Conservation History

History of Interventions

Early Written Accounts and the Discovery of the Hieroglyphic Stairway

The archaeological site of Copán has been described in several written sources since the Spanish conquest, but it has most famously been referenced by John Lloyd Stephens in *Incidents of Travel in Central America, Chiapas, and Yucatán* (for the earliest reference dating from 1576, see Garcia de Palacio 1860 and Gordon 1896, 45–48; for a later description, see Galindo 1836; Galindo 1920; Stephens 1841). Stephens's 1841 best seller made Copán, as well as other Maya sites, known to much of the world. None of these early publications, however, refer to the Hieroglyphic Stairway.

In 1885 Alfred Percival Maudslay, a British explorer turned Maya scholar, carried out the first extensive and careful exploration of the site, and in doing so, he rediscovered the Hieroglyphic Stairway by finding a section of steps resting at midslope on the west side of the pyramid Structure 26 (**Fig. 15**) (Maudslay 1889–1902, 11, 30). Subsequent excavations revealed that this section of steps, the only visible part of the Stairway at that time, is the one that slid down the slope of the pyramid, with its steps together and in sequence, from its original, higher position.

The Peabody Museum of Archaeology and Ethnology

Maudslay's first exploration of the site sparked the interest of Harvard University's Peabody Museum of Archaeology and Ethnology, which, in 1891, obtained a ten-year concession from the Honduran government to explore the ruins of the country; in particular, the concession gave the Peabody the right to carry out investigations at Copán (Gomez and Zelaya 1891, 1). Under this special edict, the Museum began archaeological work at Copán in December 1891 by clearing the site of vegetation (Saville 1892c, 14). Excavation of the Hieroglyphic Stairway started the following year, during the 1892–93 field season (**Fig. 16**).

Figure 15 Court of the Hieroglyphic Stairway looking east, with Alfred Percival Maudslay's camp in the foreground. Trees cover Structure 26 in the background. 1885.

Figure 16 Structure 26 looking east after the clearing of trees and vegetation. The Hieroglyphic Stairway is seen as it was found, with only the fallen section of steps visible. Ca. 1892–93.

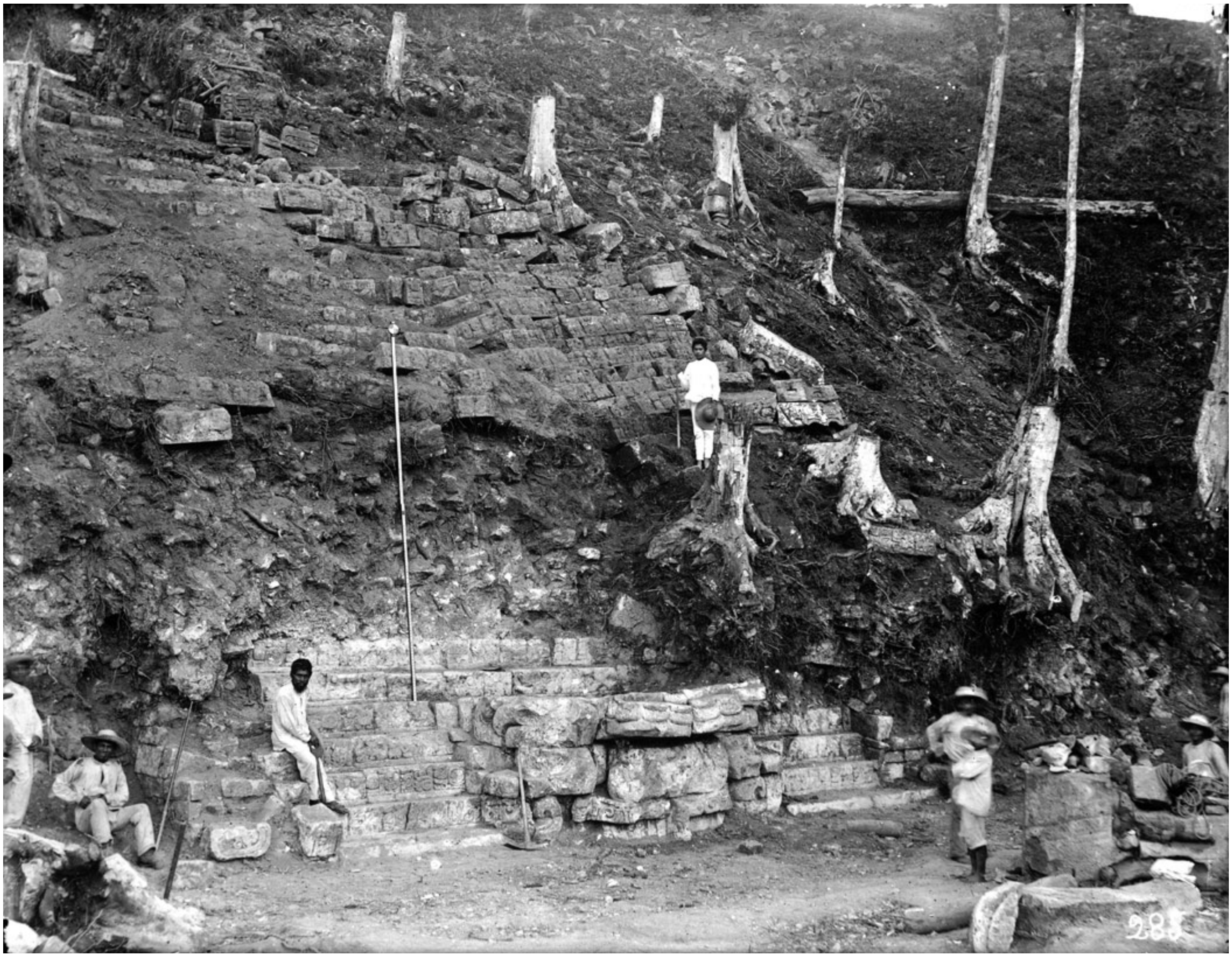


Figure 17 The Hieroglyphic Stairway during excavation of the lower in situ steps, which were covered by meters of debris and the fallen section of steps. Ca. 1893.

Between December 1892 and January 1893, the hieroglyphic blocks of the fallen section of steps were fully uncovered, and preparations were made for taking molds of them. The steps that remained in situ at the bottom of the Stairway were discovered under more than four meters of debris (**Fig. 17**).[1] Unfortunately, the Stairway excavation was cut short by the death from tropical fever of the expedition director, John G. Owens (Gordon 1893a, 1). George Byron Gordon, the young surveyor, then took charge of the expedition and brought back to Boston, among the season's finds, the second Seated Figure, sawn into pieces, and a number of hieroglyphic step blocks sawn off to four- to five-inch slabs for ease of transportation (Lincoln 1893a; Gordon 1893c, 1–2).

No expedition took place at Copán in the following 1893–94 season, because of Owens's death and a politically unstable climate in Honduras (Maudslay 1889–1902, 65). During the 1894–95 field season, directed by Gordon, the hieroglyphic blocks of the fallen section, as well as other loose blocks found in the debris, were cleaned, photographed,

Figure 18 Fallen section of the Hieroglyphic Stairway being lowered to the Plaza block by block. George B. Gordon, director of the Peabody Museum expedition, is seen in center. 1895.

numbered, and then lowered down to the plaza level "without the slightest injury to any" (**Fig. 18**). There they were placed on stone supports and photographed, and most of them were paper-molded, after probably having been "scrubbed" with water, a common site practice (**Figs. 19, 20**).[2] Work at Copán was interrupted again during the three following years (1896–1898), because of the election of a new president in Honduras, who annulled the edict that had been granted to the Peabody Museum (Gordon 1898b, 3).

After another president was elected in 1899, the Peabody Museum was able to send an expedition to Honduras in early 1900. Most of the field season was devoted to the Hieroglyphic Stairway. The lower steps found in situ and partially cleared during previous expeditions were fully uncovered, revealing a total of fifteen steps and the first Seated Figure (**Fig. 21**). The condition of the in situ steps was disappointing to Gordon, who observed that a large number of glyphs were totally destroyed and that most of the others were damaged. The balustrades on either side of the steps were also almost entirely destroyed. All of the in situ steps and all loose blocks not already molded were then paper-molded and photographed in detail (**Fig. 22**) (Gordon 1900b, 1–2; Gordon 1900g, 2, 3).

The Peabody Museum intended to continue work at Copán during the following 1900–1901 field season, but when Gordon arrived at Copán in December 1900, no work could be carried out because the ten-year work permit was not renewed. Gordon was, however, able to report damage to the Stairway done before his arrival. Using chisels, an agent (apparently sent to Copán by the governor of Santa Rosa to collect objects for the Pan American Exposition) had chipped many ornaments from the Hieroglyphic Stairway (Gordon 1901b, 4, 12). On this sad note, ten years of Peabody Museum expeditions at Copán came to an end.

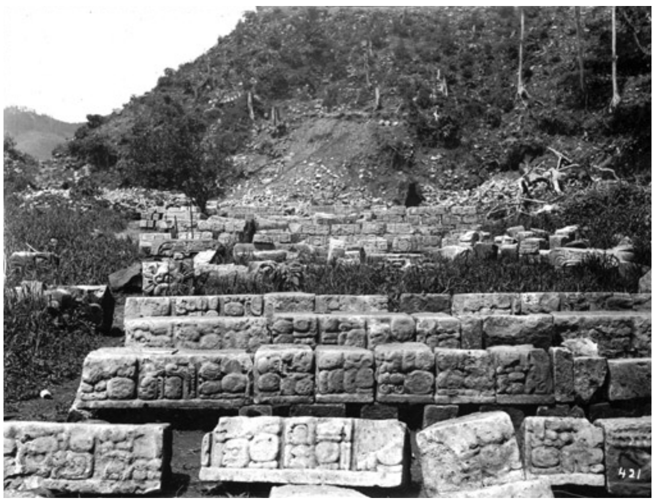


Figure 19 Blocks with glyphs from the Hieroglyphic Stairway brought down to the Plaza. They present smooth, eroded surfaces. Ca. 1895.

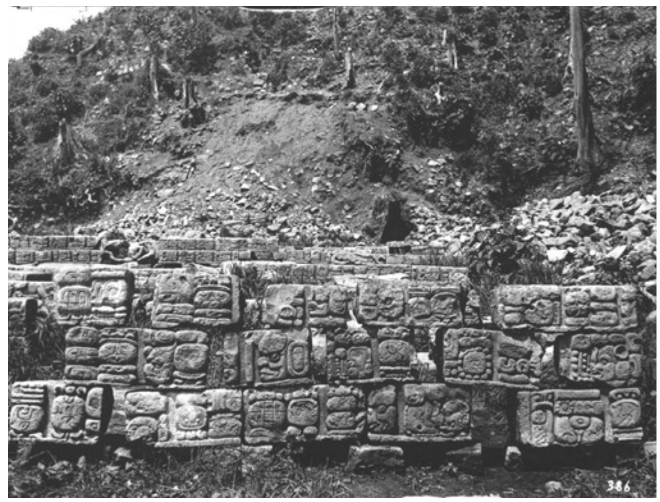


Figure 20 Blocks with glyphs from the Hieroglyphic Stairway brought down to the Plaza. They present sharply detailed carved surfaces. Ca. 1895.

Figure 21 The lower steps of the Hieroglyphic Stairway, the Altar, and the first Seated Figure still in situ after excavation. Ca. 1900.

Figure 22 Court of the Hieroglyphic Stairway looking east. The fully excavated lower steps are in situ, and the rest of the blocks are on the Plaza. Ca. 1900.

Figure 23 Lower in situ steps of the Hieroglyphic Stairway, partially recovered since their excavation. 1911.

Figure 24 Court of the Hieroglyphic Stairway looking east, with blocks on the Plaza in the foreground, and the in situ steps in the background. Vegetation has grown back on the site. 1911.

The majority of the written and photographic documents from the Peabody Museum expeditions are housed at the archives of the Peabody Museum of Archaeology and Ethnology of Harvard University, in Cambridge, Massachusetts. A published account, *The Hieroglyphic Stairway, Ruins of Copán: Report on Explorations by the Museum*, provides a good summary of the museum's work at Copán (Gordon 1902).

The Carnegie Institution of Washington

After the important work of the Peabody Museum at Copán in the 1890s, no major archaeological activities were undertaken until the expeditions of the Carnegie Institution of Washington (CIW) in the 1930s. In 1910, however, the American archaeologist Sylvanus Griswold Morley visited Copán on behalf of the School of American Archaeology, now the School of American Research (Morley 1920, 27). Photographs taken during this visit clearly show that debris from the Stairway mound above had re-covered the north side of the in situ steps, which Morley cleared again during his visit (**Figs. 23, 24**).

Morley returned many times to Copán throughout the 1910s in preparation for the publication of his monumental *The Inscriptions at Copán* (Morley 1920), and he played an essential role in the creation of the Department of Archaeology of the Carnegie Institution of Washington in 1914. Under his direction, the institution would conduct research, survey, and excavation work at many Maya sites, including Copán (Brunhouse 1971, 63–78).

The Carnegie Institution started its activities at Copán in January 1935 (Strømsvik 1935a, 118), under the direction of Norwegian engineer Gustav Strømsvik, who kept his post throughout the CIW involvement on site. The emphasis of the work was placed on the "repair" of the structures (Strømsvik 1935a, 118)—meaning their preservation and reconstruction—rather than on extensive new excavations. During the first field season, from January to June 1935, the Stairway mound was once again cleared of vegetation, and the altar at the base of the Stairway was stabilized. It was during this first season that Strømsvik learned that empty bottles had sometimes been placed on the Stairway for gun target practice.[3]

From the beginning, Strømsvik advocated the complete reconstruction of the Hieroglyphic Stairway, despite the fact that some of the blocks would be incorrectly placed because of incomplete knowledge of the Maya script at that time (Morley 1935a, 30 Mar.; Strømsvik 1941a, 51). His main argument in favor of reconstruction was to avoid further damage to the hieroglyphic blocks situated in the Plaza, which resulted from the regular cutting of the underbrush around the plaza with machetes and the subsequent careless burning of the cuttings (Maudslay 1889–1902, 17; Saville 1892c, 14). Morley, however, favored a partial reconstruction—consolidating the fifteen in situ steps and possibly returning to a higher level on the pyramid slope "the 15 steps which [had] fallen in sequence from a higher position on the stairway," the only blocks whose order was known (Morley 1935a, 30 Mar.).

Work on the Stairway was delayed another year, as the 1936 field season was almost entirely devoted to the diversion of the Copán River. The river had taken away part of the eastern section of the Main Acropolis since the time of the Peabody Museum expeditions, and its diversion was justifiably seen as a priority for the preservation of the site (Strømsvik 1936a).

The reconstruction of the Hieroglyphic Stairway finally began in January 1937, with the stabilization of the fifteen in situ steps, which were found in poor condition, largely due to vegetation and microbiological growth. The blocks of the upper four in situ steps were lowered, photographed, and, along with the first Seated Figure, reset in cement mortar. The space behind the blocks was filled with rubble set in lime mortar, and, finally, the block joints were cleared of soil and vegetation and repointed with cement mortar (**Fig. 25**).[4]

To replace the fallen section of steps, it was decided to first dig out and then build a new support stairway on which the hieroglyphic blocks would be placed. As Strømsvik wrote in his field notebook, the support stairway was constructed in part to ensure that "any steps placed would not interfere with the

Figure 25 In situ section of the Hieroglyphic Stairway at the beginning of the reconstruction. 1937.

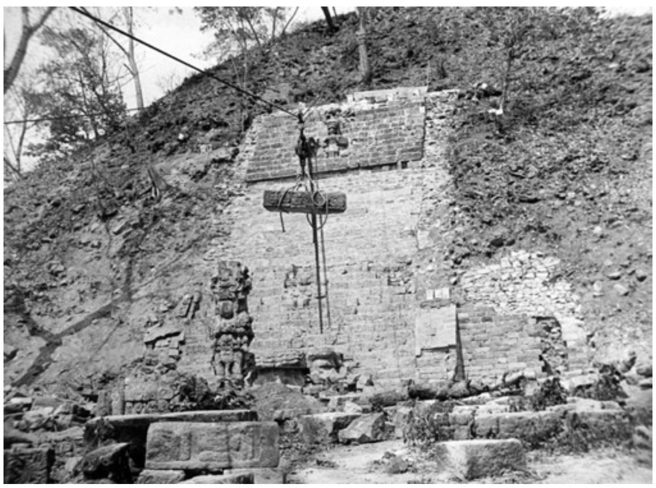


Figure 26 The Hieroglyphic Stairway during the reconstruction. The foundation stairway is built up to step 43, and the section of fallen steps is being placed from step 29 to step 43. 1937.

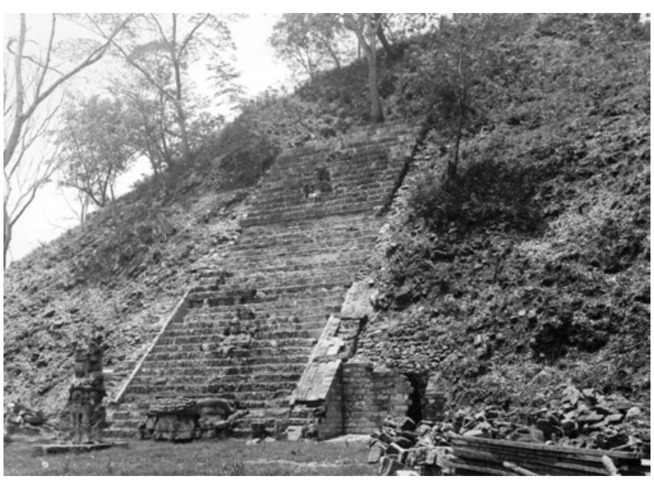


Figure 27 The Hieroglyphic Stairway looking northeast during reconstruction, showing the few hieroglyphic blocks that were reset on the north side of steps 18–21 during this season. 1938.

placing of other stones that might not be found at the time" (Strømsvik 1937c, 6 Jan. 1937). He also thought that with such a technique, "it would be a simple matter to remove any individual stone and set it in another position if it should prove to have been faultily placed" (Strømsvik 1941a, 52). The height at which the fallen section needed to be placed on the support stairway led to much discussion,[5] and after numerous arguments and a calculation mistake, the fallen section ended up being placed thirteen steps above the in situ section (Strømsvik 1937c, 20 April 1937; Strømsvik 1938–41, 25 Jan. 1938). The support stairway was built up to step 43, then the hieroglyphic blocks of the fallen section were placed from step 29 to step 43 (**Fig. 26**). Uncarved flat stones, set back a few centimeters, were used to fill areas of missing stones. On the top of the last replaced step, a channel was built to divert water coming down from the mound to the sides of the stairs to prevent biological growth on the stones. Finally, visible cracks, joints, and so-called "imperfections" were filled with cement where needed (Strømsvik 1937c, 19 April, 7, 12–13 May 1937).

Elements of the balustrades were grouped to be reset, but because of a lack of time and cement,[6] only the lowest south inclined balustrade panel was reconstructed by the end of the season. Little was accomplished during the next field season (1937–38), as the placement of most of the blocks left to be reset remained uncertain. A few more balustrade panels were reconstructed on both sides (with some uncertainty), and half a dozen hieroglyphic blocks were reset on the north side of steps 18–21 (**Fig. 27**).[7]

The following year, in the spring of 1939, the area between the in situ and fallen sections was filled with carved stone blocks. Strømsvik noted in his field notebooks that, for this section, he used only "absolutely defaced stones that could not be read, and the smallest and most broken of the lot." Fewer than a dozen support steps, and only their central parts, were also built farther up the slope, but no hieroglyphic blocks were placed on them.[8]

The 1939–40 field season witnessed the completion of the reconstruction of the Hieroglyphic Stairway. The support stairway steps were first constructed up to step 63, then the hieroglyphic blocks were reset on them with cement. A sloping terrace made of rubble and mortar was built above the last step, and the narrower upper plain steps, linking the last step of the Stairway to the floor of Temple 26, were constructed. The reconstruction of both balustrades was completed, and the uppermost Seated Figure 6 was placed in the middle of the upper steps. Finally, cracks and faults of the stone blocks were filled with cement.[9] According to Strømsvik, "all rebuilt sections are now marked that the student can distinguish between those elements which surely occupy their correct position, those which are probably rightly placed, and those as to which the doubt exists" (Strømsvik 1940, 264). It remains unclear today how the different sections were in fact distinguished, but different types of pointing mortar may have been employed for that purpose.

During the 1940–41 field season, a few missing balustrade elements were found and placed on the north balustrade (**Fig. 28**) (Strømsvik 1941b, 293). Work at Copán was interrupted at the end of February 1943, as Strømsvik enlisted in the Royal Norwegian Navy (Kidder 1943, 177), and it only resumed in January 1946. During this last full CIW field season, Strømsvik considered changing the position of four horizontal elements of the Stairway balustrades. He finally decided against it, and he mentioned in his field notebook that "a thorough and careful cleaning and a cement wash is more apropos," without giving further details, including whether this was actually carried out.[10]

As early as 1946, Strømsvik noticed that significant deterioration of the monuments at both Quiriguá and Copán had taken place over the past decade (Strømsvik 1946, 202). He attributed it to biological growth, which should be removed from stone surfaces and prevented from recolonizing. In his yearly short report for the Carnegie Institution yearbook, he also wrote that a "hardening agent" should be found to conserve the weakened stone surfaces (Strømsvik 1946, 202). During the following years, Strømsvik occasionally came to Copán while working on other Maya sites in the region. In particular, in 1949 he conducted some stone conservation trials based on those carried out by Morley at Quiriguá. Strømsvik carefully cleaned and dried the six lowest steps of the Hieroglyphic Stairway and, using a brush, applied a DuPont clear lacquer no. 1234,[11] sent to him by Robert Eliot Smith, fellow Mesoamerican archaeologist and Carnegie staff person (Strømsvik 1949, 231). It is likely that the product applied was a methacrylate lacquer, a polymer of large molecular size used to protect metals. It probably did not penetrate the stone to any significant depth and would have formed only a poorly adhering film on the stone surface.[12]

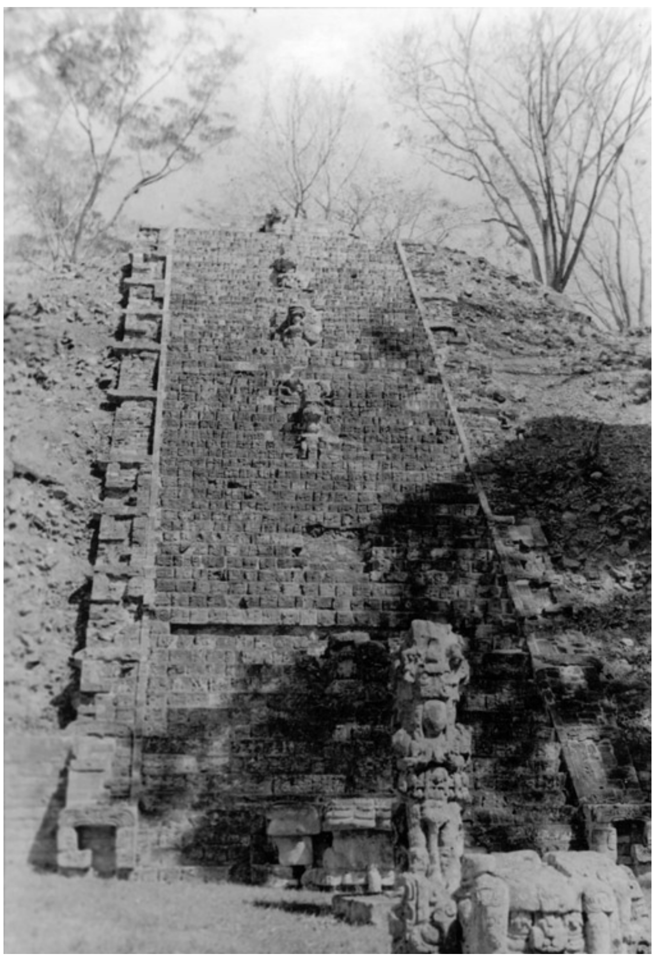


Figure 28 The Hieroglyphic Stairway looking east, after its complete reconstruction. 1942.

After more than a decade of intense activity at Copán, the Carnegie Institution of Washington left in 1946, bringing archaeological research and investigation on site to a halt. The department of archaeology of the CIW was closed in 1958, and its archives were transferred to the Peabody Museum of Archaeology and Ethnology of Harvard University. While archaeological research did not resume until the mid-1970s, the newly established Instituto Hondureño de Antropología e Historia (IHAH), which became the government entity responsible for the site in 1952, was to progressively confront the issues of the conservation of the site and its monuments in the second half of the twentieth century.

Instituto Hondureño de Antropología e Historia

First Stone Conservation Studies

The growing concern of the Honduran authorities about the deterioration of their stone monuments led IHAH to apply for a grant in 1955 from the Wenner-Gren Foundation for Anthropological Research to study stone deterioration caused by biological growth. The application was not successful (Zelaya Rubi and Hale 1983, 161; Rodriguez Gudiel 1979, 1), but a dozen years later, in June 1967, the first study was conducted at Copán by the French geologist Léon Feugueur, at the request of the director of IHAH (Feugueur 1969). In 1972, he was followed by the American anthropologist Darnell Castell, who recommended a particularly aggressive treatment of the biological growth on the stone–which, fortunately, was not carried out.[13]

The first detailed conservation proposal for Copán was made by chemist Luis Torres Montes of the Mexican Instituto Nacional de Antropología e Historia (INAH) in 1975 (Cama Villafranca and Torres Montes 1975). He proposed a number of conservation measures, such as eliminating microorganisms and preventing damage caused by visitors. This proposal may have led to the decision, made around 1975 by IHAH, to no longer allow visitors to walk on the Stairway (**Fig. 29**).[14] Torres's report also included a detailed conservation proposal for the Hieroglyphic Stairway, which called for dismantling it stone by stone, followed by laboratory conservation treatment for the individual blocks, then reinstallation in situ on a metallic structure supported by underground reinforced concrete slabs. This proposal was never carried out.

Biocide Treatments

In July 1975, Mason E. Hale, from the Botany Department of the Smithsonian Institution, came to Copán to examine the monuments and suggested a program to treat the biological growth (Hale 1975) based on his experience in Quiriguá (Zelaya Rubi and Hale 1983, 162; Rodriguez Gudiel 1979, 2). With the financial support of the National Geographic Society, the program was developed, and treatment trials on selected Copán monuments began in July 1976 (**Fig. 30**).

The treatment consisted of an application of Clorox (also called cloro, active ingredient sodium hypochlorite, $NaClO \cdot 6H_2O$), diluted from commercial strength at 1:5 parts in water (a 5.25% aqueous solution), followed by an application, on the following day, of Borax (active ingredient sodium borate $Na_2B_4O_7 \cdot 10H_2O$) as a 5% aqueous solution. The solutions were applied with a hand-pressurized sprayer, at a rate of about 300 cc/m² for Clorox and 500 cc/m² for Borax, which was less easily absorbed. The surfaces were not washed with water after treatment, in the hope that the residual chemicals would retain some biocidal effects. This treatment, which was repeated after six months, was followed by a third treatment applied approximately a year later (**Fig. 31**) (Hale 1984, 310–11).

The treatment trials were extended the following year to other parts of the site, including three areas of the Hieroglyphic Stairway: step 2, an approximately 1.5-meter riser section from the south side; step 28, a 2-meter riser section from the north side; and step 53, a 2-meter riser section from the

Figure 30 Altar Q before biocide treatment. Heavy lichen colonization can be seen on the upper part. 1975.

Figure 29 The Hieroglyphic Stairway during an official visit. Undated (1950s?).

Figure 31 A one-meter-wide test strip at the south end of the Ballcourt, after treatment by Mason Hale. Note the loss of black algae. Ca. 1978.

south side (Hale 1978a, 7). These three trial areas were treated in January 1977 and July 1977 with Clorox and Borax,[15] followed by a third, Clorox-only application, in January 1978 (Hale 1978a, 2). Because of the good results of these preliminary tests, it was decided to treat all the principal Copán monuments, including the entire Hieroglyphic Stairway (**Fig. 32**).

The Stairway was treated three times with Clorox and Borax in September 1978, December 1978, and March 1979. The microflora on the horizontal surfaces was eliminated, and 95% of the larger lichens on the vertical risers were removed. Hale insisted that the remains of the microflora would fall away naturally (Hale 1984, 320), so that mechanical cleaning by brushing was not necessary and would only add to the already extensive deterioration of the Stairway (Hale 1979d, 2). It is, however, uncertain whether Hale's recommendation against brushing was followed.

Hale was well aware that biological recolonization was unavoidable, and accordingly, he recommended that monuments be resprayed regularly with a biocide solution, preferably Clorox or Thaltox Q (a British proprietary chlorinated fluoric compound [Kumar and Kumar 1999, 2]), every two to eight years (Hale 1984, 315), depending on whether they face north or south and whether they are in the open air or are protected by trees. Thaltox Q tests were carried out on site in 1979 and in September 1980 (Martínez 1983, 8); then, previously treated areas showing reinfestation were sprayed (Zelaya Rubi and Hale 1983, 162). However, the precise location of these areas has not been identified.

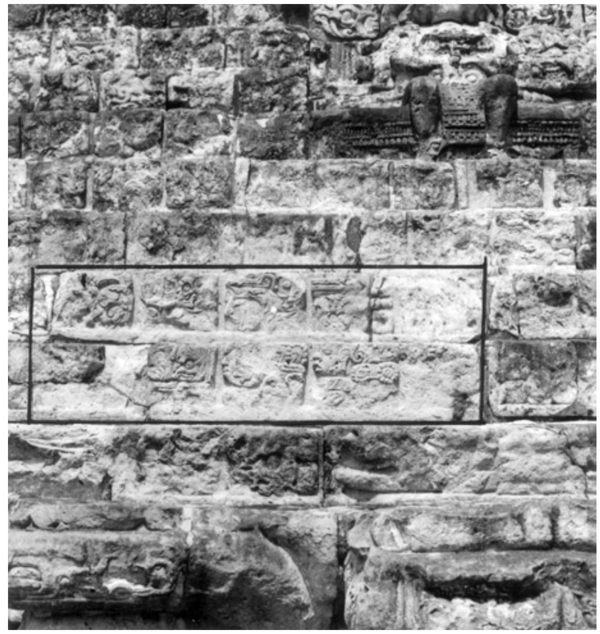


Figure 33 Area of treatment trials with Paraloid B-72 at 20% in acetone. The material was used to stabilize flaking surfaces. Paraloid B-72 at 5% was then applied as a water repellent. March 1982.

Figure 32 Hieroglyphic Stairway Seated Figure 3 before biocide treatment, showing heavy biological colonization. 1975.

Evaluation of all biocide treatments was done through photography only. Photographs and additional information on Hale's treatments can be found in several sources.[16] In 1986, seven years after the last biocide application, German scientist Joseph Riederer reported that no significant biological growth, except for algae in especially humid areas, was found on biocide-treated monuments (Riederer et al. 1986).

Surface Treatments

In the late 1970s, several researchers working at Copán expressed their concerns to the Honduran authorities about the deterioration of the monuments in general, and about the Hieroglyphic Stairway in particular (W. Fash 1977; B. Fash 1979). Reports from August and September 1978 also underscored that the lower fifteen steps of the Stairway were particularly deteriorated by flaking,[17] and they suggested that the accelerating deterioration resulted from the recent elimination of the microflora. Now that the biological deterioration had been addressed, Hale and others recognized that stone deterioration through erosion and flaking had become a more urgent problem (Hale 1984, 315), and they agreed that stone consolidation should be the next area of research.[18]

In March and April 1982, a treatment trial using Paraloid B-72 was carried out on a small area of the Hieroglyphic Stairway corresponding to blocks 21 (glyph F) and 22, step 6, and blocks 28 and 29, step 7 (**Fig. 33**) (Martínez 1983, 19,

Figure 34 Reattachment of fallen stone flakes with Paraloid B-72, block 28, step 7. April 1982.

Figure 35 Block 28, step 7 (see Fig. 34), one and a half years after its treatment; there is no evident biological recolonization. November 1983.

25). After the stone surface was cleaned, the detached flakes were re-adhered with a 20% solution of Paraloid B-72 in acetone (**Fig. 34**), and the entire step riser surfaces were treated with a 5% Paraloid B-72 solution as a water repellent. The treads of the steps were not treated, to provide for the evacuation of humidity (Cruz 1983, 18; Martínez 1983, 19). Interestingly, this experiment was seen more as an attempt to slow down biological recolonization than as a consolidation trial, and in that regard, it was successful, as shown by photographic documentation of the trial area a year and a half later (**Fig. 35**).

By summer 1982, possibly following recommendations from Mexican INAH conservators, Paraloid B-72 was being regularly used on site for stone surface treatments (Riederer 1982, 6; for published versions see Riederer 1983; Riederer 1986a). Three principal types of treatments were carried out: consolidation of fragile stone surfaces with a low-concentration solution (1%–5% in acetone) of Paraloid B-72, re-attachment of stone flakes with a 15%–20% Paraloid solution as an adhesive (Martínez 1983, 12, 14), and edging repairs of stone flakes with a mix of Paraloid B-72 and Copán stone powder.[19]

An August 1986 work program specifically included a proposal for surface conservation treatment on the Hieroglyphic Stairway with Paraloid B-72 at 12%, mixed with Copán stone powder for edging repairs; Paraloid at 5% as a surface consolidant; and 50 cc syringes, likely for Paraloid B-72 injection (Martínez 1986, 2). In the late 1980s, Mowilith 30 partially replaced Paraloid B-72 as the edging repair binder on site, including on the Stairway; it was used at 12% and 15% solutions in acetone (Axume 1987–89). Both Paraloid- and Mowilith-based surface treatments were carried out on a regular basis on the Stairway until spring 1998. All other conservation and maintenance activities, such as the semi-annual brushing of the step risers and treads, were discontinued in June 2000.[20]

Sheltering as Preventive Intervention

In the early 1980s, as surface treatment trials were being carried out on site to address the deterioration of stone, the idea of moving sculptures to a roofed area or to the climate-controlled environment of a museum (and to place replicas on site) was advocated by many as the best conservation solution.[21] In April 1983, a meeting of experts held at Copán on stone deterioration recommended sheltering tests, among numerous propositions (Véliz R. 1983b). This important meeting led to the production of several studies and to two follow-up meetings in 1984 and 1986.[22] One of these studies singled out the action of water cascading on the Hieroglyphic Stairway steps during the rainy season as a principal deterioration agent leading to both mechanical and biological damage. The study proposed stone consolidation, sheltering, and dismantling as the three different conservation options for the Stairway (Martínez 1983, 18, 20). By 1984 the stelae were being roofed (**Fig. 36**), and the idea of sheltering the Hieroglyphic Stairway during the rainy season was seen as a compromise between conservation needs and visitor experience, while ways to consolidate the stone and make it “waterproof” continued to be pursued.[23]

In 1984 the director of IHAH made the decision to shelter the Stairway, and preparations for the installation of three main cables supporting the large canvas tarpaulin were carried out during the winter of 1984–85, so that the shelter would be ready at the beginning of the 1985 rainy season (IHAH 1997, 4; Véliz R. 1985, 2). During the tensioning of the south cable, a clamp broke, and the cable fell on the Stairway; however, no description of damage to the Stairway could be

Figure 36 Thatched shelter above Stela J, looking west. Ca. 1983–84.

Figure 37 Structure 26, showing the extension of the larger tarpaulin over the Hieroglyphic Stairway. 2000.

Figure 38 Replacement of the tarpaulin above the Hieroglyphic Stairway. 2003.

found. The Stairway tarpaulin was finally installed on May 2, 1985, and at the same time, a short ledge was built on the edge of the upper platform to divert rainwater, which came from above, away from the Stairway. However, the uppermost section of the tarpaulin canvas, which was part of the initial design, remained to be installed by the end of May 1985.[24] This shorter-length tarp, which left the upper three steps exposed to rain, would not be extended until approximately 1998, when the tarp was also made wider, as recommended in the Stairway conservation program of the 1998 Pilot Preservation Program for Copán (**Fig. 37**) (IHAH 1998, 13).

The Stairway shelter, first in place only during the rainy season, became permanent around 1987, and it has remained in place to this day.[25] As part of its maintenance, the tarpaulin canvas has been replaced regularly—in spring 1991, spring 1998, February 2001, April 2003 (**Fig. 38**), and September 2006.[26]

A chronological summary of the conservation history of the Hieroglyphic Stairway is provided in Appendix B.

Previous Scientific Studies

Conservation of Volcanic Tuff

A relatively recent review of the stone conservation literature reveals that published information concerning volcanic tuff, a type of stone present at major cultural sites such as Easter Island, Borobudur in Java, and Goreme in Turkey, is not common; therefore, the factors and mechanisms of deterioration of this type of stone have not yet been clearly explained (Grissom 1994). Water is often cited as the principal agent of alteration of volcanic rocks, gradually solubilizing specific ions, transporting soluble salts, promoting biological growth, and participating in freeze-thaw cycles. Consequently, the most frequently advocated conservation treatment for volcanic stones involves consolidants, often alkoxysilane solutions, sometimes together with water repellents. The role of biological growth in the deterioration of volcanic stone has also been an important concern in tropical sites, and this concern has sometimes led to the use of biocides. Issues related to air pollution and cleaning treatments, which often drive conservation research for other stone types, seem to be of little concern at sites with volcanic stone monuments.

Conservation of Copán Stone

The earliest found scientific study related to the Copán stone is a short appendix of Morley's 1920 epigraphic study, *The Inscriptions at Copán* (Morley 1920), which provides a petrographic description of the stone. It was carried out by one of Morley's colleagues from the geophysical laboratory of the Carnegie Institution of Washington, but its only aim is the geological identification of the stone, rather than an understanding of its deterioration.

In 1952 the Instituto Hondureño de Antropología e Historia (IHAH) became the governmental authority responsible for the care of the site of Copán, and through the years, it grew increasingly concerned about the deterioration of its stone monuments. Consequently, often at IHAH's request, several scientific studies of the Copán stone and its deterioration have been conducted since the late 1960s, and a number of meetings of experts on the conservation of the Copán site have been organized since the 1980s (1983, 1984, 1986, 1997, and 2000) (Véliz R. 1983b; Rodriguez Gudiel, Soto G., and Sandoval 1984; Riederer et al. 1986; IHAH 1997; GCI 2000a). The scope and depth of these studies vary widely, as do the analytical methods used. This review summarizes the findings of each of the main studies, focusing on the deterioration conditions observed on site, the results of the analyses performed, and the main deterioration factors and mechanisms proposed by the authors.

Fred E. Wright, 1920

Small specimens from three Copán monuments were collected, and polarized microscopy was used to examine the thin sections (Wright 1920). Wright found all samples to be essentially the same dull, porous, fine-grained rock, pale green and yellow-green in color, containing small, denser, harder inclusions. He concluded that it is a tuffaceous rock, ranging in composition from dacites to andesites high in silica, and made of a highly altered matrix with inclusions of harder, unaltered tuff fragments. The matrix seems to be made of glassy tuff fragments that suffered rapid devitrification and subsequent alteration, whereas the primary plagioclase and quartz crystal fragments remained unchanged, except for minor alterations, forming the inclusions. In the matrix, much of the material is too fine for satisfactory identification with an optical microscope, but some argillaceous material, some secondary calcite, and some quartz can still be distinguished.

In one of the specimens, there is a brown, more or less layered, weathered crust along with a sharply defined junction between this crust and the adjacent interior. In each thin section, short, irregular lines of dark material appear, partially filled with secondary material, such as secondary quartz; calcite in thin, thread-like lines; and chlorite, commonly found filling cracks and interstitial spaces. Small grains of iron oxide surrounded by a brown alteration zone are also common.

Figure 39 Basal erosion on Stela C, shown from the west. 2003.

Léon Feugueur, 1969

In the late 1960s, French geologist Léon Feugueur was the first to conduct investigations for the purpose of understanding the deterioration mechanisms of the stone (Feugueur 1969). During his site visit in June 1967, he concentrated his attention on the stelae. Some of them presented large areas of alteration by flaking and blistering, and they were often particularly deteriorated at the base (**Fig. 39**). He also observed that powdering deposits were sometimes found between the exposed crusts and the apparently healthy stone. In section, a darker line parallel to the surface of the crusts was generally present, which he linked to the alteration phenomena. He also observed that monuments protected from direct sunlight by trees seemed less deteriorated.

Three types of analyses were performed on weathered and unweathered Copán stone samples that Feugueur brought back to France: optical microscopy of thin sections, stone bulk chemical analysis, and microbiological analyses. He characterized the rock as being of andesite or trachyandesite type, with an extremely fine microstructure, which did not permit him to determine the rock mineralogical composition without X-ray diffraction (XRD). The darker line seemed to contain a large proportion of clayey elements, as well as some small, isolated crystals that may be gypsum (calcium sulfate). Bulk composition of weathered and unweathered samples was relatively similar, with 68%–69% of SiO_2; but an increase of phosphorus (P_2O_5) and sulfates (SO_3) was shown in the weathered sample. Feugueur tentatively attributed this difference to bacterial activity, as it correlated well with the high number of total bacteria found through microbiological analyses.

These preliminary analyses led Feugueur to postulate that stone deterioration at Copán was due to microbiological activity, but also to the physical action of rapid wetting-drying cycles. Since most stelae are placed on slabs, groundwater was unlikely to be the source of water. More likely, humidity came from the air (mist or fog, for example) and could be increased by the extensive presence of grass on site. In conclusion, Feugueur recommended that more in-depth microbiological analyses be carried out, as well as humidity measurements in the soil and in the stone, before and after exposure to direct sunlight. Finally, he suggested that a site experiment be conducted with freshly quarried stone blocks, leaving one block exposed and another under cover, in order to observe the difference in deterioration.

Darnell Castell, 1972

The next study was conducted by the American anthropologist Darnell Castell from Lyndon State College in Lyndonville, Vermont. Castell visited Copán in March–April 1972 and again in August 1972 (Cueva V. 1972, 2–5). During two weeks of work in August, Castell carried out eighty to ninety "experiments" (Sandoval 1984, 3), but as his original reports have not been located, information about his methods and results comes from summaries in secondary sources and, consequently, is quite limited. It does not seem that Castell performed any analytical work, so his identification of the Copán stone as an andesite volcanic rock is probably based solely on visual observations, as might well be his hypotheses about the main deterioration factors: algae, mosses, bacteria, water, rain, sun, and man. He also considered the degree of deterioration to be dependent on differences in chemical composition of the stone. He proposed eliminating the main deterioration factor, the microflora, with a harsh hydrochloric acid–based treatment.

C. Jaime Cama Villafranca and Luis Torres Montes, 1975

A more substantial study of the stone deterioration problems at Copán was carried out in the mid-1970s by two chemists from the Instituto Nacional de Antropología e Historia in Mexico (Cama Villafranca and Torres Montes 1975). Details of the analyses are not given in their report. Copán stone was characterized as a fine-grained volcanic tuff, very soft and porous, with hard, round inclusions of flint. Feldspar, plagioclase, biotite, and isolated quartz crystals were identified through preliminary petrographic analyses. The microorganisms identified include crustose lichens, chlorophyll algae, mosses, and fungi. No soluble salts (sulfates, chlorides, or nitrates) were found through chemical analyses, but calcium carbonate was identified in the superficial layers of the stone. Finally, a smaller concentration of iron oxides was found in proximity to lichens.

Based on this evidence, the authors suggested three main causes of deterioration: the intrinsic nature of the Copán stone (a very soft stone with high porosity and high moisture retention coefficient), the local climate (high average annual rainfall and temperature, and a constantly high relative humidity), and, finally, the abundance of microflora, especially lichens and algae.

The proposed deterioration mechanism is the following: moisture infiltration in the stone from rainwater, causing dissolution, which induces an accelerated hydrolysis of some minerals (transformation of biotite into iron oxide and other alteration products; of calcium feldspar into calcium carbonate and soluble salts; and sometimes of plagioclase and other silicates into clays–kaolinization). The alteration products from this physicochemical deterioration (dissolution and hydrolysis) furnish nutrients to microbiological organisms, promoting their growth. They, in turn, contribute to the stone deterioration through the mechanical pressure their small rootlets exert in pores and microfractures, and through the ionic interchange taking place through their rootlets as the microorganisms retrieve nutrients. The latter phenomenon may explain the iron oxide depletion observed near the lichens. The presence of the microorganisms also impedes water evaporation, increasing humidity in the stone and creating a microenvironment that promotes both further biological growth and further chemical deterioration. This state, in turn, produces more nutrients for the microorganisms, in a vicious circle. The absence of soluble salts is explained by the high rainfall, which washes them away, but the presence of calcium carbonate indicates that salt crystallization takes place, a phenomenon at least partly responsible for the stone exfoliation and its deterioration.

Mason E. Hale, 1975–1979

Mason Hale, a botanist from the Smithsonian Institution in Washington, D.C., visited Copán in July 1975 to examine the biological growth on the monuments and to suggest a treatment program (Hale 1975). Collecting a very large number of lichens, mosses, liverworts, and several algae, he carried out the first inventory of the principal species of the microflora (Hale 1978b; Hale 1979a). He considered the principal factor related to the biological deterioration of the stone to be the action of lichens, an already well documented phenomenon. According to Hale, lichens have both a physical effect, breaking up stone crystals as they swell in the presence of water, and a chemical effect, disintegrating stone minerals through the action of their acid secretions. Through photographic comparison of blocks preserved in a museum and those in situ covered with lichens, he put forward his case for removing them (**Figs. 40a, b**).

He went on to conduct the first treatment tests in Copán to assess the effectiveness of various biocides. This preliminary testing led to a full-scale treatment of all the principal monuments of the site in the late 1970s, in which a combination of Clorox, Borax, and Thaltox Q was used to control biological growth (see "History of Interventions" for treatment details) (**Fig. 41**).

Gail Mahood, 1983

In the 1970s, geologist Gail Mahood, as part of the Proyecto Arqueológico Copán (PAC), studied the geology of the Copán Valley and characterized the local rocks, particularly in relation to agricultural productivity and building construction (Turner et al. 1983). While the study was not concerned with the deterioration and conservation of the stone, Mahood performed the first XRD characterization and the first in-depth study of stones both from Copán Valley quarries and from buildings and structures from the Copán site.

Figures 40a and b Comparison of Stairway blocks in situ covered with lichen growth (a) and preserved at the Peabody Museum (b). Ca. 1978.

Figure 41 A monument being sprayed with biocides. 1978.

According to Mahood's studies, Copán construction stones came from outflows of light green tuff and show zeolitic alteration. From XRD analyses, the main zeolite was characterized as mordenite. As this zeolite is normally white, Mahood felt quite certain that the green color of the stone comes from minuscule traces of montmorillonite or celadonite, even though these were not perceptible in diffractograms. Examination of stones from different areas of the Copán Valley showed that there are two types of green tuff that can be distinguished by the presence or absence of biotite. However, all stone blocks examined from the Copán site, from either monuments or sculptures, do not contain biotite, probably because the most-used Maya quarry, situated in the hills northeast of the site, yields tuff without biotite. She also singled out, in another area of the valley, an outcrop of green tuff that fractures into columns, naturally producing large rectangular blocks ideally suited for stelae. This tuff is characterized by the presence of cannonball-size spheres of a very dark blue-green color, denser and harder than the tuff matrix. These spheres, or voids left by them, can be seen in different sculptures throughout the site, as well as on some of the Stairway blocks.

Significant differences in crystalline content can be observed in samples of tuff without biotite from the site (this range can also be observed in the different tuff outcrops of the valley). The author gives a few examples: stone from Stela 50 has a large quantity of quartz and feldspar, while stone from Altars B and D has only a moderate quantity. Stela C is anomalous because it contains very few ferro-crystals, and its matrix is of a much finer grain than that of stone from other stelae or from the most well-known quarries.

Josef Riederer, 1982–1986

Josef Riederer, head of the Rathgen Research Laboratory of the National Museums in Berlin, visited Copán in September 1982, analyzed the Copán rock, surveyed the deterioration types on site, and formulated a number of deterioration hypotheses, before conducting field tests of commercial consolidants, water repellents, and biocides (Martínez 1983; Riederer 1982, 7; Riederer 1983; Riederer 1986a).

Riederer analyzed Copán stone from both the Maya quarry north of the site and from the site monuments. According to Riederer, stone from the quarry and from Copán monuments is clearly the same heterogeneous stone, a yellowish to greenish andesite containing abundant feldspar granules 1 mm in size; clayey materials; and some very large (fist-size to head-size), hard and dense, grayish black, basaltic, spherical inclusions. The color, structure, and other macroscopic characteristics of the rock are clearly varied among the different stelae, so one cannot speak of the andesite as a homogeneous material. Salt crystallization was observed at the base of stelae, as well as on the Hieroglyphic Stairway, although the concentration, origin, and composition of the salts were not elucidated. The salts may come from the cement used in stelae repairs (sulphates), from the gypsum used for molding some of the sculptures, or from bacteria producing sulfates and nitrates.

Riederer outlined five forms of deterioration of the Copán stone: powdery decomposition, detachment, spherical holes, macrofractures, and microfractures. Powdery decomposition, the slow loss of grain cohesion under the influence of physical and chemical forces, affects all stones exposed to weathering—the intensity of the process depending on the stone's orientation. Detachment is the progressive breaking and falling off of flakes parallel to the stone surface. Riederer attributed this type of deterioration to rising damp and considered it to be the main form of deterioration in the Hieroglyphic Stairway. Spherical holes, from a few millimeters to a few centimeters in diameter, formed mainly on horizontal surfaces and rarely on vertical ones, are due to the dislocation of stone inclusions under the action of rain; they are directly linked to the heterogeneity of the material. Macrofractures have a geological origin, predating the use of the stone by the Maya, and they open up with time. Microfractures are present in relatively concentrated locations as "map cracking," the origin of which is unknown; this type of fracturing is often produced under the action of fire, but it also could have been produced by a mechanical shock during the fall or the restoration of the stelae.

Riederer concluded that the stone deterioration at Copán has three main causes: presence of water from rainwater or from soil humidity, temperature differences at and below the stone surface, and the actions of humans. These factors act upon the stone through different deterioration mechanisms. Water acts through three main mechanisms: first, water leads to the chemical transformation of rock compounds—for example, silicates such as feldspars are altered into clay compounds and other secondary minerals, which cause damage because of their swelling behavior, and iron minerals such as pyrites are oxidized into compounds of larger volume. These transformations produce superficial disaggregation of the stone, which allows moisture to penetrate even further. Water also leads to the physical breaking up of the stone structure through the daily dissolution/crystallization of salts. Finally, it contributes to the growth of microorganisms. Temperature differences at and below the stone surface—which can warm to 50°–60°C during hot days and can be rapidly cooled by heavy rain showers during the rainy season—induce daily dilatation-contraction cycles, which lead to the separation of mineral grains from the surface. This type of deterioration is easily recognizable around the dark basaltic inclusions because they are heated more than their lighter-colored surroundings.

Finally, some of the observed deterioration is due to human activity—that of the Maya themselves, the conquistadores, and modern-day robbers and restorers, through their use of cement mortars, gypsum molds, and iron cramps.

To address this deterioration, Riederer proposed that tests be conducted on site on a number of commercial products: consolidants, in particular ethyl silicates, to address powdery decomposition and stone detachment; water repellents; and biocides other than the ones used by Hale—in particular fungicides and biocides based on solutions of metallic salts (Riederer 1982, 13; Riederer 1986b, 153–54).

During the following years, Riederer tested at Copán a number of products donated by the West German government (Martínez 1983, 10). In October 1985 two water repellents (Sikovin and Funcosil-SL), two consolidants (Tegovakon-T and Funcosil-H), and two biocides (Alkutex and Preventol) were tested in different areas around the site ([Riederer] 1985). In September 1986 these six products plus two new biocides (Platten Rein and Grab Stein Rein) were applied on two new treatment trial areas. The consolidants and water repellents were applied by immersion to stone samples, which were then returned to their original location.

Both sets of tests were evaluated only visually, fifteen days after application for the 1985 tests, and one year and two years later for the 1986 tests (Cruz M. 1985, 1–3; Sandoval 1988, 3–4; Rodriguez Gudiel et al. 1988, 3–4). The microflora turned dark brown and started to fall off with Preventol (**Figs. 42a, b**), while Alkutex seemed to have no effect. The evaluation of the consolidation and water repellent tests proved to be more difficult. It was observed that less moisture accumulated on treated areas, with water drops disappearing through evaporation. The three altars of the East Court were also impregnated with Funcosil-H by IHAH staff, and many particles and fallen flakes were found after treatment. However, in the absence of before-treatment documentation, it was very difficult to attribute this deterioration to the consolidant (Sandoval 1988, 5). Additional surface treatment trials were carried out in 1988 and 1989, with the same German products brought by Riederer, as well as with a 1% solution of lime in water as a biocide, and a 20% solution of Primal in water to consolidate stucco in the tunnels (Axume 1987–89). Some of the trials were documented photographically. There is no indication that any of the products tested by Riederer were ever used on site on a larger scale.

Sigfrido Sandoval, 1984

Following the 1983 expert meeting, which recommended carrying out further scientific analysis, Sigfrido Sandoval made a proposal, pointing out that the previous geological studies did not give a consistent identification of the nature of the stone, making it impossible to understand deterioration processes and find conservation solutions (Véliz R. 1983b, 2; Sandoval 1983).

Sandoval analyzed the chemical composition of a total of twenty-one stone samples using a gravimetric method for the silica content and atomic absorption spectrophotometry for all other compounds (Sandoval 1984). Two samples were collected from the hill and the river quarries of the Copán Valley, and nineteen came from different monuments in the archaeological site (already detached samples were used). Two thin sections were also prepared from the quarry samples. Bulk chemical analysis showed that all stone samples have similar chemical composition, with a silica content varying from 54% to 64% (except for one sample). Based on these analyses, Sandoval identified the rock as an andesite—but not a typical one. From optical microscopy, Copán stone was characterized as an extrusive igneous rock with a semicrystalline structure, with some large crystals (including plagioclase but without biotite) in an amorphic mass of small crystalline grains, giving the rock

Figures 42a and b Treatment trial with the biocide Preventol, before cleaning (a), and after cleaning (b). Ca. 1987–89.

a porphyritic texture. A more complete mineralogical identification could not be carried out because of the absence of XRD instrumentation in Honduras. One microsample scratched from the interior of a piece of stone was identified as a natural clay, a result that Sandoval interpreted as a confirmation of the frequently postulated deterioration mechanism of the Copán stone–namely, the chemical alteration of plagioclase into clays.

Sandoval considered the chemical transformation of the rock minerals to be the dominant deterioration process in Copán, with physical and biological weathering secondary. He explained the different mechanisms, drawing heavily on the previous studies of Cama Villafranca and Torres Montes, Hale, and Riederer.

Chemical alteration is due to water from rain, soil, and air. A principal deterioration process is hydrolysis, in particular of silicates, which leads to the formation of clays (kaolinization or sialitization processes), and oxidation hydrolysis of iron minerals, which transforms them into iron oxides (seen as red-yellow stains or streaks on monuments). The greater volume of the alteration products causes the disaggregation of the stone surface. Hydrolysis can be accelerated by a number of factors, including a natural or man-made increase of the pH of the water.

Biological weathering consists of any deterioration process resulting from higher plants or microorganisms (algae, mosses, and lichens). These processes can be either physical or chemical. Physical processes include the breaking up of rock crystals from the swelling and contraction of lichen roots as a function of humidity, or from pressure exerted by roots of higher plants. Chemical processes include the absorption of stone elements as nutrients or the release of organic acids. Microflora also prevents water evaporation, creating an environment suitable for its own growth and accelerating chemical weathering, which, in turn, produces more nutrients for the microorganisms, further promoting their growth.

Four mechanisms of physical weathering were proposed by Sandoval: the mechanical action of rain, which leads to surface disaggregation, and sometimes to the development of cavities; the thermal dilatation-contraction of the rock, due to high daytime temperatures and daily cooling during the rainy season, which causes fissures, microcracks, and the breaking up of minerals; external mechanical forces that cause detachment, fissures, microcracks, and macrocracks in the stone; and internal mechanical forces from salt crystallization (due to previous cement repairs or from molding) and from the formation of hydrated compounds of greater volume, which cause fractures.

Toshiharu Tashiro, 1992

A study of the deterioration of Copán stone, focusing on two stelae, was conducted more recently at IHAH's request by Toshiharu Tashiro, a Japanese geologist working for the La Entrada Archaeological Project (Tashiro 1992). He used only simple investigative methods (visual observation, stereophotography) of each stela face, as well as graphic recording, and he did not perform advanced scientific investigations (**Fig. 43**).

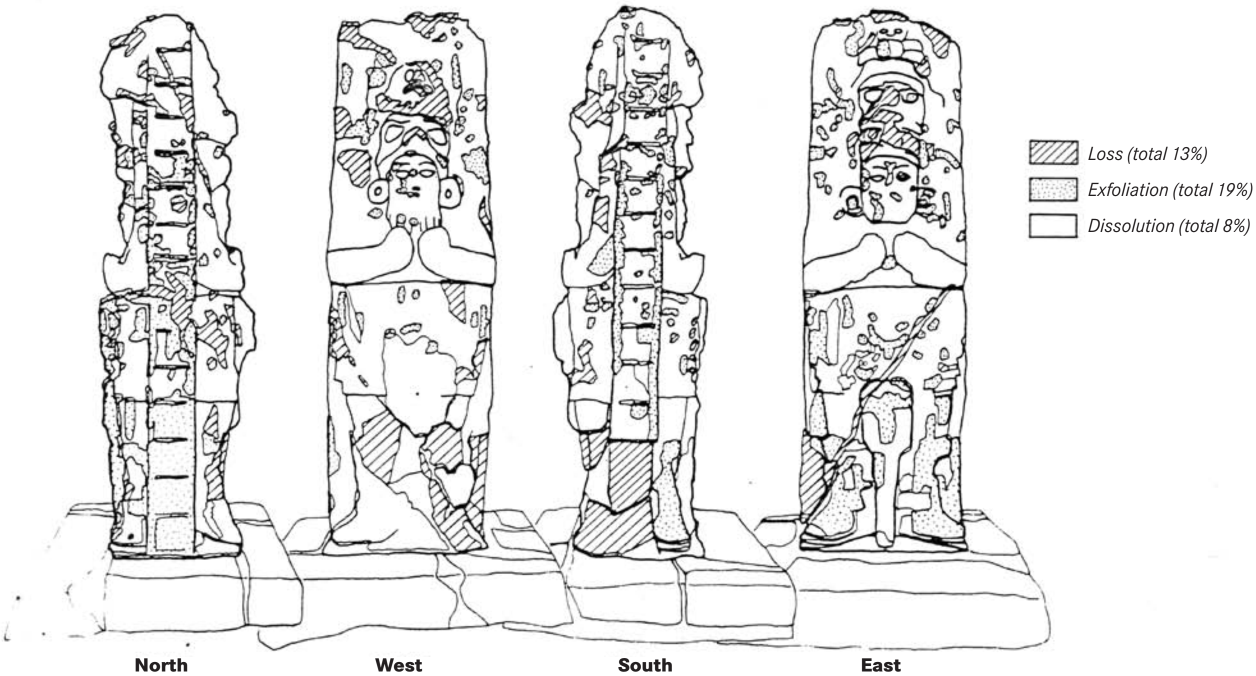


Figure 43 Graphic documentation of the condition of Stela C.

He identified three types of deterioration: loss due to fractures, forming naturally along secondary mineral planes of weakness or under an artificial force; exfoliation (or flaking), which starts by the formation of microcracks parallel to the stone surface, then leads to the formation of thin flakes that ultimately fall; and dissolution–that is, the chemical transformation of minerals. He considered the principal cause of deterioration to be rain, which induces humidity fluctuations, while he considered the secondary cause to be temperature variations.

The three types of deterioration occur in succession and correspond to a progression in the deterioration, and therefore also in its depth, from dissolution (0.0–0.2 cm) to exfoliation (0.2–1.0 cm) to loss (>2 cm). The deterioration starts by the dissolution of mineral compounds (hydrolysis and oxidation) due to the normally slightly acidic rainwater (pH 5.5), followed by exfoliation, with the appearance of microcracks parallel to the original rock surface due to alternating dilatation-contraction from variations in humidity and temperature. The microcracks are then enlarged by the recrystallization of secondary minerals produced by the chemical dissolution. This process is followed by the loss of thin flakes from variations in temperature and relative humidity, as well as from the dilatation-contraction of the microorganisms present within the stone crust. The ultimate step in the deterioration process is the loss of larger fragments.

Through a graphic survey of two stelae, Tashiro determined that 40% of the surface of Stela C and 15% of the surface of Stela A showed one of the three forms of deterioration. He explained that the difference in condition was due to the nature of the stone–Stela C being made of a softer and finer-grained tuff. He concluded that more chemical and mineralogical analyses of the stone, as well as experiments in the lab, were needed to obtain a complete understanding of the deterioration mechanism.

Conclusion

Most of the scientific reports related to the deterioration of the Copán stone have tried to identify the nature of the stone using one or more laboratory analytical techniques (optical microscopy, bulk chemical analysis, and, in one instance, XRD). However, none of the previous studies have characterized the physical and mechanical properties of the stone (such as porosity), which play an important role in its deterioration. More or less detailed microbiological analyses have also been performed by some of the authors of these previous reports.

The deterioration factors identified by most authors are water (rain, humidity from the air, and sometimes also rising damp), which is often seen as the most important factor; biological organisms (principally microorganisms, but in one case higher plants are mentioned); and temperature variations. Some authors also point to the intrinsic nature of the Copán stone and to human actions (vandalism, restoration, etc.).

The deterioration of the Copán stone has generally been explained in the past by a few main mechanisms. The chemical transformation of some of the minerals that make up the stone, in particular the transformation of silicates into clays, is often seen as the initial and most important deterioration mechanism. Hygric expansion-contraction due to the regular wetting-drying of the stone surface is also seen as a key mechanism by most authors, while some reports underline the role of the similar mechanism of thermal expansion-contraction due to temperature variations. Biological organisms are mentioned in most reports, either as a leading cause of deterioration or as a secondary factor, acting through physical mechanisms (swelling of roots) and chemical ones (acid secretions and extraction of nutriments). Finally, dissolution-recrystallization of salts is often given as a deterioration mechanism, despite the fact that few reports have found salt in the stone–or have even conducted salt analyses. In contrast, physical erosion due to rain and the impact of visitors are hardly mentioned in the reports as deterioration factors.

Overall, little quantitative data are presented in the reviewed scientific reports. The information contained in them is largely descriptive and based on site observations. The lack of quantitative data has limited the ability of successive scientists to prove or disprove some of the hypotheses, as well as to reach more substantiated conclusions about the deterioration mechanisms.

Comparison of Stairway Photographic Documentation through Time

It is fortunate that the Hieroglyphic Stairway of Copán has been frequently photographed in detail since its initial excavation more than a hundred years ago, and that these historic images survive in archives. They permit observation of the changes of surface conditions over time and allow a visual analysis of deterioration phenomena, as well as a determination of whether these phenomena are active and ongoing, or whether they occurred at a certain moment in time and are no longer active. The photographic documentation is also important for assisting in the diagnosis of the causes and mechanisms of stone decay on the Stairway, both past and present.

The historic photographs of the Stairway were not originally taken with the intent of documenting conditions on a regular basis; therefore, the time intervals between them are not regular. The quality of the photographs is not equal either, because different equipment and technologies were used. The focus, definition, angles, and lighting conditions of the different photographic campaigns are not the same either. Despite these significant differences, with the information about the intervention history of the Stairway provided in the previous section, researchers can still draw conclusions from comparisons of the photographs about whether stone surface deterioration and loss are active or not, and what its causes are or were.

Certain blocks of the Stairway were chosen during the project for the monitoring of present and future conditions, and the same blocks were used for analyzing the past condition history as well. These blocks, referred to as control blocks, were chosen to provide a range of current surface conditions and locations throughout the Stairway, so that a complete picture could be obtained of the overall condition of the Stairway (**Fig. 44**).

Photographic Time Line

Copies of historic photographs of the Stairway and individual blocks were obtained from archival collections at the Peabody Museum of Harvard University and from the Centro Regional de Investigaciones Arqueológicas of the Instituto Hondureño de Antropología e Historia in Copán. The earliest surviving photographs of the Stairway consist of glass plate negatives taken by the Peabody Museum expeditions between 1891 and 1901, during the excavation of the Stairway. In the 1910s and 1920s, occasional photographs were taken of individual blocks for the epigraphic study of the hieroglyphs. Then, during the Carnegie Institution of Washington's work at Copán between 1935 and 1946, general photographs of the Stairway, as well as of some individual blocks, were taken–in particular during the reconstruction in 1937–40. Between 1946 and 1948, Raúl Pavón Abreu, a Mexican archaeologist, did a full and detailed photographic survey of the blocks of the reconstructed Stairway ([Pavón Abreu and Sanchez Vera] 1989). Over thirty years later, in 1979, Maya Bracher did a partial, detailed photographic survey of the Stairway, which was followed in 1987 by Jean-Pierre Courau, who carried out a full photographic survey. All of these various campaigns used black-and-white photography in normal daylight conditions, and they did not include the carved balustrade on either side of the Stairway. In 1989 the balustrade was photographed block by block by the PAAC and the photos placed in the Copán photo archives.

In 2000, GCI consultant Photarc Surveys Ltd. took stereo-pair photographs of the entire Stairway in black and white (with a flash, because of the canvas tarpaulin that covered the Stairway), as well as stereophotographs of some of the control blocks. In 2003, the GCI (assisted by the local staff of other Copán projects) took black-and-white, color, and digital photographs of all of the GCI-designated control blocks under natural light.

In December 2004, Photarc Surveys carried out another series of stereophotographs of all of the control blocks, in order to have a duplicate series to compare conditions accurately over a four-year period, as well as to have complete stereophotography of all control blocks. These stereo images have yet to be analyzed or processed into 3-D models.

Once collected, the photographs for each control block were scanned, scaled, and printed as a time line series on one sheet for ease of visual comparison. Not all of the control blocks have the same photographic series, because not all the photographic campaigns from the past were complete for the whole Stairway (see Appendix C for a list of control blocks with their photographic time line).

Comparison of Condition over Time

A visual comparison of the historic images and those taken most recently, during the GCI's involvement with the Stairway, reveals that most of the control blocks have generally had a similar condition history since they were excavated. However, the condition of Stairway blocks when excavated a century ago varied greatly, so the starting point of their conditions has been

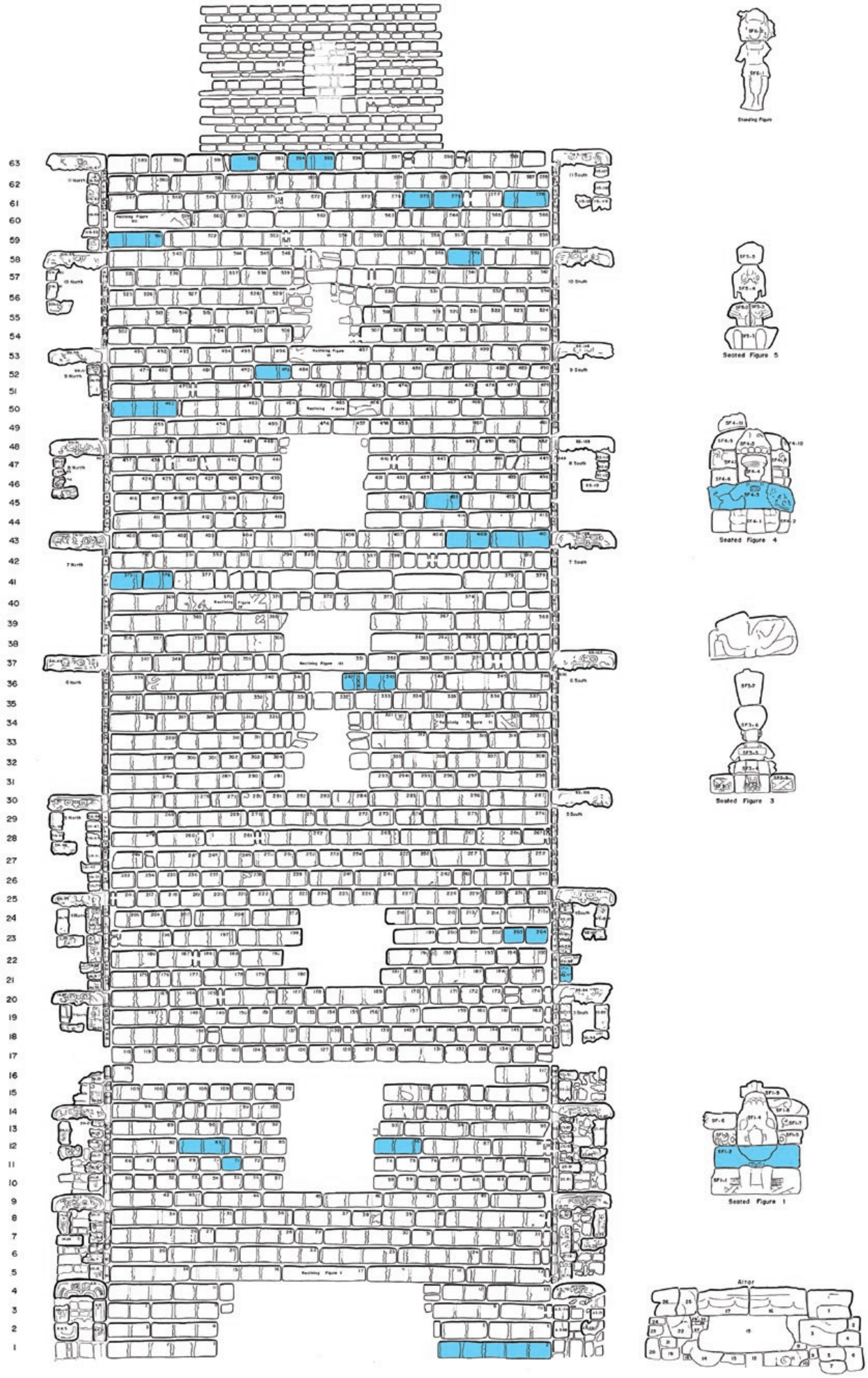


Figure 44 Map of Stairway control blocks (in blue) selected for monitoring conditions.

extremely different among the various blocks of stone. Upon excavation, some blocks were devoid of any carved surface remains, and they presented smooth, eroded surfaces, while others presented sharply detailed carved surfaces–and even retained some of the original lime plaster covering in the most recessed surface areas.

From these variable starting conditions, the photographic time lines of the control blocks (see **Figs. 45a–f**, for example) reveal that between their excavation in the 1890s and their placement on the reconstructed Stairway in the late 1930s, the block surfaces became increasingly covered with microbiological growth, even though there was little perceptible damage or loss to carved surfaces. As outlined in a previous section, "History of Interventions," during this period the Stairway blocks, except for those found in situ, were placed in rows on stone supports on the unpaved Plaza in front of the remains of the Stairway.

By the next complete photographic survey of Pavón in 1946–48, the surfaces of the blocks present less biological growth, but one begins to observe some differential weathering of surfaces, with the carved surfaces that project to the greatest degree beginning to appear lighter and more uneven. By this date, because the Stairway had been reconstructed, the blocks had been reset on the slope of the pyramid structure for five to ten years. The generally cleaner surfaces reflect the cleaning that the blocks were likely to have undergone before being placed on the reconstructed Stairway. However, the beginning of surface deterioration reflects their new, more exposed position on the side of the pyramid, where, in particular, rainwater could pass over surfaces in far greater volume and at far greater speed than when they were situated on the Plaza.

Between 1946–48 and 1987 (or in some cases 1979), when the photographic campaign by Courau was carried out, one can observe carved surfaces with significant areas of loss, particularly in the lower half of the blocks, and active surface flaking, especially in the upper parts of the carved surfaces (**Figs. 46a, b, 47a, b**). Biological growth on surfaces is still present, but it is generally on the areas most recessed and without surface loss and whiteness. In these forty years, one sees the accelerating deterioration and cumulative effect of the exposure of the stone surfaces both to the natural environment and to human actions. Visitors were allowed to climb on the Stairway until the mid-1970s, and an aggressive biocide treatment was carried out to remove the covering layer of lichen growth in 1978–79. Between this treatment and 1987, the surfaces of many blocks had become recolonized by biological growth, but this time, dark algae replaced the lighter-colored lichen cover.

A comparison of the condition of the stone during the first forty years after excavation and the condition during the second forty years shows a very significant difference. That difference is related to the fact that during the first forty years, the blocks were located above ground on the Plaza. Subsequently, the blocks were placed on the reconstructed side of the pyramid, a location in which they were far more exposed to an aggressive and changing environment.

Figures 45a–f A series of historic photographs of block 409, step 43. Ca. 1895 (a), 1946–48 (b), 1979 (c), 1987 (d), 2000 (e), and 2003 (f).

Figures 46a and b Block 409 in 1946–48 (a) and in 1979 (b).

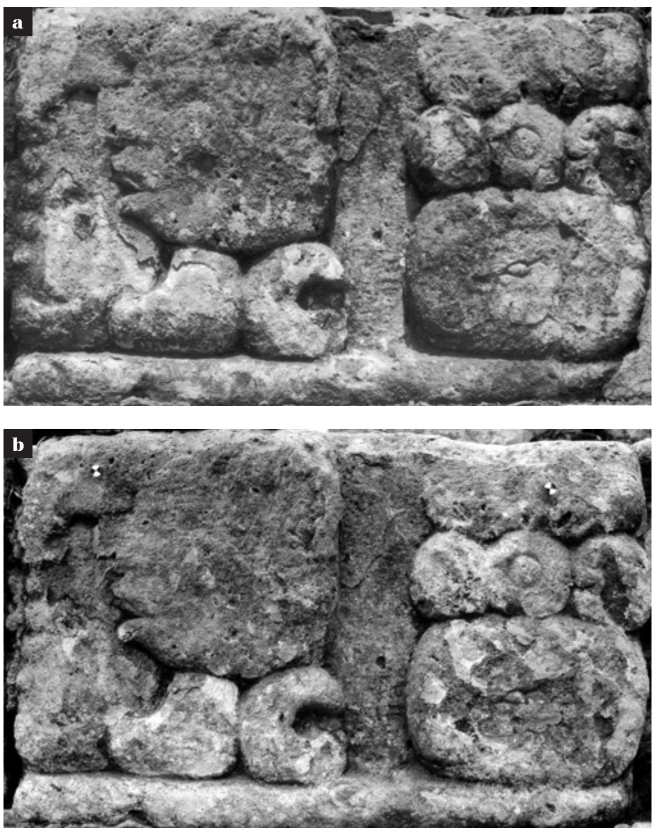
Figures 47a and b Block 343 in 1946–48 (a) and 1979 (b).

The next photographic campaign was undertaken in 2000; these photographs were taken with a flash, because a canvas shelter had been erected over the entire Stairway. As a result, the photographs from 2000 show the surfaces to be much flatter in appearance (because of the lack of shadow), and they are therefore not good for comparison purposes (Figs. 45, 50). The flash also produced a greater contrast of dark and light surfaces, so that white areas appear far whiter than if they had been photographed under natural light. For these reasons, in 2003, when the tarpaulin was changed, the control blocks were photographed again, this time without a flash.

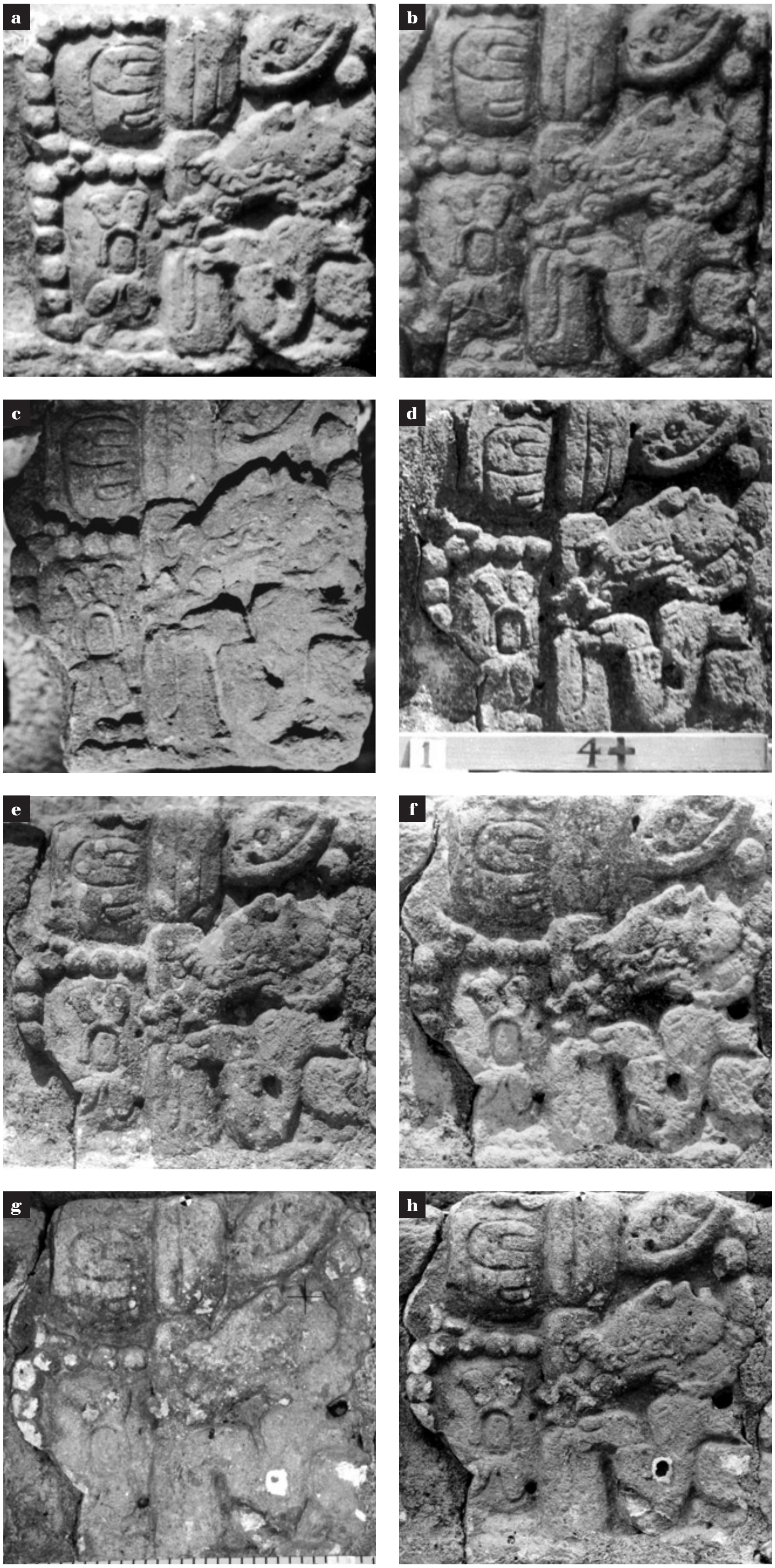
A comparison between the 1979 and the 2003 photographs shows that the major change is the loss of biological growth on surfaces; otherwise, there is very little change in surface conditions (**Figs. 48a, b, 49a, b**). The comparison shows that the accelerating deterioration and loss seen during the forty years prior to 1987 had almost stopped during the subsequent sixteen years. Both the lack of biological growth and diminishing deterioration can be attributed to the shelter constructed over the Stairway in 1985, which was first kept in place only during the rainy season, then was installed year-round in approximately 1987. The removal of almost all water and direct sunlight from the block surfaces has caused the almost complete cessation of biological growth and rapid wetting-drying cycles, as well as a significant diminishment of heating-cooling surface changes. These phenomena are likely to have been the primary causes of deterioration and loss of surface when the Stairway was unprotected. The continued prevention of direct tourist access to the Stairway, in place since the 1970s, has also contributed to the much more stabilized condition of the stone during the past decade and a half.

The comparison of historic and contemporary photographs of the control blocks has revealed a history of initial stability before the Stairway reconstruction, then a period of accelerating deterioration and loss following the reconstruction, and then stable conditions again, after the Stairway was protected with a shelter. However, there are some limited areas of current instability where surface deterioration and loss are ongoing, and this is revealed by the photographic time line of block 594 from the top step, step 63 (**Figs. 50a–h**). A comparison of the photographs of 1987 and 2003 reveals that a few new areas of surface whitening and loss have developed since 1987. Evidently, there are conditions particular to the top step that are provoking this slow loss of material, despite the protection of the shelter. However, some of the blocks of the top step are in stable condition, so the ongoing deterioration is specific to certain blocks and not to the entire step. The potential causes of this will be discussed in the section on the assessment of current conditions.

Figures 48a and b Block 409 in 1979 (a) and 2003 (b).



Figures 49a and b Block 343 in 1979 (a) and 2003 (b).



Figures 50a–h A series of historic photographs of block 594, step 63. Ca. 1895 (a), 1915 (b), 1937 (c), 1946–48 (d), 1979 (e), 1987 (f), 2000 (g), and 2003 (h).

Notes

1. Owens [1893b], field notes on the excavation of mound #26, 1, 3.
2. Gordon 1895h, 1; Gordon 1895e, 2; Bowditch and Lowell 1893, 4–5.
3. Strømsvik 1935c, 22 Mar., 8, 10, 12, 25, 29 April.
4. Strømsvik 1937c, 5 Dec. 1936, 27 Jan.–12 Feb., 17 May 1937.
5. For a discussion of the different arguments concerning the total number of steps of the Hieroglyphic Stairway and placement of the section that slid, see Strømsvik 1937c, 3 and 5 Feb. 1937; Morley 1937, 26 and 29 Jan., 1 and 3 Feb. 1937.
6. Strømsvik 1937c, starting 12 Feb.; 29 April, 14 May 1937.
7. Strømsvik 1938–41, 3, 6, 9, and 25–26 Jan., 8 Feb. 1938.
8. Strømsvik 1938–41, 28 Mar., 10 and 15 April, 18 May 1939.
9. Strømsvik 1938–41, 9 and 12 Feb., 2, 4, and 28 Mar., 8 Mar.–27 May, 26 April, 1 May 1940.
10. Strømsvik 1942–46, 26 Mar. 1946.
11. Smith 1949. The authors would like to thank Olaf Husby, without whom this information about an early surface treatment of the Stairway stone would not have been located.
12. The authors would like to thank Bill Ginnell for shedding light on this DuPont product.
13. Cueva V. 1972; Sandoval 1984, 2–5; Rodriguez Gudiel, ca. 1992, 3.
14. Thomas Roby and Elsa Bourguignon, personal communication with Miguel Rodriguez Gudiel, 2003.
15. Hale 1978a, 7; Extractos de informes relacionados con el tratamiento de la microflora en las ruinas de Copán 1978, 1. Other reports by Mason Hale himself give conflicting data on the date on which the three risers of the Stairway were treated. The dates January and April 1978 are given in Hale 1979d, 2, but this seems to be a mistake, as Rodriguez Gudiel 1977b confirms that two treatments had already been carried out on some steps of the Stairway.
16. Cruz M. 1983; Rodriguez Gudiel 1979; Extractos de informes relacionados con el tratamiento de la microflora en las ruinas de Copán 1978.
17. Extractos de informes relacionados con el tratamiento de la microflora en las ruinas de Copán 1978, 12–13.
18. Rodriguez Gudiel 1979, 7; Torres Montes and Franco V. 1980. For the particular case of the Hieroglyphic Stairway, see Extractos de informes relacionados con el tratamiento de la microflora en las ruinas de Copán 1978, 12.
19. Synthesis of personal communications between Thomas Roby and Elsa Bourguignon, and René Martínez, Rufino Membraño, and Hernando Guerra, 2003.
20. Thomas Roby and Elsa Bourguignon, personal communication with Françoise Descamps, 2003.
21. Véliz R. 1983a; Sanders 1983; Soto G. 1984, 5.
22. Sandoval 1983; Sandoval 1984; Martínez 1983, 12, 14; Rodriguez Gudiel, Soto G., and Sandoval 1984; Riederer et al. 1986.
23. Rodriguez Gudiel, Soto G., and Sandoval 1984; Sandoval 1984, 41.
24. Larios V. 1985a, 3; Larios V. 1985b, 3; Larios V. 1985c, 3.
25. Personal communication between Thomas Roby and Elsa Bourguignon, and Hernando Guerra or Rufino Membraño, 2003.
26. Personal communication between Thomas Roby and Elsa Bourguignon, and Ramón Guerra, Hernando Guerra, and Rufino Membraño, 2003.