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THE SCIENTIFIC EXAMINATION AND RE-TREATMENT OF AN EGYPTIAN LIMESTONE RELIEF FROM THE TOMB OF KA-APER¹

KATHLEEN M. GARLAND AND JOHN TWILLEY

ABSTRACT

Egyptian limestone sculpture in Western collections has often been subjected to repeated, well-intentioned treatments that are the result of an incomplete understanding of the issues surrounding the removal of sculpture from an archeological setting to a poorly controlled interior environment. Remedial treatments often follow without scientifically investigating the causes of deterioration. An important Old Kingdom painted limestone relief from the tomb of Ka-aper (fig. 1) at The Nelson-Atkins Museum of Art will illustrate past treatment failures and successes, and the need for consultation and scientific investigation in planning re-treatments.

Severe flaking of the surface required consolidation to withstand de-installation from a wall in 1992, resulting in major staining. In 2006 experts gathered to study the deterioration and staining with re-treatment of the stone in mind. A scientific study included mineralogical analyses, pore size measurements and soluble salt content studies. Analyses of areas with staining or apparent prior consolidation revealed applications of natural resins, a drying oil, polyvinyl acetate and cellulose nitrate.

These results and the experiences of the consultants formed the basis for the re-treatment. Backing removal and desalination posed greater risks than surface treatment, while environmental control was seen as the means for preventing future damage. Consolidation was undertaken with methylcellulose paste. The stains from previous consolidation attempts were reduced using benzyl alcohol in Laponite poultices.



Fig. 1. Relief of *Ka-aper and his Wife*, Fifth Dynasty, after conservation, 2008 (Photograph by K. Garland)

1. DESCRIPTION AND BACKGROUND

Fragments of a limestone relief from the early fifth Dynasty depict Ka-aper facing to the left, holding a staff in his left hand, embraced by his wife, who stands to his right. There is an inscription listing titles and names of Ka-aper and his wife running along the proper right side

and across the top. The low relief sculpture has traces of polychromy, mostly in the flesh and hair, and measures 28 x 59 in. (71.12 x 149.86 cm). Both Ka-aper and his wife's eyes have gouge marks done with chisels. Under magnification these gouges have a patina that matches the patina and texture of the aged stone surface, suggesting that the damage dates to antiquity.²

The relief is part of the Abusir mastaba of the royal official, Ka-aper (Fischer 1959; Kanawati and Hassan 1996, 35; Barta 2001). Much smaller relief fragments from the same tomb can be found at the Metropolitan Museum of Art (08.201.2) and at the Detroit Institute of Art (57.38). The relief in Detroit is apparently in good condition and may never have been treated (Peck 2007). There are no treatment records at the Metropolitan Museum, but the limestone appears to have been heavily cleaned at some time. The relief was acquired from the Parisian dealer Paul Mallon in 1946.

2. CONDITION

Eleven fragmentary blocks of fine creamy limestone are held with modern plaster mortar and copper cramps to a grey limestone backing support. It is evident from tool marks along the edge of the relief that the blocks were cut from the wall of the tomb. Several of these blocks have been broken and repaired. A larger area of fill material from the proper right side of the relief, measuring 8 x 13 in. (20.32 x 33.02 cm), was found to be a piece from the late 5th–early 6th century C.E. Egyptian *Arch* (48-11), displayed nearby and purchased from Paul Mallon in 1948. The proper right corner has been filled with a similar material measuring 4 x 6 in. (10.2 x 15.3 cm). There is an old break with plaster fills running diagonally between Ka-aper and his wife. Large areas of shallow stone loss exist in the chest of both figures. Some of the losses in Ka-aper have been filled with white plaster and crudely overpainted, though generally the overpaint on the plaster fills is close in tone to the limestone. There is a triangular piece of carved limestone forming the nose and chin of the woman that has a very different yellow tone, and might be questioned as a modern replacement carving. However the blue and green paint of the necklace are clearly ancient. Three early undated negatives reveal the appearance of the relief prior to and during a restoration campaign.^{3,4} One negative shows the fragments assembled without any fills. Handwritten in French on the negative is “*Etat primitif du bas relief lors de l’achat,*” and “*mise en place des morceaux avant la mise en place du fragment*” (fig. 2). A second negative shows the missing fragment with the chin and nose, with the note “*partie du grand bas relief collée sur un papier d’emballage lors de son achat*” (fig. 3). A third negative shows the chin and nose fragment in place on the relief fragments, which are resting on blocks of wood. The handwritten inscription says “*deuxième état du bas relief après l’achat de la partie reproduite photo B*” (fig. 4). Apparently the triangular piece of stone does belong to the relief, but was separated at some point, then was found, purchased and re-inserted in its original location, possibly by a restorer employed by Paul Mallon.⁵ The different appearance of this fragment is likely due to a slightly different restoration history. These three negatives also indicate that some carved areas, such as the wigs, are in much better condition than in the earliest Nelson-Atkins images, but loss had already occurred before the Museum purchased the relief.



Fig. 2. Enhanced digital image taken from an undated negative (Courtesy of The Nelson-Atkins Museum of Art)

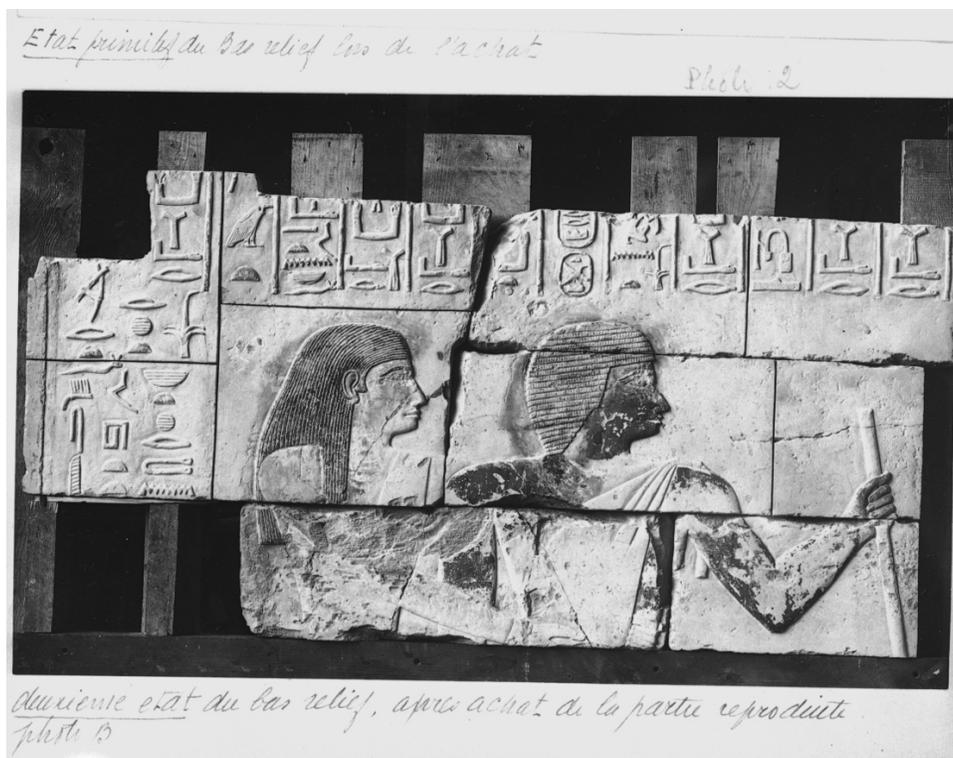


Fig. 3. Enhanced digital image taken from an undated negative (Courtesy of The Nelson-Atkins Museum of Art)

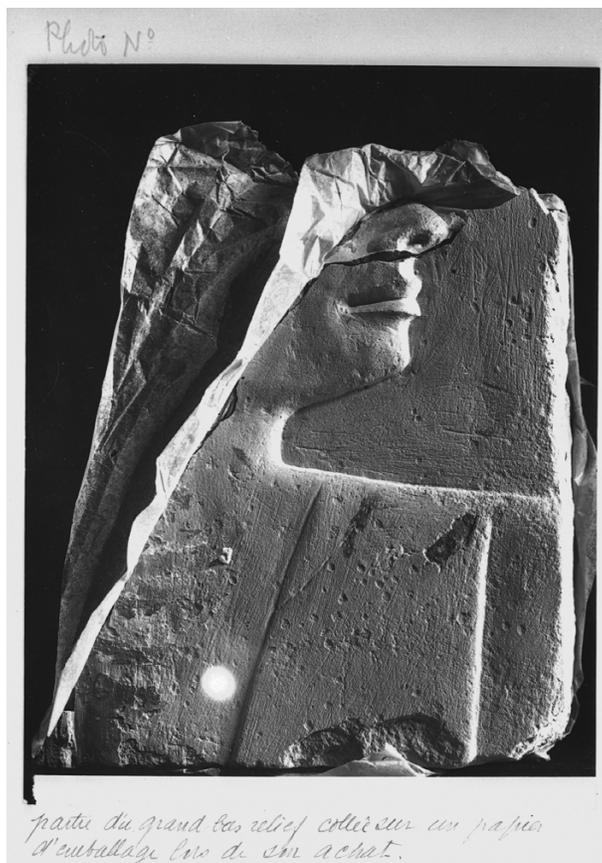


Fig. 4. Enhanced digital image taken from an undated negative (Courtesy of The Nelson-Atkins Museum of Art)

3. CONSOLIDATION TREATMENT PRIOR TO 1992

Many areas of the relief were given consolidation treatments to re-adhere fragile paint and flaking stone, which saturated and stained the colors on the figures producing a darker, glossy surface. Analysis (see below) identified three different materials used for consolidation, possibly during a restoration done while in the hands of Paul Mallon. Consolidation seems to be the cause of the grey shadow or discoloration around the figures noted by Henry Fischer in his article on the tomb as “paint being applied too thickly, so that the aqueous medium has spread into the surrounding area” (Fischer 1959, 239). These stains around the heads of the two figures are obvious in the earliest known black and white negative (fig. 2), but have a different shape than the ones visible in the undated black and white image of the installed relief (fig. 5). The latter have produced a somewhat gray discoloration that appears very clearly as a shadow around the woman’s head, and may be related to a stain seen on images of the Ka-aper fragment in Detroit where a similar line of discoloration is present. More analysis needs to be done to distinguish the possible consolidation sequence, but visual observation suggests that the gray stain is different from a material applied to consolidate the stone flakes, which has a yellowish tone. This yellowish adhesive is mostly covered by a chalk wash or slurry, presumably applied to conceal the adhesive stains (figs. 6, 7). A third consolidation material found on the painted areas is a clear, shiny resin that has remained acetone-soluble. Many of the consolidated flakes are misaligned, or out-of-place, and particles of dirt have been incorporated into the consolidation.

The woman's hair is a good example of this untidy consolidation; her wig is now saturated with consolidant and appears almost black, when it should probably have looked blue. Pigmented wax fills were added to Ka-aper's face, probably all at the same time as the third consolidant, since the losses are un-restored in all the pre-installation photographs.



Fig. 5. Undated photograph of the relief in the Museum installation (Courtesy of The Nelson-Atkins Museum of Art)

4. SOLUBLE SALT DAMAGE AND THE 1946 MUSEUM INSTALLATION

The earliest, undated photograph of the relief in the Museum installation shows the relief restored, but with severe flaking around the two figures (fig. 5). This flaking is visible to some degree in the early negatives (fig. 2), but the lighting in the image makes it difficult to assess precisely how much deterioration occurred after installation. The original Nelson-Atkins installation had placed the relief in a niche closely adjacent to water pipes so hot that a hand could not touch them for more than an instant. Furthermore, hygrothermograph charts in the galleries indicated frequent periods of relative humidity above 80% as the heating and cooling systems (HVAC) only ran during operating hours until 1989, when the HVAC started to run 24 hours a day. The environmental fluctuations and hot, dry conditions behind the limestone could easily have contributed to the solubilization and re-crystallization of salts, leading to more loss on the carved surface.⁶

A conservation examination report from 1992 describes the loss of surface, particularly in the hair, flesh and surrounding the figures (Conservation Department 1992). Much of this loss is visible in the undated negative described above (fig. 2), but it is likely that more occurred after the consolidation attempt discolored the stone, possibly while in the care of Paul Mallon. The surface exfoliation is particularly serious around the heads, with less activity in the inscription. Under the flakes of stone there is usually a pitted area or shallow loss about 1–3 mm. There is little visual evidence of soluble salt activity in the form of small salt crystals, except around some of the fresher plaster fills, but scientific studies (described below) later confirmed soluble salts have been involved in the flaking. A slurry of chalk and water, close in color to the Egyptian limestone, was brushed over the damaged areas, as well as over the stains around the two figures. This wash was not applied to the entire surface; the usual scraping and tool marks can be seen around the inscription and areas without the chalk wash are in distinctly better

condition. The slurry restoration is likely to have occurred before the relief came to Kansas City, perhaps to conceal stains caused by the initial consolidation. Another crude intrusion is thought to have taken place during installation at the Museum. The top edge of the relief was cut away, using a circular saw, by 2 cm and the proper left side by 1 cm, probably to make the relief fit better into the gallery wall.

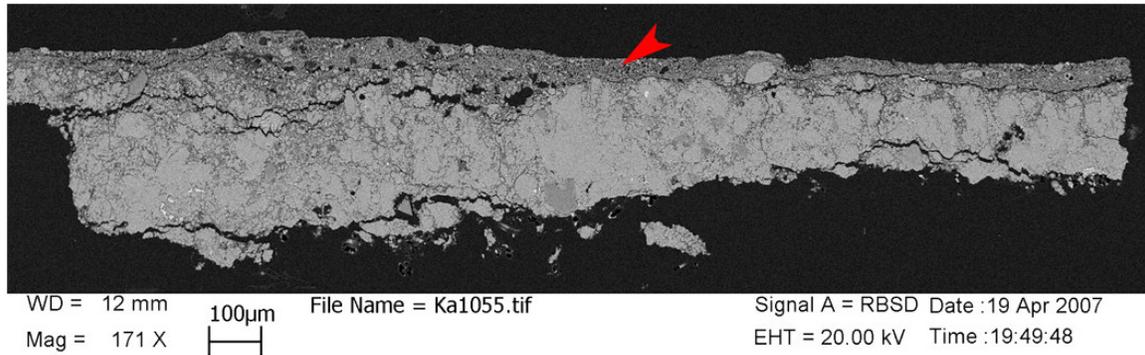


Fig. 6. Cross section through the carved surface in the SEM. The red arrow indicates the slurry layer.



Fig. 7. UVC radiation showing fills. Arrows indicate areas with slurry. Slight orange fluorescence indicates consolidants applied at some time prior to 1991.

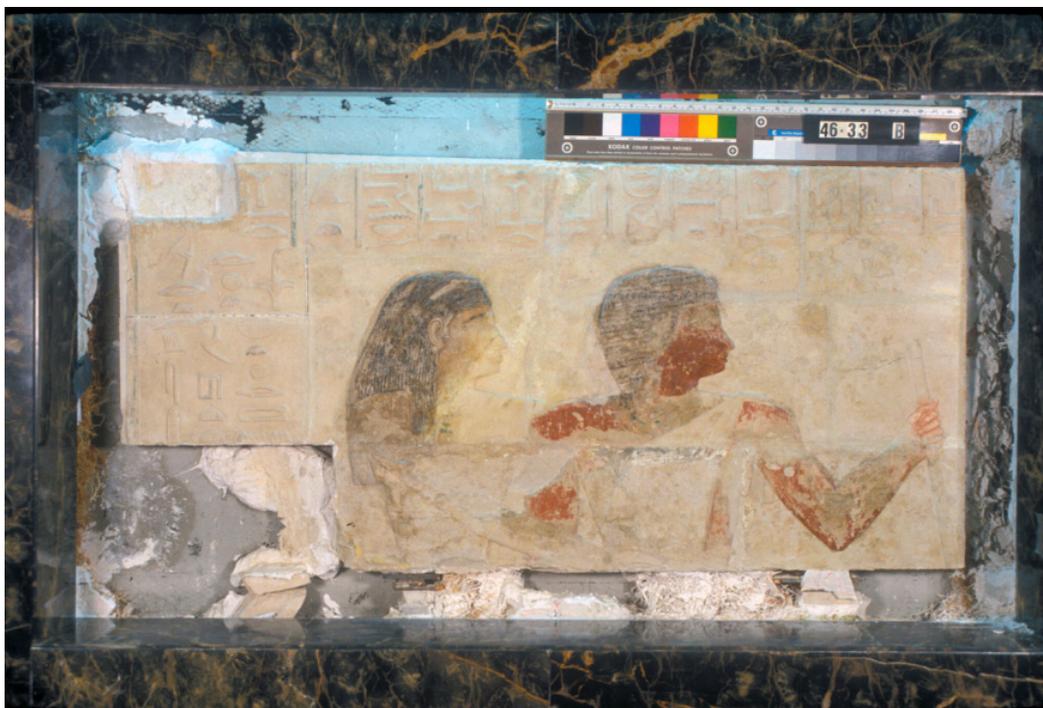


Fig. 8. Removing *Ka-aper* from the wall, 1992

5. CONSERVATION INTERVENTION 1992

A gallery renovation in 1992 with a tight construction schedule necessitated the removal of the relief without pursuing detailed scientific studies. The relief had been firmly plastered into a niche since it was acquired by the Museum, and was covered with a sheet of clear acrylic at some point. An undated drawing in the files suggested that the stone fragments were mounted within plaster on a wire mesh set against a brick tile wall (Conservation Department 1992). Marble trim matching the walls of the gallery had been plastered and tied with wire twists to the brick tiles (fig. 8). The fragile flaking surface clearly required yet another consolidation treatment before the relief could be subjected to the vibration involved in chiseling off the surrounding plaster and marble (fig. 9). An ideal consolidant should be just strong enough for the job, reversible, stable over time, have low toxicity for the user, and be unlikely to aggravate soluble salt migration.

Since fine Egyptian limestone is easily stained and discolored by most consolidants typically used by conservators, a variety of reversible adhesives with a sound history of conservation use were discretely tested by the primary author. These tests were located along the flaking edge surface of the relief. The consolidant mixture was applied either with a hypodermic or by using drips from a fine brush. Methylcellulose 2 % w/v in water was found to be the consolidant that least affected the color of the stone, but it was also deemed too weak for the purpose, plus the addition of any water to a stone with probable soluble salt deterioration was not desirable. A 2 % isinglas (fish glue) solution was much stronger but also darkened the surface, and had the same concerns about introducing water into the limestone. Paraloid B-72 3 % w/v in acetone, toluene and 1:1 ethanol acetone mixtures were judged to stain the stone unacceptably, though of the two the ethanol acetone mixture had the best appearance. Of the synthetic adhesives, the one that best fit the criteria of strength, acceptable staining and reversibility was a

resin more frequently used in wood consolidation, Butvar B-98⁷ in an ethanol/toluene mixture (Spirydowicz et al. 2001). There is evidence that the resin may crosslink under extreme circumstances such as high temperature, or excessive ultraviolet radiation, but these are unlikely in a museum environment (Spirydowicz et al. 2001, Horie 1987). Another slight risk is the dissolution and re-crystallization of soluble salts on a small scale because of water naturally present in ethanol. These risks were weighed by the conservator and the curator of Art of the Ancient World against the other desirable qualities of the Butvar B-98, and the risks were deemed acceptable. The consolidation of the flaking stone proceeded using a mixture of Butvar B-98 2%–3% w/v in 80:20 ethanol and toluene injected with a hypodermic after ethanol was used to pre-wet the surface. The consolidant wicked under the slurry and flaking stone and the usual darkening of the surface occurred as the mixture wet the stone surface. The relief was again tented with Saran wrap to slow the evaporation of the solvent mixture. This technique would theoretically minimize the adhesive from following the evaporating solvent to the surface of the object and cause saturation or darkening. However, when the surface was examined the next morning there was considerable darkening, more than had been suggested by the earlier testing along the edge. Attempts were made to move or remove what appeared to be excess consolidant using cotton swabs and/or sable brushes with solvents, as described above. Regrettably the staining only got worse, perhaps because older consolidants were re-dissolved by the fresh solvents (fig. 10).

At this point the curator and conservator decided to press forward with dismantling the relief from the wall, since the exfoliating surface did seem much stronger, and the staining could be further investigated after the relief was detached. The conservator chiseled the plaster out of the wall and found that the installation was close to that suggested by the undated diagram. When the relief was removed it was found to have been mounted using plaster of paris with small copper alloy clamps to a gray limestone backing 2 cm deep and shaped to conform to the relief (fig. 11). Once the relief was brought to the conservation laboratory, further attempts were made to reduce the staining by dissolving and drawing the consolidant out of the stone and into paper poultices. These did not help much with stain removal. After much discussion the relief of Ka-aper was put in storage until a proper scientific investigation into the causes of the flaking and staining would be possible.

6. CONSERVATION STUDY 2006–2008

In 2006 a group of specialists was assembled at the museum to study the relief and propose a treatment methodology.⁸ In order to plan for the treatment and future display of the relief of Ka-aper a series of meetings between consultants, the Nelson-Atkins Conservation staff and the museum's Mellon Scientific Advisor were held to review the history of the relief and its present condition. All agreed that scientific investigation was critical before a treatment could be proposed. A series of follow-up meetings, examinations of the companion relief at the Detroit Art Institute, and examinations of the long-studied Abydos reliefs at the Metropolitan Museum of Art resulted in recommendations by the consultants regarding the need for testing of this art work and proposals for treatment. A series of analytical investigations were undertaken in order to understand the root causes of the surface damage and discoloration phenomena and to answer questions posed by conservator in advance of treatment.



Fig. 9. Raking light detail of the surface flaking



Fig. 10. Location of some of the consolidation stains from the 1992 treatment



Fig. 11. Right side of the relief during conservation showing the plaster and limestone backing, 2008

7. SUMMARY OF LABORATORY INVESTIGATIONS⁹

Tests that could best be handled by standardized methods of analysis available in the commercial sector, or through agreement with colleagues, were conducted by outside laboratories on samples collected by the project scientist. The project scientist performed tests for which observational experience with antiquities was important for interpretation, or where flexibility was required in the methods to be applied to extremely limited material.

Quantitative X-ray diffraction analysis was performed on two samples of stone from below well-preserved and poorly-preserved surfaces. Particular attention was paid to the quantity and type of clays found in the stone and their potential for swelling. Petrographic analysis was conducted on the same samples as a means of identifying localized concentrations of clays and of assessing the cohesion or “lithification” of the limestone. No clay-rich strata were observed in the samples and the overall clay content was only between 1.4%–1.8 %. Fortunately, montmorillonite clay was in the minority even in this total, suggesting that this example is not one highly susceptible to damage due to clay swelling. Petrographic analysis indicated that the

calcareous sediments have been extensively recrystallized, and that this contributes to the cohesion of the resulting stone.

Nannofossil analysis, which holds the potential to place boundaries on the geological period in which the limestone originated, was made difficult by the scarcity of intact examples in the recrystallized stone. Based on a very limited population of examples, the stone was determined to be a marine limestone broadly dated to the Middle Jurassic to Late Cretaceous period of 170–165 million years before present (Quinn 2007). It was found to be relatively free of the deleterious properties associated with the most unstable Egyptian limestone sculptures: layered strata containing expansive clays, high salt content, and poor intergranular bonding of sediments (Talbot 2007). Trace levels of iron pyrites found in the stone were not undergoing or showed no evidence of active oxidation or damage, but seemed to be the geological basis for small amounts of iron that contribute to the yellow cast of the stone. Natural redistribution of iron traces may have been a confusing factor in prior restorations during attempts to match local colors.

The plaster used in the relief's prior mounting was found to be a simple plaster of paris without evidence of any role in exacerbating damage to the relief. The overall salt content of the limestone was found to be around one half of one percent, a relatively low value compared to many salt-damaged stones (West Coast Analytical 2007). Importantly, the only salt associated with surface damage was sodium chloride and the next largest components were nitrates in the interior of the stone. Numerous sodium chloride crystals were observed through scanning electron microscopy under the flakes of stone. Sulfates, with their higher potential for damage, were found at lower levels and not associated with the surface losses.

Samples collected from the surface demonstrated that some of the damage resulted from applications of a chalk slurry applied in prior restorations, probably to conceal surface losses in the limestone. Analyses of the organic components of areas exhibiting staining, surface sheen, or apparent prior consolidation revealed a history of applications involving natural resin, a drying oil, and cellulose nitrate. Polyvinyl acetate was found locally, but was not confirmed to have been intentionally applied to the relief. The mechanism and materials associated with the discoloration around Ka-aper's head, mentioned in Fischer's article, and also visible on the Detroit relief, could not be positively identified.

Pigments that could be identified represented simple components of the Egyptian palette drawn from natural mineral sources with the exception of carbon black and the man-made furnace product Egyptian blue. A final determination on whether the female originally was painted with an iron oxide yellow could not be made, since only slightly elevated levels of iron were found in the stone surface. The situation was complicated by the fact that calcium oxalate alteration products were found in a few locations on the relief surface, including some of the ones which presented a yellowed appearance.

8. SOLUBLE SALT CONTENTS

The existence of efflorescent or sub-fluorescent salts at the surface is an indicator of the presence of potentially damaging salts. However, the species that can be identified in surface deposits are dependent upon the environmental history of the stone and do not necessarily represent the type or proportions of salts found deeper in the stone. Information on these is needed because salts play an important role in maintaining the equilibrium moisture content of the stone at any given relative humidity imposed by the environment. This information must be considered in order to

anticipate the potential benefits or detriments of a shift in environmental conditions. While the equilibrium relative humidity of saturated solutions of common salts is well-established, the behavior of mixed salt solutions is considerably more complex. There have been organized attempts to develop systems for predicting the behavior of mixed salts (Price 2000). However; there have also been well-controlled practical experiments that document deviations from the behavior predicted by such models. In at least one case, important deviations have been noted in salt -damaged Egyptian limestone with continued salt crystallization under conditions predicted to halt crystal growth (Nunberg et al. 1996). It has been noted that systems involving nitrate ions are less-adequately modeled than others at present and that non-uniform distribution of salts in stone imposes a limitation on the ability of such methods to predict behavior (Price et al. 1994). In the present case, and in many prior investigations involving exterior stone and masonry, nitrates were readily detected in interior samples but were not present in surface samples.

The information gained about the soluble salt contents of the limestone was later incorporated into the case design. The primary environmental threat is sodium chloride dissolution, at around 75% relative humidity (Brigham Young University), and the subsequent damaging re-crystallization of the salt in the stone pores. Since the relative humidity at the Museum is maintained at a very even $50\% \pm 5\%$, we anticipate that a well-designed display case with silica gel added to the interior chamber will be sufficient to protect against major spikes of humidity due to possible HVAC malfunctions.

9. CONSERVATION TREATMENT 2006–2008

Once the scientific report was complete, a treatment approach was developed. All past interventions have caused some damage to a very fragile surface (figs. 9, 12). The history of treatment of salt-damaged Egyptian limestone has shown that scientific study is critical for understanding the true physical condition of the stone and its inherent vulnerabilities, and thus to prevent future damage. As noted above, the analysis indicated that the modern plaster backing is not contributing significant quantities of salt to the deterioration of the surface, so that a risky plaster and backing removal is not necessary. Furthermore, the clay-rich strata that often are responsible for a high degree of swelling susceptibility in Egyptian lime stones are not present. The only soluble salt of major concern is sodium chloride, which can be controlled environmentally. The risks inherent in poulticing to remove the salts did not seem justified in light of their type and distribution. The disfiguring modern materials, the shiny adhesive and white slurry covering the surface of the relief were found to be 20th century additions, to be removed if possible. Treatment could be limited to consolidation with weak adhesives; stain removal, and if possible should be followed with judicious cosmetic re-integration. While the extreme deterioration suffered from poor restoration in the past cannot be reversed, the visual results can be reduced.

The choice of consolidant was limited to methylcellulose (mc) 1.5%–2% in water, since it did not stain the stone. Methylcellulose is not a very “strong” consolidant, but the other synthetic polymers tested in 1992 are likely to result in more stains. Other possible plant or animal-based consolidants such as gelatin, fish glue and funori¹⁰ require more water than methylcellulose, darken the stone more, or cause light tide lines. The small quantities of water in the methylcellulose are also unlikely to activate any soluble salts. The methylcellulose has good aging qualities and remains re-treatable (Feller et al. 1990; Kühn 1986; Hatchfield 1988). Gentle pressure with a sable brush on some of the consolidated flakes suggested that the methylcellulose

was a stronger adhesive than might be expected. Any areas requiring a structural adhesive were adhered using Paraloid B-72 50% w/v in acetone.

Flaking and stained areas several inches wide were selected for cleaning and consolidation tests. All cleaning and consolidation was done under a binocular microscope. Ethanol was applied with a small brush to pre-wet the areas needing consolidation. The ethanol quickly soaked under the top of the stone surface, confirming the project scientist's observation that most of the carved surface has a porous sub-surface caused by the soluble salt activity. The methylcellulose was then injected to fragile areas and allowed to dry. Laponite RD poultices were made using benzyl alcohol. The solvent was added to the powder to make an appropriately thick slurry. The slurry was applied using small spatulas where the stone was strong enough, or using a hypodermic without a needle in weaker areas. The hypodermic required a more dilute poultice mixture.



Fig. 12. Relief before treatment in 2006

The poultices were allowed to dry for two or three days, until cracks developed in the poultice. At this point the Laponite was dry enough to be lifted with a scalpel off the surface in small flakes, and dusted up using a vacuum cleaner on low suction. If the Laponite was removed before it was dry, the stone below was too spongy to clean safely. The poultice was very effective at removing stains, even those caused by the methylcellulose, but the solvent gelled the methylcellulose making it harder to clean the dried poultice in places where there is excess consolidant. It was often necessary to reconsolidate areas, and then apply another poultice to remove the mc stains. Any small fragments of stone that were dislodged were either re-adhered, if they could be relocated, or bagged and saved. A number of small stone fragments (millimeters in diameter) were completely pulverized, especially during the early phases, before the technique was more developed. The removal of discolored, increasingly intractable, old consolidants seemed to justify the very small stone losses. The biggest visual changes occurred in the wigs and faces, where the shiny, saturated resin was very effectively removed. A further benefit was the removal of the adhesive stains behind Ka-aper's head, revealing a discoloration similar to that seen in the Detroit relief. Surprisingly, the remaining particles of paint in the jewelry were well attached, so cleaning was quite effective even in these areas.

After poulticing, the stone often had a hazy white appearance. Several samples of materials used in the cleaning of the stone were examined to determine whether any salt was being transferred from the relief into the mixture, and whether residues of the Laponite remained on the limestone. SEM examination showed that it was removed fully, even in areas of high surface roughness. Chlorides were not detected in the dried Laponite, suggesting that the stain removal had been achieved without remobilizing salts near the surface. Nevertheless, particles of Laponite have unavoidably been left in and under many of the flaking areas. These were excavated as completely as possible using #11 scalpel blades, but the Laponite cannot be removed entirely without further damage to the stone.

Unfortunately it was not possible to remove the white slurry without damaging the original limestone beneath; however the slurry is close in color to the stone and is not too visually disturbing. The exfoliating stone surface does remain visible since there is no way to lay the flakes of stone flat. However the methylcellulose consolidant is preventing further loss and can be re-applied should it be necessary. Reducing the stained and shiny adhesives from the previous consolidation efforts has considerably improved the appearance of the relief, and was well worth the effort.

Filling and inpainting was undertaken after consulting with Dr. Diana Craig Patch, Metropolitan Museum of Art, and with Dr. Robert Cohon, Curator of Art of the Ancient World at the Nelson-Atkins. The filling material consisted of 7% Klucel G (hydroxyl propyl methyl cellulose) in ethanol with 1:1 glass microballons (3M Scotchlite) and cellulose powder mixed with dry pigments. This matched the texture of the stone quite well, was thixotropic and may be easily reversed with solvents or by mechanical means. Inpainting was done with dry pigments mixed with methylcellulose. The inpainting was restricted to old and new fills only; no paint was applied to stone. Thus there are fill areas which remain visually obvious, but it was deemed preferable to reduce further treatment of the already damaged stone. Only the fill on Ka-aper's cloak and nipple area were modeled to match adjacent carving, since Patch felt that these two areas would not interfere with art historical dating, and would make the piece more legible. Filling the wife's right arm and Ka-aper's mouth was discussed, but this was considered too extreme for an important archeological piece.

10. CONCLUSION

The limestone relief of *Ka-aper and his Wife* has suffered greatly from past interventions, and regrettably the damage will always be visible. Sometime during the 1940s disfiguring surface flaking caused by soluble salt re-crystallization required consolidation. The restorers used materials current at the time, such as natural resins, drying oils, and cellulose nitrate, probably without considering appearance changes as these resins aged and shifted color. Stains from the initial consolidation were concealed by a chalk and water slurry, close in color to the stone. It is probable that the wet slurry aggravated the soluble salt activity that originally caused the surface exfoliation. The plaster of paris used by the restorers for assembly must have introduced considerable water to the stone as well. The 1992 consolidation by this conservator was well intentioned, but done under the pressure of a deadline, and without the benefit of a scientific investigation. When this study did take place it guided the treatment by identifying the salts responsible for the surface damage. The quantity of plaster of paris used in the early restoration made it likely that gypsum might be a source of the damaging salts and that these might be sulfates, but the scientific study indicated that sodium chloride was the salt involved in the

surface damage. Thus a risky plaster removal and backing was avoided, and the sodium chloride can be controlled with a stable museum environment of 50% relative humidity. Regrettably the flaking of the stone surface cannot be reversed.

A collaborative approach to the scientific study and treatment methodology should be considered part of any intervention on artifacts that are in poor condition and have suffered from past restorations. Viewing the relief in person with the consultants, comparing associated stones from the same tomb and discussing similar treatments with experts was important to establish the treatment methodology, and allowed for a rich exchange between the responsible art historian, conservator and conservation scientist. Together we were able discuss our concerns and expectations, make informed decisions, and do the best possible treatment for the relief of *Ka-aper and his Wife*.

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APPENDIX

Consolidant tests, 1992	
Methylcellulose and Klucel G	Darkened stone the least, but did not seem strong enough.
Isinglas (fish glue) and Jade 303	Darkened the stone and required water. Removable only with water.
Acryloid B-72 3% in toluene	Provides enough strength, but darkens the stone in spotty areas. Hard to remove evenly.
Acryloid B-72 3% in acetone	Very dark and spotty. Hard to remove evenly.
Acryloid B-72 3% in acetone/ethanol 1:1	About the same as B-72 in toluene, but may darken stone less. Hard to remove evenly.
Butvar B-98 2% in ethanol and toluene	Darkened stone acceptably. Easily removed with acetone.

Pigments Identified using SEM, 2007	
Black pigment from woman's wig over ear	Carbon black
Black of Ka-aper's wig	Carbon black
Blue-green pigment over white ground on woman's neck	Egyptian Blue (calcium copper silicate) and malachite
Dark green pigment under brown coating from Ka-aper's necklace (alternates with contrasting green)	Copper chlorides. It is likely that larger samples would have contained other copper species responsible for the greater saturation and bluish cast of this layer.
Light green pigment on hieroglyph	Copper chloride. It should be remembered that in the presence of sodium chloride, many ancient Egyptian pigments containing copper have been found to have altered to copper chlorides, so that the original mineral may have been another copper species
Stain Removal Tests, 2007	
Toluene and acetone on swabs	Moved stain around, not much is removed
Toluene and acetone, cotton poultices	Moved stain around, large tide lines
Benzyl alcohol on swabs	Moved stain around, tide lines
Benzyl alcohol, cotton poultice	Not much effect, stain moves, removes shiny resin on faces
Benzyl alcohol, Laponite RD	Excellent stain removal, not too much tide line. Must wait till full dryness of poultice. Minimal residues, except where preconsolidated with methyl cellulose.
Benzyl alcohol, acetone Laponite RD	Same as above
Cyclododecane in benzine applied to strengthen lifting stone flakes, benzyl alcohol Laponite poultice applied.	Heavy tide line even after CDD sublimates
Benzyl alcohol, Sigmacell 50 cellulose powder	Decent stain removal, but the cellulose powder is very difficult to remove
Methanol on swabs	Not much effect, moves stain around
Methylene chloride on swabs	Even less effect
Benzyl alcohol, Laponite RD, Japanese paper interleaf	Decent removal, but very thick tide line around the edge of the paper
Benzyl alcohol, Sigmacell 50 cellulose powder with a Japanese paper interleaf	Poor removal, tide lines.

NOTES

1. A version of this paper will appear in *The Journal of the American Research Center in Egypt* (JARCE 45).
2. A similar gouge mark is visible in the smaller fragment of Ka-aper from the same tomb, now in the Detroit Museum of Art.
3. The negatives are located in Imaging Services, The Nelson-Atkins Museum of Art, accession number 46-33.
4. Fischer obtained prints of negatives he had seen in the Saqqara office of the Egyptian Department of antiquities in 1956. He apparently used images of two blocks of hieroglyphs above the Nelson-Atkins image to assist in determining a possible location of the relief in the mastaba.
5. There are no records before the 1990s noting any restoration. Until the objects conservation lab was established in 1989, sculpture purchased by the museum was usually restored prior to its arrival in Kansas City. The notations in French on the negatives and the discovery of a fragment of the *Arch* purchased in 1948, used in the restoration of the relief, purchased in 1946, both from Paul Mallon, suggest that the restoration may have taken place under his direction. It is not uncommon for mason/restorers to reuse old fragments that are lying around in their shops.
6. When salts naturally present in the stone, or ones that wick into the stone from adjacent sources go through cycles of wetting and drying, they can migrate through stone pores when wet and recrystallize when dry. This re-crystallization can exert physical pressure on the stone pores, often causing physical decay in the stone. Typical soluble salts of concern are sodium chloride (table salt), as well as various compounds of nitrates and nitrites, sulfates and carbonates.
7. Polyvinyl butyral, a polyvinyl acetal resin formed by the reaction between aldehydes and alcohols.
8. The team included Dr. Robert Cohon, Curator, Art of the Ancient World; Elisabeth Batchelor, Director of Conservation and Collections Management; Kathleen Garland, Conservator; and Joe Rogers, Conservation Associate, all from the Nelson-Atkins Museum. Consultants included Jerry Podany, Head of Antiquities conservation, The J. P. Getty Museum; John Twilley, Project Scientist, Hawthorne, NY; and George Wheeler, Research Scientist, Metropolitan Museum of Art, NY.
9. For the complete study, see John Twilley (2008). *Scientific evaluation of a salt-damaged Egyptian 5th Dynasty limestone relief: testing in support of treatment and stabilization. Analysis and Materials for the Preservation of Cultural Property*, Hawthorne, NY.
10. Funori is a mild consolidant and adhesive used by Japanese scroll conservators, and is made from seaweed.

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SOURCES OF MATERIALS

Sigmacell cellulose fiber, type 50
Sigma Chemical Co.
St. Louis, MO

Cyclododecane
Kremer Pigment, Inc.
228 Elizabeth St.
New York, NY 10012

Glass microballoons
3M Scotchlite
St. Paul, MN 55144-1000
612-736-1691
available from:
Conservation Support Systems
P.O. Box 91746
Santa Barbara, CA 93190-1746
800-482-6299

Isinglas: fish glue
L. Cornelissen & Son
105 Great Russell St.
London WC1B 3RY, England

Butvar B-98
Klucel G: non-ionic adhesive (hydroxypropylcellulose) soluble in water and alcohol
Methylcellulose
Talas
568 Broadway
New York, NY 10012
212-219-0770

Laponite RD: synthetic inorganic colloid gel-forming powder

Conservation Resources International, Inc.

8000-H Forbes Place

Springfield, VA 22151

Paraloid B-72: ethyl methacrylate/methyl acrylate copolymer

Rohm & Haas Co.

Philadelphia, PA

Supplied by:

Conservation Support Systems

P.O. Box 91746

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