shrinkage cracks and wall abutments.

MODERN REPAIR (1891–1996)

All documented interventions made since 1891 including, but not limited to, brick underpinning, plaster repair, wooden and metal tie rods, waterproof coatings, consolidation, and protective wire mesh installation.

Room space

The space defined by the walls, floor, and ceiling of the original rooms as evidenced by construction

features such as beam (viga) pockets. Numbering is sequential from the excavated semi-subterranean room space 1 up through to room space 4 of the centre Tier C.

Salt deposits

Salt-laden water moving through the walls crystallizes within the pores and on the surface as the water evaporates forming white crystalline deposits. Ground water, animal faeces, urine, and cement-based repairs are possible sources of damaging salts.

Soil deposits

Soil which washes down from wall tops and upper wall surfaces, and from highly eroded areas, forms rivulets of dried mud on lower walls, and is an indicator of potentially active wind-driven rain and snow.

Surface erosion

Differential surface weathering defined by large areas of coarse texture and surface loss greater than 1 cm in depth. Often in association with major and moderate loss.

Surface finish detachment

Separation of the applied surface finish layer(s) from the earthen substrate or from each other as interlayer detachment, generally occurring in discrete areas of the wall, either as blind- or concealed-detachment or open- or edge-detachment.

Tier

The plan of the Casa Grande is rectangular and divided into five multi-level unit spaces defined as tiers A, B, C, D, E.

Unexcavated fill

Laminated deposits found in corners and erosion holes and channels of room spaces 1 and 2, probably as residual room fill not removed during the 1891 excavations.