TREATMENT OF THE ABYDOS RELIEFS: CONSOLIDATION AND CLEANING

G. E. Wheeler, J. K. Dinsmore, L. J. Ransick, A. E. Charola and R. J. Koestler

Abstract—The Abydos reliefs, from the small temple of Rameses I, have had a difficult history since they were unearthed in 1910. Due to a high soluble salt concentration the reliefs have exhibited severe flaking and powdering over the following decades. Wax and oil treatments failed to prevent further deterioration and darkened the light-coloured limestone considerably. The present study discusses the problem of cleaning and consolidating reliefs in such delicate condition and the approach taken of consolidating first with silane before removing the wax of previous treatments.

1 Introduction

The small temple of Rameses I at Abydos had a difficult history from the earliest times. Built between 1314 and 1300 BC, it was subsequently buried and fell within the Nile's seasonal overflow where it remained for many centuries.

The temple was accidentally unearthed in 1910 and thus began a less-than-scientifically executed dig. The relief sculpture which decorated the temple was cut from the walls and sawn into sections at that time to facilitate handling and transport [1, 2].

Most of the reliefs were donated to the Metropolitan Museum of Art in New York and today these sections of the temple are commonly known as the Abydos Reliefs. Their difficult history before arriving at the museum has been matched by an equally unfortunate history of deterioration while in the museum. The combined collection of salts from the Nile and the soil has resulted in severe flaking and powdering which has persisted despite several campaigns of treatment (Figure 1). By necessity, the reliefs were finally removed from exhibition in 1966.

For the purpose of this paper the reliefs will be designated in the following way:

A—'Offerings to the dead King Rameses I' (5 sections).

B—'Offerings to the Osiris symbol at Abydos' (5 sections).

C & D—'Procession and offerings in honour of Osiris' (10 sections).

and one section from the façade—'Sethi I reciting the offering prayer'.

Received 6 April 1983

2 Previous treatments

The concentration of soluble salts (mainly sodium chloride and sodium nitrate) in the stone of the Abydos reliefs is around 4%, causing considerable deterioration [3]. During the years 1911–13, the five sections of the A reliefs were immersed in paraffin wax to prevent this deterioration. The B sections were brushed with partially purified tung oil and the C and D sections were treated first with tung oil and then with paraffin wax [4, 5].

These treatments darkened the ivory-coloured stone noticeably (Figure 2). In addition, the oil treatment resulted in the formation of a partially consolidated leather-like layer of stone about 1mm thick. In the years following, this impermeable, hydrophobic layer lifted up in many areas because of salt crystallization (Figure 3).

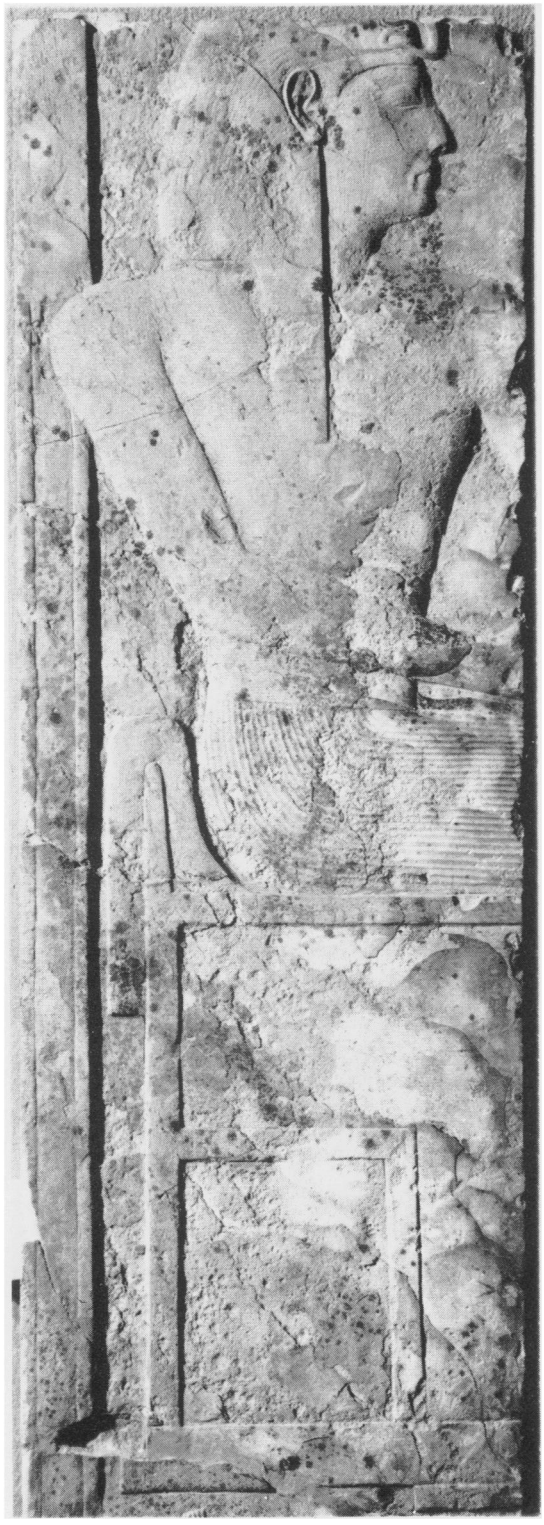
In 1938–40, a heavy coat of paraffin was applied to the surface of the A and B sections and the section from the façade. The sections were then soaked in water to remove soluble salts. The paraffin protected the surface of the reliefs but also prevented the removal of salts in that region. The only effect was to damage the stone not coated with wax. After drying, these reliefs were set in iron-reinforced plaster and framed with angle-iron for support. In some cases, about 3cm of stone was removed from the back of the reliefs before the plaster was applied.

In 1952, another attempt to remove the soluble salts by total immersion was made on one D section without first applying a coat of wax. After two days the surface of the relief began to lift. The wax-tung oil impregnated layer of the original treatment may have prevented complete destruction of the surface (Figure 4). Other treatments on individual sections over the years 1943–75 are described elsewhere [5].

3 Preliminary study

Experiments to determine the consolidant to be used on the reliefs resulted in the choice of methyl trimethoxy silane ($CH_3Si(OCH_3)_3$) (Dow Corning Z-6070 or T-4-0149) either by itself or mixed in different proportions with an acrylic-silane (Raccanello Acrilsiliconico no. 55.050, formerly E 0057) [3].

Samples of an Egyptian limestone similar to the Abydos stone were treated in the laboratory to



simulate the oil and wax treatments received by the reliefs. These treatments are described elsewhere [3].

It was noticed that when the samples treated with wax and tung oil received an application of the methyl trimethoxy silane (henceforth referred to as silane), part of the wax was dissolved by the silane and was carried further into the stone (Figure 5a). The wax could be removed by poulticing with attapulgite and PERC (perchloroethylene or tetrachloroethylene) even after consolidation with silane. For total removal of the wax, several poultice applications were needed. The effect of the first two poultices can be seen in Figures 5b and 5c.

Specimens from these test samples were prepared for SEM (scanning electron microscopy) examination. The specimens were polished and lightly etched in 1M HCl. Figures 6a and 6b show samples before and after poulticing.

4 Treatment

This paper reports only the current treatment of the A reliefs.

4.1 Rationale of the proposed treatment

The cleaning of the reliefs was approached with trepidation, as previous attempts at cleaning in the 1970s had damaged the surface considerably [4]. Cleaning was an important issue because the wax treatments, as mentioned earlier, had darkened the stone of the reliefs from ivory-white to molasses-brown. The effect was to mute the chiaroscuro so important to bas-relief sculpture.

Having decided that cleaning was necessary, each section of the reliefs was examined with a view to its suitability for cleaning before consolidation. It seemed desirable to remove the wax before consolidation so as to open the capillary network of the stone to the consolidant. However, the surfaces of some sections appeared too sensitive to permit poulticing; therefore it was decided to consolidate these sections first. Laboratory tests demonstrated that cleaning was feasible after consolidation; however, this is not a general principle and must be established on an individual basis.

The silane can be applied by brushing, pipetting or spraying [6]. Brushing was discarded for fear of dislodging parts of the surface; pipetting, while probably the safest technique, was discarded

Figure 1 (left) One of the A sections of the Abydos reliefs representing Rameses I. Notice the heavy exfoliation by salt crystallization and the unevenness in colour due to the treatments received. There are black spots—dendritic, pyrolusite-like in close-up—dotting the surface.

Figure 2 (left) Partially cleaned area of another section of the A reliefs. Notice the lightening in colour of the area that was poulticed (attapulgite/PERC).

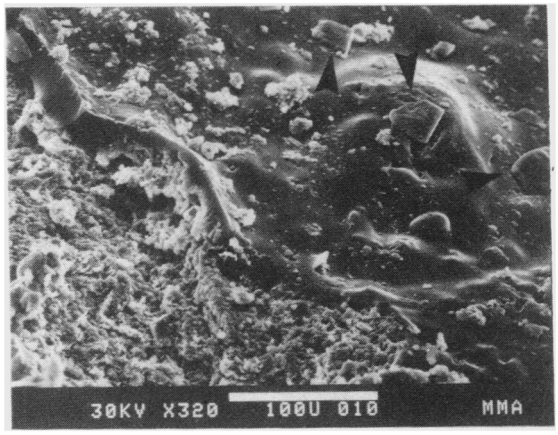


Figure 3 Scanning electron micrograph showing the surface of the reliefs. Notice the skin, a result of previous treatments, consisting of stone partially consolidated by oil and wax which is being lifted up and broken due to salt crystallizing under it. Arrows point to halite crystals that break through this skin and form on top.

Figure 4 One of the D sections of the Abydos reliefs representing a member of the family of Rameses I. Notice the breaking up of the surface due to an attempt to remove the soluble salts by the conventional method of total immersion in water.

because of the size of the project. Spraying, however, did present some problems:

1 the atomization which is the foundation of any spray technique increases the evaporation of the already volatile silane and necessitates the insertion of each section of the reliefs into a tented plastic bag during application;
2 spraying can also dislodge parts of the surface simply by the force of the spray.

After some experimenting, the use of squeeze-bottles was adopted. This technique offered the control of pipetting and a flow-rate similar to spraying.

4.2 Cleaning prior to consolidation

It appeared that three of the five sections that comprise the A reliefs could be cleaned before consolidation. Test areas of each of these sections were cleaned without damage and with marked improvement in colour; the poulticing of the entire surface of each section followed with similar results. It was not until consolidation was attempted that problems

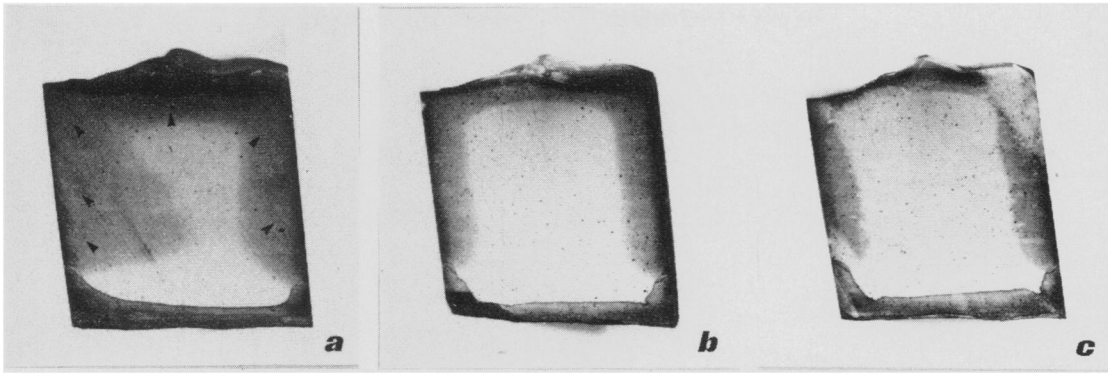


Figure 5 Egyptian limestone test sample treated in the laboratory with paraffin wax and tung oil and consolidated with silane. (a) Cross-section of the sample showing how the wax is partially mobilized into the stone by the silane. The wax had originally penetrated only about the thickness marked by the arrows. The oil layer is not appreciably mobilized by the silane. (b) Appearance of the cross-section after one poultice (attapulgite/PERC) application. (c) Appearance after a second poultice application.

began to arise with these sections. (At this stage the consolidant was still being applied by spraying.) The removal of the wax by poulticing and the dissolution of any residual wax by the silane loosened thin pieces of the reliefs which were dislodged by the spraying. Fortunately, most of these pieces could be reattached, but many hours were required to glue these small pieces back into place. The disadvantages of removing the wax before consolidation are not balanced by the advantage of the enhanced initial rate of penetration of the silane. As has been indicated, wax is easily removed after consolidation, leaving the silane in place.

4.3 Consolidation prior to cleaning

The sections to be consolidated before poulticing were surface cleaned with cotton swabs and PERC. This procedure removed much of the excess wax while posing little danger of dislocation to the delicate surfaces. The exposed limestone has a higher surface attraction for the silane than it does when wax-coated; precleaning therefore reduced the initial extra evaporation of the consolidant. The consolidant was applied by means of squeeze-bottles and the use of the cumbersome tented plastic bags was abandoned.

During the consolidation of these sections, the silane dissolved any wax that still remained on the surface. The wax was carried further into the stone, as described previously, and deposited within the capillary system. Some of the wax was also redeposited on the surface as the silane evaporated.

The consolidation of these sections was executed over a period of several days until the reliefs appeared not to draw in additional silane (a film of liquid silane would remain on the surface for several minutes and only disappear by evaporation). They were then set aside to cure for at least eight weeks [6]. Most of the sections were cured uncovered despite the widespread practice of wrapping in polyethylene after treatment. This procedure does not appear to affect the consolidation achieved.

Following the curing period, each of these sections was poulticed with attapulgite and PERC. Both thick (about 25mm) and thin (about 5mm) poultices were used. The thick poultices removed the bulk of the wax, although a seemingly endless reservoir remained in the stone. The thin, fast-drying poultices were then applied to remove the surface wax without drawing out more of the wax from within the stone to the surface.

Larger pieces from each section which had loosened due to migration of the wax dissolved by the silane were reattached with either pure Raccanello acrylic-silane, or Acryloid B72 dissolved in silane (25% w/v). The B72 provided better adhesion in some cases. In general, it is difficult to glue together pieces of stone that have been consolidated with silane alone. The adhesion was made possible by including 5–10% w/v acrylic silane or 5–10% w/v B72 in the consolidant [6].

4.4 Microconsolidation

Microconsolidation by injection [7, 8], described elsewhere [3], was used throughout the treatment of the A reliefs. In some cases, it was used before the actual consolidation took place in order to adhere small flakes that were too delicate to survive the application of the consolidant. Pure acrylic-silane was injected along the edges of the flakes with hypodermic needles. The syringes used were 1cm³ with 0·46mm (O.D.) needles.

After curing of the consolidant, any other remain-

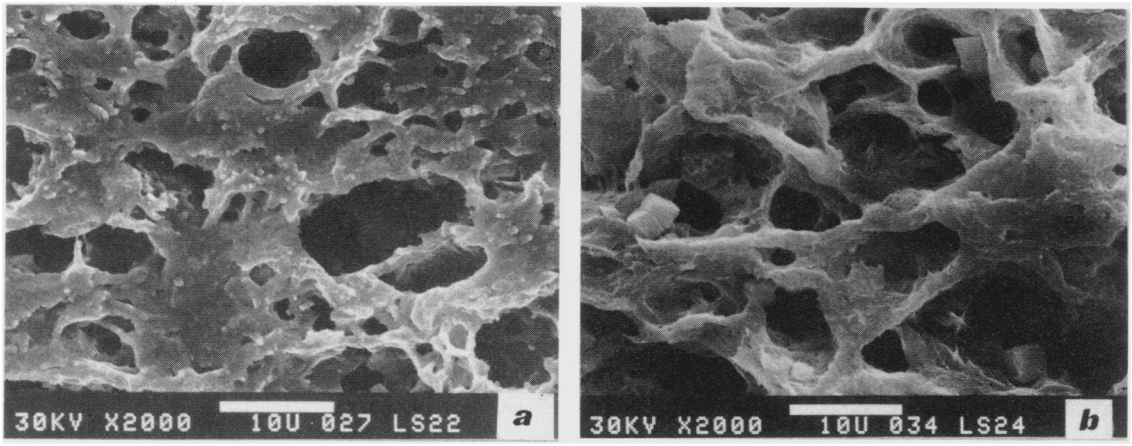


Figure 6 Scanning electron micrograph of the Egyptian limestone test sample. The specimen used for SEM was polished and lightly etched with 1M HCl to dissolve some of the limestone, thus emphasizing the matrix of the consolidant. (a) The wax forms a homogeneous matrix with the silane. (b) After poulticing, most of the wax had been removed without disruption of the silane matrix.

ing loose flakes, now consolidated, could be picked up with tweezers and moved to allow examination of the underlying surface. Microconsolidation could then be applied where necessary in the otherwise hidden cracks and crevices, and then the flakes could be reattached as described above. In this case, a solution of 95% v/v acrylic-silane in silane was injected followed by pure acrylic-silane. In some instances, as was mentioned earlier, B72 in silane was used, first in a 10% w/v solution and then in 25% w/v. The hypodermic syringes used were larger: 3cm³ and 5cm³, with 0·64mm and 0·81mm (O.D.) needles, respectively.

Every day, for one or two weeks, each section was re-examined and checked for the adhesion of the pieces that had been microconsolidated, with subsequent re-treatment where necessary.

In some sections, very large subsurface cracks and holes were found. To fill these, a liquid suspension of plaster was injected by means of a 50cm³ syringe and a 1·25mm (O.D.) needle. Plaster was also used to fill larger cracks. Smaller cracks were filled with a mixture of marble powder with inorganic pigment and acrylic-silane. B72, because of its higher shrinkage, did not work as well as the acrylic-silane for this purpose.

4.5 Safety precautions

Organic vapour face-masks were used during the application of the silane and where possible the consolidation was carried out in an extraction hood. (Full face-masks are recommended as the silane is an eye irritant.) Methyl trimethoxy silane is also quite flammable, so adequate ventilation is needed.

5 Discussion and conclusions

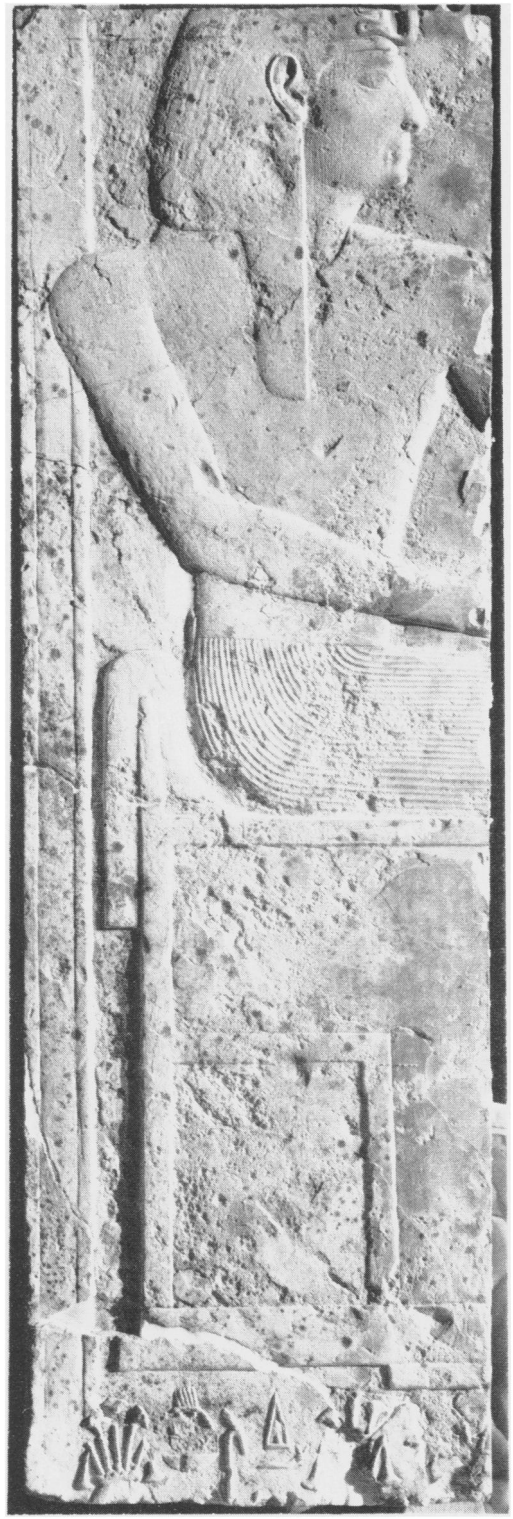
From the V/A ratio (volume of consolidant/area of section) in Table 1 it can be seen that some sections took significantly more silane than others. Section 3 was consolidated first. The silane was sprayed on, and the use of a tented plastic bag with glove inserts for the operator's hands was developed only towards the end of the treatment of this section. The volume of consolidant (7·5l) was not necessarily all received by the stone because much was lost through evaporation.

Table 1 Treatment of the Abydos A reliefs

Section	*Area (m²)*	*Volume of consolidant (l)*	*Ratio vol/area (l/m²)*
1	*0·33*	7·9	24
2	1·4	12	8·8
3	0·41	7·5	18
4	0·60	7·9	13
5	0·62	7·6	12

Section 4 was treated next. The silane was sprayed on but the whole procedure took place in a tented plastic bag. Then section 5 was treated, and at this point the use of squeeze-bottles was developed, so that this section was partially sprayed and the consolidation was finished using the squeeze-bottles.

These three sections had been poulticed before applying the consolidant. It can be seen from the decreasing V/A ratio how the application method was improved.



Sections 1 and 2 were consolidated before cleaning. Section 1 (see Figure 1) was in the worst condition. Because of its delicate surface, the precleaning with swabs and PERC was minimal, and much surface wax was still present when the consolidant was applied. Because of this, the silane was exposed to the atmosphere for a much longer period of time before it was drawn into the stone, allowing for more evaporation to take place. This section also had a large subsurface crack along its short axis that drew in large amounts of the silane. This explains the unusually high V/A ratio. The appearance of section 1—after cleaning and before major cosmetic repairs were undertaken—is shown in Figure 7. Section 2 was in the best condition and therefore did not need quite as much consolidant as the others. Both sections were cleaned by poulticing after consolidation, and then re-treated with acrylic-silane or B72 to consolidate the parts that had loosened due to dissolution and mobilization of the wax by the silane. Microconsolidation was carried out before, during and after consolidation. The silane was allowed to cure at 50% RH and 20°C for a period of at least eight weeks. After that time, the sections were re-examined and re-treated as necessary.

One of the most important facts that was established during the study and treatment of the reliefs is that silane dissolves and mobilizes the wax readily, forming with it a homogeneous matrix in the stone. The wax can then be removed without apparent disruption of the cured silane. The removal of wax was carried out exclusively for cosmetic reasons as wax *per se* does not have any deleterious effect on the stone.

The relative humidity conditions in which these reliefs will be exhibited is under study. The stone of these reliefs still contains soluble salts. Previous experiences have shown that the removal of salts from these stones by traditional techniques—total immersion or water/clay poultices—could not be applied before consolidation. After consolidation, total immersion was not advisable because they are backed with iron-reinforced plaster. Ideally, this iron and plaster should be removed but the risk seemed too great given the overall condition of the reliefs. Water/clay poultices, although not such a drastic technique, would still put too much stress on the surface. Furthermore, the reliefs are treated with a compound that polymerizes by a hydrolysis reaction with subsequent condensation [9]. Any prolonged contact with water, or a high relative humidity, may influence the long-term curing of the polymer. The conditions that will make such a

Figure 7 (left) Same section of the A reliefs as in Figure 1, after consolidation and cleaning and before major cosmetic repairs were undertaken.

system—soluble salts and polymer—stable over time must be chosen carefully. Experiments are currently under way to establish those conditions.

Acknowledgements

The authors wish to thank C. A. Price for insight into the chemistry of silanes, and J. Larson for his helpful comments on the application procedures. Also to be acknowledged are R. Sheryll for the photographic reproduction of the SEM micrographs and help in SEM sample preparation, and the Photo Studio Department for the photographs of the reliefs.

Suppliers of materials

Dow Corning Z-6070 or T-4-0149: Dow Chemical, Midland, MI 48640, USA. The numbers refer to the same chemical compound but with different marketing purposes.

Raccanello Acrilsiliconico no. 55.050 (formerly E 0057): Ard. Flli. Raccanello SpA, Industria Vernici e Smalti, 35100 Padova, Italy.

Acryloid B72: Rohm & Haas, Philadelphia, PA 19105, USA.

References

1 WINLOCK, H. E., 'Bas reliefs from the Temple of Rameses I at Abydos' in *Papers Vol. I Part I,* Metropolitan Museum of Art, New York (1921).

2 WINLOCK, H. E., 'The Temple of Rameses I at Abydos' in *Papers No. 5,* Metropolitan Museum of Art, New York (1937).

3 CHAROLA, A. E., WHEELER, G. E., and KOESTLER, R. J., 'Treatment of the Abydos reliefs: preliminary investigations' in *Proceedings of the 4th International Congress on Deterioration and Preservation of Stone Objects,* University of Louisville, Louisville KY (1983) 77–88.

4 AUSSENBERG, L., 'Preliminary report on the Abydos reliefs', unpublished report on file at the Egyptian Department, Metropolitan Museum of Art, New York (1974).

5 HELMS, G. M., 'Conservation of Egyptian limestone: the Abydos reliefs' in *3rd Annual Conference of Art Conservation Training Programme,* Queen's University, Kingston, Ontario (1977) 40–51.

6 LARSON, J., 'The conservation of stone sculpture in historic buildings' in *Conservation Within Historic Buildings,* IIC, London (1980) 132–138.

7 GURRIERI, F., 'La microcementazione per il restauro dei monumenti. Un contributo', *Bolletine degli Ingegneri* **10** (1979) 3–6.

8 DADDI, B., 'Considerazione per una impostazione teorica del problema', *Bolletine degli Ingegneri* **10** (1979) 6–9.

9 MONCRIEFF, A., 'The treatment of deteriorating stone with silicone resins: interim report', *Studies in Conservation* **21** (1976) 179–191.

GEORGE E. WHEELER is Assistant Conservator in the Department of Objects Conservation at the Metropolitan Museum of Art. *Author's address: Department of Objects Conservation, Metropolitan Museum of Art, New York, NY 10028, USA.*

JENNIFER K. DINSMORE is a graduate of the Wintherthur/University of Delaware Program in the Conservation of Artistic and Historic Works. She is presently working in the Conservation Department of the Victoria and Albert Museum. *Author's address: Conservation Department, Victoria and Albert Museum, South Kensington, London SW7 2RL, England.*

LESLIE J. RANSICK received her BA in Art History/Studio from New York University in 1982. She has been part-time Technical Assistant in the Department of Objects Conservation at the Metropolitan Museum of Art for the last three years. *Author's address: as for Wheeler.*

A. ELENA CHAROLA received her PhD in Chemistry at the University of La Plata, in her native country Argentina, in 1974. She is presently Associate Chemist in the Department of Objects Conservation of the Metropolitan Museum of Art. *Author's address: as for Wheeler.*

ROBERT J. KOESTLER is completing his PhD in Microbiology at the City University of New York. He is in charge of the Scanning Electron Microscopy facilities in the Department of Objects Conservation of the Metropolitan Museum of Art. *Author's address: as for Wheeler.*

Résumé—La connaissance précise de bas-reliefs d'Abydos du petit temple de Ramesès I est relativement difficile du fait de leur sortie de terre en 1910. En effet, par leur haute teneur en sels solubles, ces bas-reliefs ont subi des écaillages et des efflorescences pendant les décennies qui ont suivi. Les traitements à la cire et à l'huile n'ont pas pu empêcher cette détérioration de se poursuivre et ont eu pour effet de foncer la couleur claire du calcaire. Le présent mémoire discute la problème du nettoyage et de la consolidation de bas-reliefs fragiles et dans des états analogues, et propose de consolider d'abord avec du silane avant d'enlever la cire des traitements précédents.

Auszug—Die Abydos-Reliefs aus dem kleinen Tempel von Ramses I haben seit ihrer Ausgrabung im Jahre 1910 eine schwierige Zeit gehabt. Infolge einer hohen Konzentration aus löslichem Salz haben die Reliefs über die folgenden Jahrzehnte schwere Abschilferungen und Pulverisierungen aufgewiesen. Wachs- und ölbehandlungen konnte einen weiteren Verfall nicht verhindern und ließen den hellfarbenen kalkstein erheblich andunkeln. Die vorliegende Studie erörtert das Problem der Reinigung und Konsolidierung von in einem derart anfälligen Zustand befindlichen Reliefs und den beschrittenen Lösungsweg, d.h. zunächst die Konsolidierung mit Silan vor Entfernung des von vorherigen behandlungen stammenden Wachses.