Treatment of the Abydos Reliefs: Preliminary Investigations

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Abstract

A study was conducted to determine the best type of impregnant to be used for the consolidation of a set of Egyptian limestone bas-reliefs, the Abydos reliefs. These reliefs had been previously treated by various methods, mainly by paraffin impregnation or the application of oil-based coats to stop the efflorescence of salts. The damage produced by these salts, primarily NaCl, is compounded by the fact that the extremely fine-grained, clay-containing limestone is cross-bedded with internal laminations of approximately 20°.

Test specimens of a similar Egyptian limestone were impregnated with silanes or pre-polymerized methyl methacrylate. Some of these specimens were first treated with paraffin to simulate the former consolidation attempts on the Abydos reliefs. The specimens were then studied in thin sections by light microscopy and in sawed and fractured sections by scanning electron microscopy.

The different degrees of penetration and consolidation are discussed.

Introduction

The Abydos bas-reliefs were part of the decoration for the mortuary temple of Ramesses I. The construction of this temple is supposed to have been started by Ramesses I about 1314 BC and finished by his son Sēthy I about 1310-1300 BC. A detailed description of the history, religious significance, plans of the temple and its inscriptions is to be found in the work by Winlock[1,2].

The temple was accidentally found in 1910 AD during the digging of a water-well in the village of ʿArabēh el Mādfuneh. Only some of the relief-containing blocks of the temple were recovered. These were then cut and sawed for easier transportation, but due to the fact that the resulting cross-sections of the reliefs were too thin to withstand mechanical stress, most of the reliefs were broken during the moving.

The majority of the Abydos bas-reliefs in the collection of The Metropolitan Museum were obtained through a gift made by J. Pierpont Morgan in 1911. The remainder of the reliefs were contributed by Dikran Kelekian in 1912. Figure 1 shows a view of some of the panels in the collection.

The reliefs have suffered from severe damage due to salt crystallization. The fact that the limestone is cross-bedded at angles between 15° to 30° has only worsened the problem. Already in 1911 the problem was evident, and by 1919, when Winlock prepared his first paper, he wrote: "*Mixed with the salt almost always present in Egyptian limestone, these nitrates* (due to seepage from the above built hamlet) *make a combination which causes unending worry to all who are responsible for the preservation of monuments so impregnated*"[1].

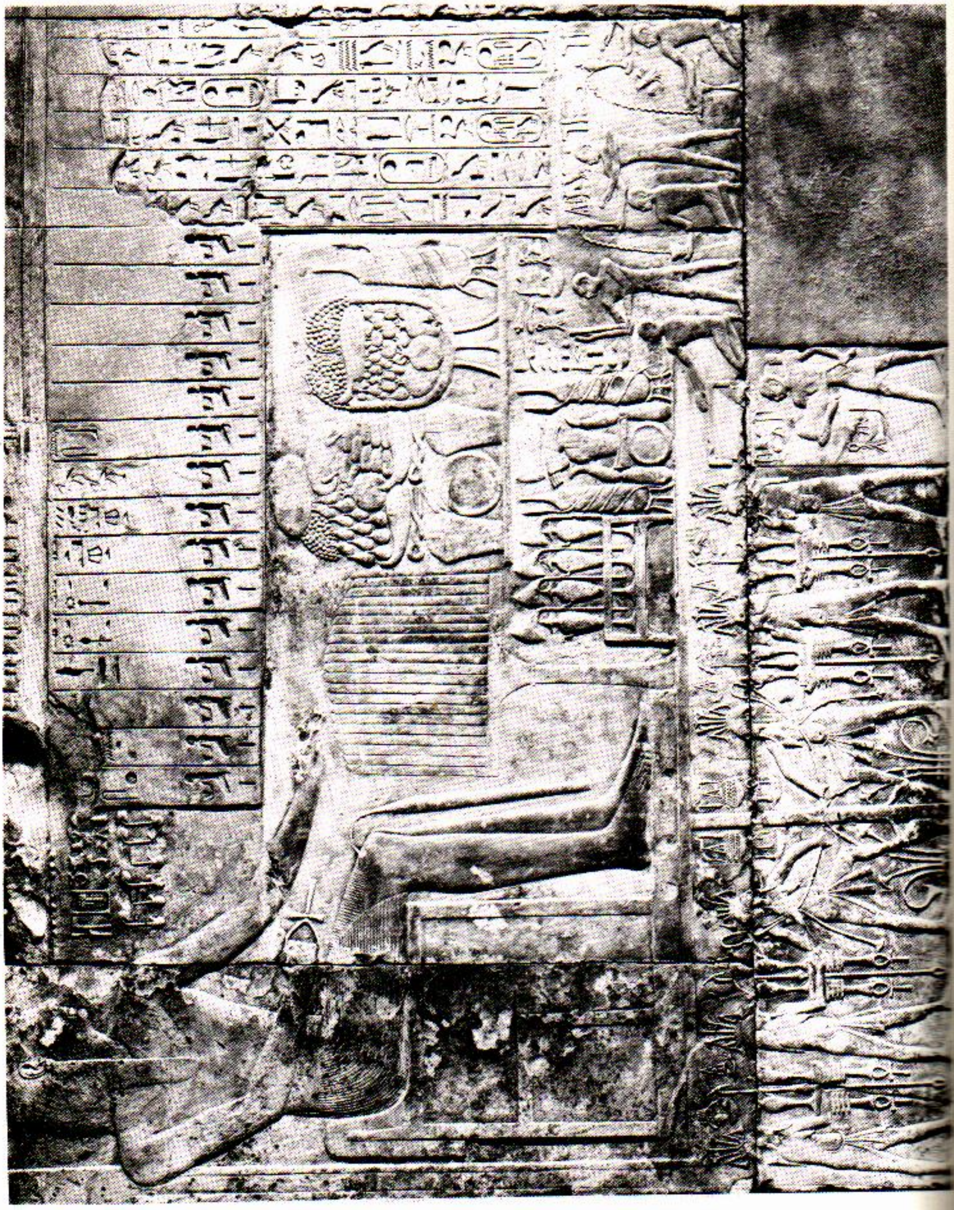

Figure 1.

View of one of the Abydos reliefs. The scene represents the offerings to the dead King Ramesses I. The photograph dates from 1920. Note the spalling, discoloration and the presence of disfiguring black spots.

It was impossible to remove the salts present in the stone by immersion in water or by any type of washing, as the stone disintegrates into powder on any prolonged contact with water.

From 1911 to the present, several treatments were applied to these reliefs in the hope of consolidating the stone, immobilizing the salts, and so preventing new damage from occurring. Two of the first and most widely applied treatments during the period 1911-1913 were: (1) Paraffin - immersion of stones in molten paraffin; and (2) Tung-oil - heated under vacuum, treated with lead or manganese oxide and dissolved in white oil or carbon tetrachloride, applied to the surface of the reliefs.

The result of these treatments was the formation of a hardened leather-like crust that lifted up and flaked-off the reliefs when salts recrystallized. Figure 2 shows a cross-section of this outer crust. In addition, these treatments darkened the stones thus obscuring the little polychrome that had survived the centuries of interment.

In 1930-40, about one inch of the back of these stones was sawed off and the reliefs were set in an iron-reinforced plaster backing framed with angle iron for support.

Other treatments[3,4] that were later applied to some of the panels were: (3) Beeswax (1943); (4) PVAc (Vinilyte) to reattach some of the flaking pieces to the reliefs (1957-9); (5) Barium ethyl sulphate (1975) and (6) Epoxy (Maraset 655) impregnation (1975). None of these treatments contributed to the stabilization of the panels so treated.

The present condition of the Abydos reliefs is: severe flaking, exfoliation and powdering of the surface, efflorescence of salts, non-uniform darkening and discoloration of the surface. In view of this it was considered necessary to attempt the consolidation first, followed by a cleaning procedure. A consideration in the choice of consolidant is its applicability to the panels in situ thus avoiding any further damage to the stones during transportation and prolonged handling. Several impregnants were tried out: pre-polymerized methyl methacrylate in methylene chloride, methyl trimethoxysilane and acrylic-silane in methyl trimethoxysilane.

The tests were carried out on small, detached pieces from the Abydos reliefs without any workmanship on them. An Egyptian limestone of similar characteristics was used to provide the bulk of the test samples. Some of these were treated first with paraffin and/or tung oil to simulate former treatments of the reliefs.

Experimental

(A) Description of the stones

The limestone of the Abydos reliefs is an extremely fine-grained stone, as can be seen by the thin-section micrograph in Figure 3. The Egyptian limestone, from a First Intermediate Period tomb excavated by Petrie at Dendera, had a similar texture.

Both stones were analyzed by x-ray powder diffraction (XRD). The extracted soluble salts and the insoluble residue remaining after treatment of the stone with diluted HCl (≃6 M) were also analyzed by XRD. Energy dispersive x-ray spectrometry (EDS) and analytical microtests were used to complement the identification of minor elements present.

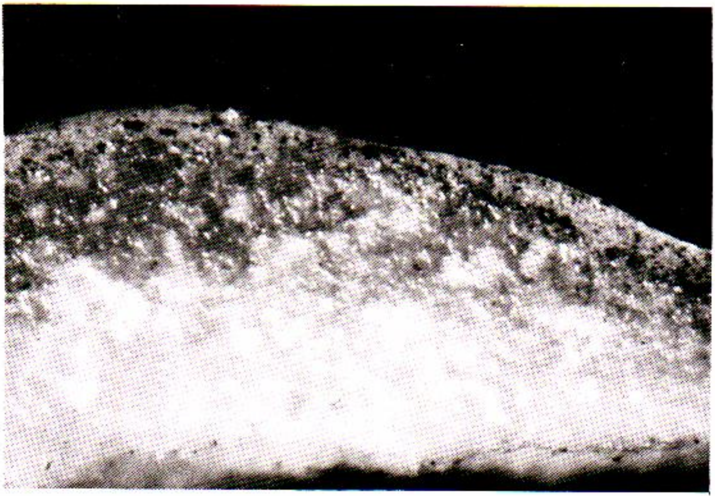

Figure 2. Cross-section of the Abydos stone showing the hardened outer crust formation and the penetration depth of the previous oil-paraffin treatments (40 x).

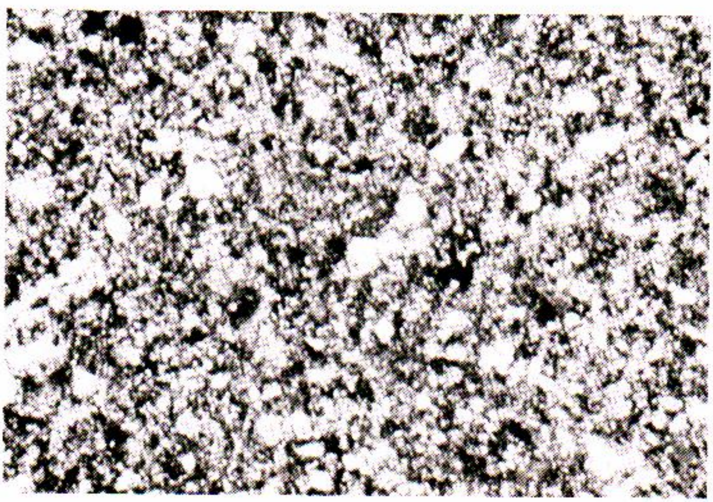

Figure 3. Thin-section of the Abydos stone under crossed nicols. Note the extremely fine-grained texture of the limestone (100 x).

Table I summarizes the results obtained from the analyses of both stones.

TABLE I

	Abydos limestone		Egyptian limestone	
	%	composition	%	composition
water	2		1-1.5	
soluble salts	4	halite, soda-niter Ca^{++}, Mg^{++}, K^{+}	<1	gypsum Mg^{++}, NO_3^-, Cl^-
calcareous part	81	calcite, minor dolomite	87	calcite, minor dolomite
acid-insoluble residue	13	clays: possible illite and sepiolite; quartz	11	quartz; clays: possibly illite

The Abydos limestone also had another mineral constituent that was tentatively identified as stilpnomelane.

The surface of the reliefs is in parts thickly dotted with dendritic, pyrolusite-like black spots (see Figure 1). These spots did not produce any XRD pattern. EDS analysis of the few spots that could be removed from the surface of the reliefs without disfiguration was inconclusive as the matrix of the stone contains trace amounts of Mn.

Veins of similar-looking black material run through the Egyptian limestone. On a cross-section of these veins, the resulting black spots are not as noticeable as the ones on the reliefs. The enlargement of these spots on the reliefs could result from microorganisms that cause reprecipitation of manganese oxides[5].

From the composition given in Table I both stones can be classified as marly limestones[6] and it can be considered that the Egyptian limestone used also belongs to the Thebes formation[7].

The main difference between these limestones is the amount and composition of the soluble salts present. Because the Abydos limestone has a higher content of magnesium salts, the amount of water retained by this stone is larger. Magnesium salts are notoriously deliquescent and form several hydrates. The presence of soluble salts in stone is known to be one of the major causes of stone deterioration. The presence of deliquescent salts will make the stone particularly susceptible to changes in relative humidity.

The damage produced by the salts present in the Abydos reliefs can be seen in Figures 4 and 5, which are scanning electron microscope (SEM) micrographs of a surface flake from the reliefs. The ubiquity and diverse shapes of the salt crystals can be seen at the larger magnification. At the lower magnification a remnant of the crust-like coating can be seen, and on it, a multitude of pin-sized salt crystals growing through it.

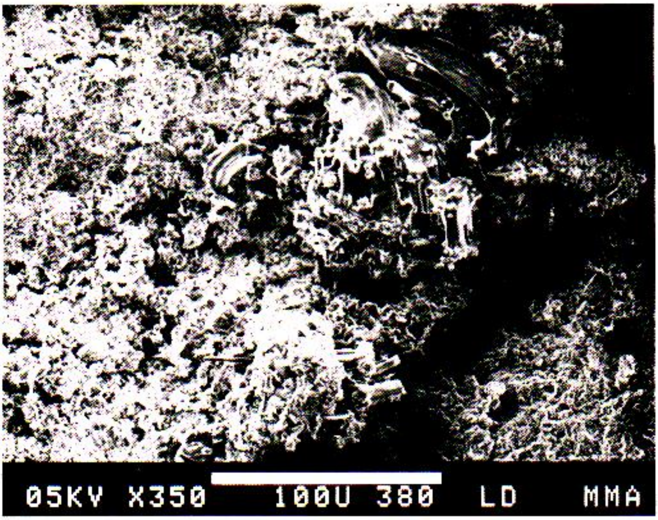

Figure 4. Surface of a flake from the Abydos reliefs. Note the breaking up of the stone matrix by the growth of the salt crystals.

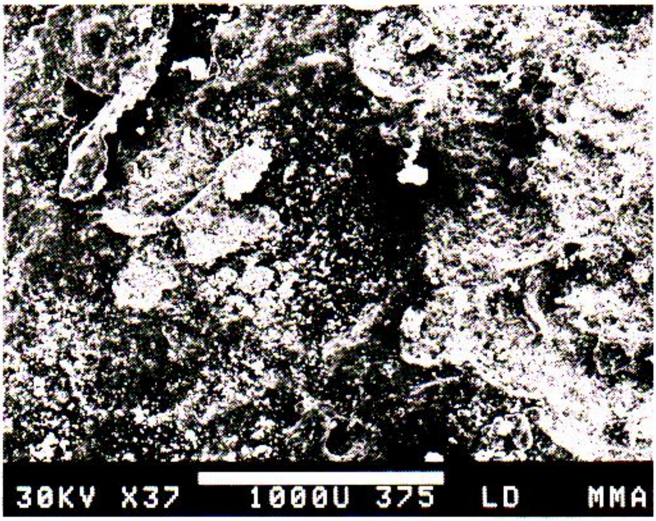

Figure 5. Flake from the Abydos reliefs. The darker area is the hardened surface resulting from the paraffin-tung oil treatments. White pin-points on that surface are NaCl crystals breaking through it.

(B) Description of the treatments

Blocks of approximately 5x5x5 cm were cut from the Egyptian limestone for testing purposes. From the Abydos reliefs only 6 specimens of assorted shapes could be obtained.

Some of the blocks of Egyptian limestone were treated first with a tung oil preparation, which tried to reproduce as faithfully as possible the poorly defined formula that had been used on the Abydos reliefs. Only half of each block was treated with it, the tung oil mixture being allowed to rise through capillarity into the stone. The stones were then artificially aged by heating to 40°-45°C and by long wavelength UV light irradiation. In turn, half of the blocks treated with tung oil were further treated with molten paraffin by complete immersion. Another set of blocks was treated only with paraffin.

The first consolidant to be tried was pre-polymerized methyl methacrylate (PMMA) (Eastman Organics #P4942) in a 15% w/v solution in methylene chloride. This system was chosen because it appeared to give suitable impregnation for limestones[8]. The solution was applied dropwise to the surface of the blocks. No noticeable penetration was observed. As a glossy coat formed on the surface of the block the application was stopped.

The second consolidant tested was methyl trimethoxysilane (Dow Corning Z-6070 or T-4-0149). The pure silane was applied dropwise to the top of the block until the surface of the stone remained wet for some minutes. The treatment was repeated 3-4 times every 2-3 hours. The specimens that had been treated with paraffin and/or tung oil took longer to absorb an equal amount of silane than the untreated specimens. The silane partially solubilized the oil and/or paraffin and carried them further into the stone.

The third consolidant used was a 10% v/v solution of the acrylic-silane (Raccanello Acrilsiliconico #55.050 [ex E 0057]) in the above mentioned Dow-Corning silane. The application method was the same as for the pure silane.

The acrylic-silane consolidant was also applied by means of the microconsolidation by injection technique[9,10] on a piece of Abydos and on an untreated Egyptian limestone block. Fine needle-like holes were drilled into the specimens at right angles to the lamination planes of the stones. The consolidant was injected by means of a hypodermic syringe until it overflowed at the injection point. The injection was repeated 3-4 times every 2-3 hours. Figure 6 is a SEM micrograph showing the cross-section through the injection point of the Abydos sample. The resin fills the part of the cracks that are in the injection direction. Figure 7 is a high magnification view of the resin left behind near the injection point.

Samples of all prepared specimens were obtained for SEM examination. They were studied in fractured surface and also in cut, polished and etched with dilute HCl (≃1 M) surface as suggested by Lewin[11].

Discussion and Conclusions

The choice of the impregnation method, i.e., by surface spraying, was based on the fact that the Abydos bas-reliefs are in such fragile condition. Impregnation by capillary rise from the back of the blocks is precluded by the plaster and iron mounts in which they are set.

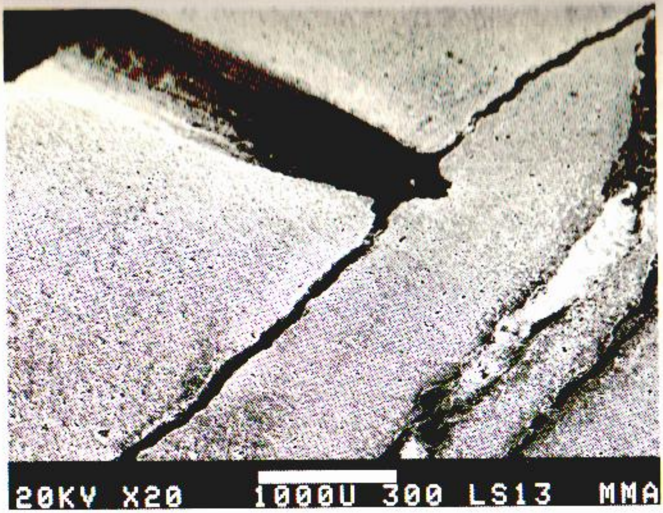

Figure 6. Cross-section of the Abydos stone through the injection point. Note the filling of the crack below the drilled hole. The white spots around the injection point and near the filled crack are due to the high concentration of consolidant.

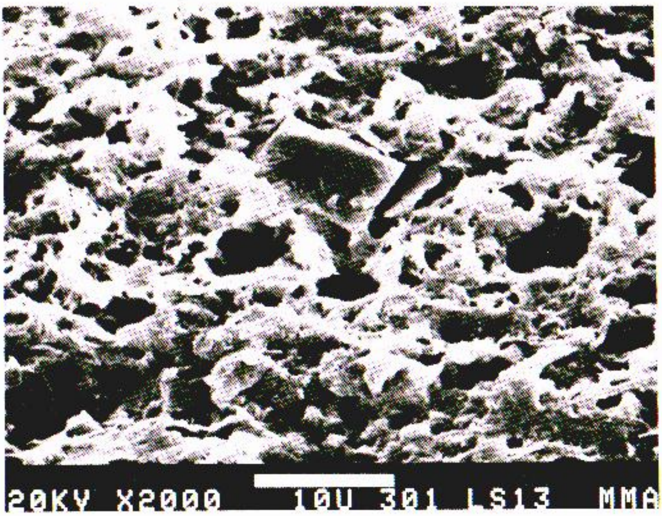

Figure 7. Area near the injection point showing the white spots of the resin at high magnification. The specimen was sawed, polished and etched with 1 M HCl. Note that the calcite crystal was not significantly etched.

The PMMA-CH_2Cl_2 solution did not have good penetration characteristics and furthermore formed a glossy film on the surface of the block. This could be attributed to the presence of the residue from former treatments in the matrix of the stone. The amount of penetration and actual impregnation resulting after the solvent evaporates is dependent not only on the polymer-solvent relationship but also on the competition between the solvent and the stone surface for the polymer[8].

The methyl trimethoxysilane and the acrylic-silane solution gave similar looking impregantions as observed by SEM. This is not surprising considering that 90% of the acrylic-silane solution is pure silane. The acrylic-silane was tested primarily because of its adhesive properties that would facilitate reattachment of loose flakes of the reliefs.

One of the major concerns in this study was to examine the interaction between the impregnant and the tung oil/paraffin residue in the stone. As was indicated earlier, the silane partially solubilized the tung oil and the paraffin. This could also be observed at high magnification in the SEM. Figures 8 and 9 show a comparison between a sample of Egyptian limestone treated only with silane and one that had also been treated with tung oil and paraffin. As can be seen, the silane homogeneously dissolves the organic residue forming a smooth matrix.

In Figures 10 and 11 a comparison is made between a sample of the Abydos stone with and without the silane treatment. Figure 10 shows the etching pattern obtained due to the hydrophobic nature of the residue in the stone. Compare the etching of the calcite crystal with the ones in Figures 7 and 9.

The similarity of the appearance of the consolidant matrix in the stone can be seen comparing Figures 9 and 11. Thus, the type of consolidation obtained is affected noticeably by the presence of residues from previous treatments in the stone.

The degree of consolidation obtained on the small Abydos limestone pieces impregnated with silane, as determined roughly by the fact that the stone did not disintegrate when immersed for prolonged periods of time in water, and observations made by SEM, are encouraging enough to attempt application of the silane to the actual bas-reliefs. Testing of the changes in porosity during the impregnation, degree of immobilization of the salts and different cleaning procedures to be applied are still in progress.

It is foreseen that a first impregnation by spray application and microconsolidation by injection in larger spalling and cracked areas will be carried out. The reliefs thus strengthened will then be subjected to cleaning. If necessary, a second impregnation will be carried out. Finally, it is considered that even when consolidated, the reliefs should be kept in an extremely well-controlled temperature and relative humidity environment.

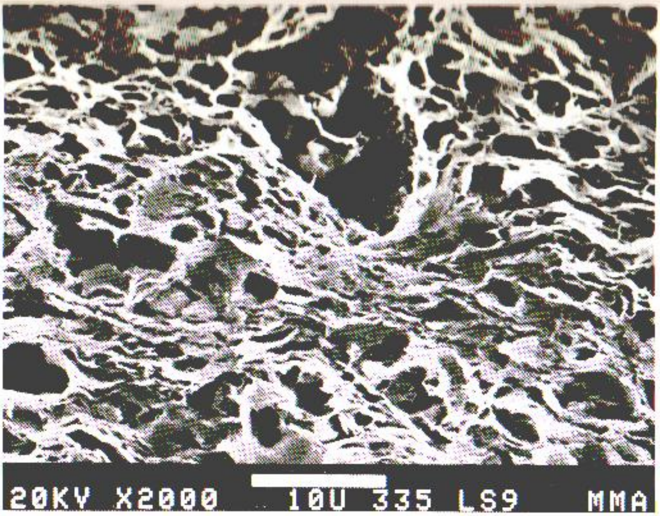

Figure 8. Egyptian limestone impregnated with acrylic-silane. Specimen surface was etched with 1 M HCl. Micrograph shows the impregnant matrix.

Figure 9. Egyptian limestone treated with tung-oil and paraffin and impregnated with acrylic-silane. Specimen surface was etched with 1 M HCl. Not the homogeneous impregnant matrix.

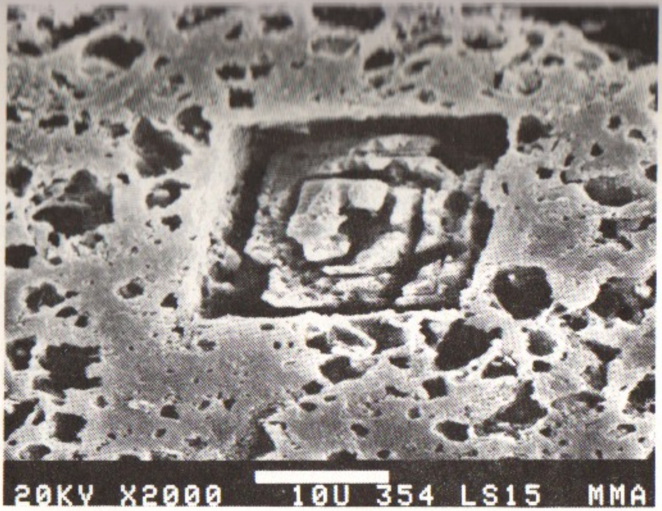

Figure 10. Abydos reliefs limestone specimen. Surface was etched in 1 M HCl. Note the ragged edges of the etch holes.

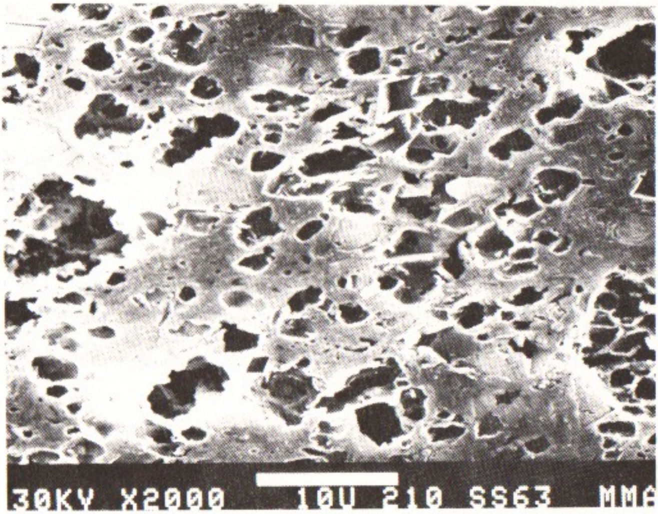

Figure 11. Abydos reliefs limestone treated with silane. Specimen surface was etched with 1 M HCl. Note the homogeneous impregnant matrix and smooth contours around the etch holes.

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Acknowledgements

The authors wish to thank R.Sheryll for the photographic reproduction of the SEM micrographs and help in SEM sample preparation; J.Dinsmore for the treatment of some of the specimens and most of the cutting and polishing required. Also to be acknowledged are the staff of the Egyptian Department, Photo Studio and Slide Library for the help received.

FOURTH INTERNATIONAL CONGRESS ON THE DETERIORATION AND PRESERVATION OF STONE OBJECTS

July 7-9, 1982

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Edited by

K. L. Gauri and J. A. Gwinn

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Louisville, Kentucky