A Conservation Study of Djin Block No. 9 in Petra

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Abstract:

The Djin Blocks are amongst the very few 3D rock carved tombs in Petra. They are carved out of white Ordovician sandstone, that lies between the Precambrian Petra layer and the higher limestone strata found outside Petra. In this study an analysis of the weathering condition of Djin Block No. 9 is performed, using standard laboratory and field tests. Eolain and water weathering seem to be the main operating mechanisms of weathering. Some consolidants are evaluated for use to arrest, or at least hinder, the severe damage to which the monument is subjected. The evaluation involved the use of the salt test as well as application of the chemicals to Ordovician rocks of no historic significance.

1- Description of the Monument

The Djin Block No. 9

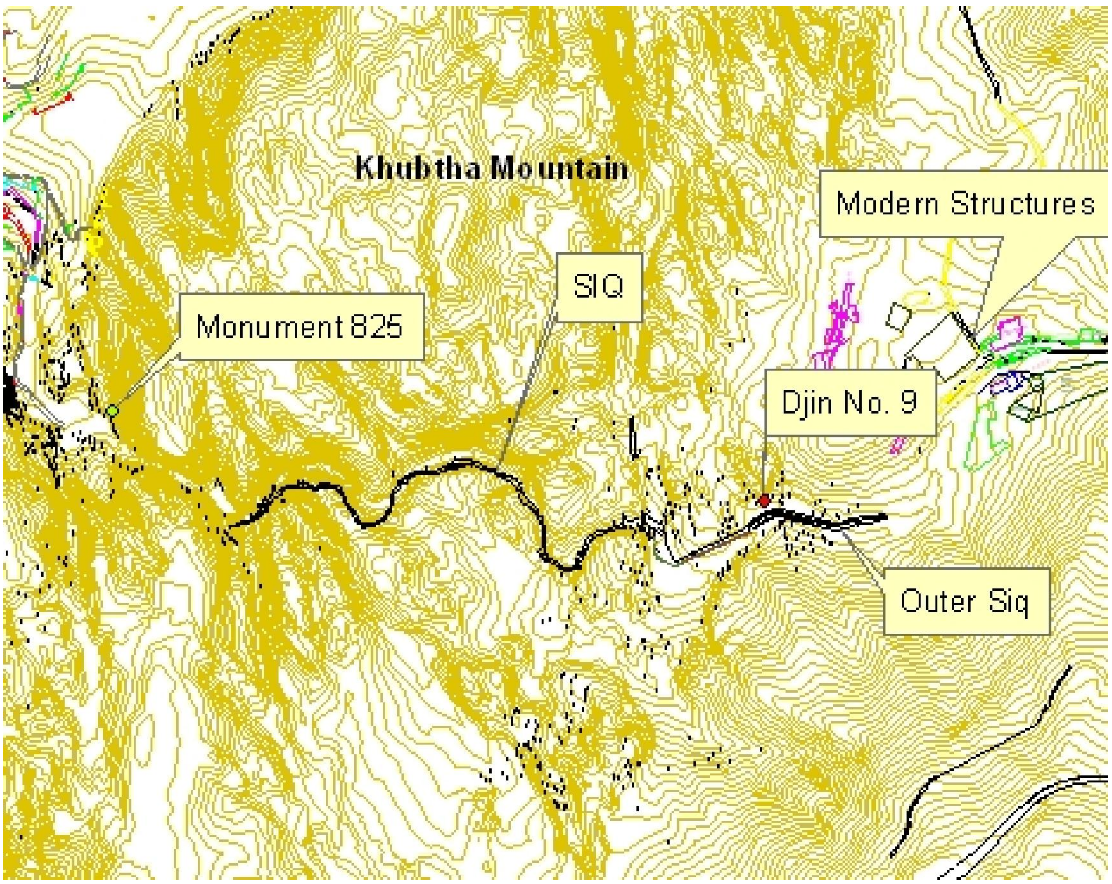
The ancient Arab Nabataean city of Petra lies in the southern parts of Jordan. The city has about 4000 archaeological features of varying importance. Most of them are carved from the sandstone rock massif which roughly flanks the eastern and western sides of the Petra plateau. While stone masonry structures are known to have existed in abundance, very few have been excavated. At the same time, a small number of three dimensional rock carved tombs, called the Djin Blocks lie in the upper Ordovician sandstone (umm Ishrin sandstone) formations along the open streambed (called the Outer Siq. See Map below) that forms the main entrance leading to the famous gorge conduit (the Siq) that leads into the city. Of these we have chosen the biggest one to study, namely because Ordovician monuments have never been subjected to conservation studies, although weathering damage has been recorded by Heinrichs and Fitzner (1) as well as Paradise (2). The German funded Petra Stone Preservation Project (PSPP) has concentrated on the Precambriam monuments in the city center (3). The monument we focused is known as Djin Block number 9 (Monument Number 9, as per Brunowe and von Damazeuski (4)). It is shown as a red point in the map below. The green point is the location of Precambrian Monument 825, which was the main focus of the PSPP. Little black spots show the abundance of monuments in Petra, each point marking the location of a feature of varying importance in the site. The purely Nabataean Djin block number 9 is squarish in plan and about 8.9 meters of height, with a side length of about 4 meters. Its four sides are all similarly carved. The square rooftop has a carved grave in its center. Each of the four identical facades consists of 4 main units. The top unit is a block of rectangular sides. As seen in Figure 1 this top entablature is very plain. Below it there is a rectangular groove in which stone insets were fixed with mortar. The row of stones forms a cornice all around the Block from all sides. Each stone has a sharp triangular front end section with a horizontal side pointing upwards and a diagonal side facing downwards. Below, the groove, another entablature follows, lying on top of a thin torus and a wider fascia. The latter curves inward into a thinner entablature (the second unit). At the north eastern corner of this unit, another stone inset is noticed although it does not cover the perimeter of the block. Inside the inset there lies a hole that seems to form a conduit that could be for a clay pipe, although there seems to be no indication as to what purpose or from which point to which other point is the water being carried. Another possible use is as a support for a rope to hang goods from. The possibility that the hole is just a result of weathering must not be ignored. The third unit of the façade is highest in elevation and has two engaged columns (of semicircular cross section) that lie in the middle. On either side of the façade a pilaster is carved forming the right angled corner of the block. The pilaster is attached to a quarter engaged column on both of its sides, thus enhancing the overall side to side symmetry, that is reflected in the architectural concept. The last unit, the base unit, has steps that add to the majesty of the monument. An interesting observation can be made that the monument is surrounded by water features. This seems to be a religious ritual that surrounds the tombs of notables in Petra.

The roof of the monument consists of a flat surface with a grave in its center (figure 2). To the North side an Ordovician sandstone hill formation is carved in such a way that people can climb an inclined path to reach behind the top of the monument. At this point the surface is flattened so that a small wooden or stone bridge (that no longer exists) provides access to the roof and the grave. This is sensible as the need to burry a person on the top requires this arrangement, although it is surprising that an inclined plane rather than a staircase was used for the purpose of the climb. No evidence is noted that the incline was a staircase whose steps have been completely weathered. Perhaps the difficult climb was intentional to discourage climbing by unauthorized persons.

At the bottom of the Northern sandstone ridge, a channel that has been carved to carry clay water piping to the city of Petra exists. The water management around the Djin Block is extensive and its damage may have contributed to weathering of the monument. Coming from higher grounds at the outer Siq entrance, the clay pipe meanders alongside the Outer Siq on the Northern side. It reaches around the bottom of Djin Block No. 8 and crosses above a small streambed (a wadi) to reach the floor of Djin Block number 9, and passes into the channel at the bottom of the Northern hill. It seems to continue into or above a small streambed to the West of the Block. The small wadi (valley or streambed in Arabic) East to the Djin Block 9, and above which the clay piping crosses, has a small dam that collects water from its upper regions. An open water channel, also coming from the higher region of the Outer Siq poured its content into the dam.

2- Materials and Methods:

Specific gravity (SG) is defined as the ratio of rock weight to the weight of an equal volume of water (Goodman, 1989). It can be used for calculating porosity, void ratio and other rock properties. In this study, two types of specific gravity were calculated: Apparent specific gravity (ASG) and bulk specific gravity (BSG), to test this property ASTM C (127 – 77) standard was adopted. Several other experiments were conducted to study the properties of ordovician sandstone. The following techniques were used: a- Polarized optical microscopy (Leica), b- Portable XRF (Amptek) which was used to measure elements at the bottom of the eastern façade, c- Specific Gravity (SG) (from apparent SG (ASG) and bulk SG (BSG) ((Derucher and and Heins, 1981) according to standard test method ASTM C(127-77)), d- Porosity (Brown 1981), e- Uniaxial Compressive Strength (Obert 1966, and ASTM D1074) (tests c-e were kindly performed at the Laboratories of the National Resources Authority). In addition, careful



Map of the site of Petra showing The Djin Block No. 9

examination of the monument and photographic recording as well as 3D laser scanning were used to document the state of damage of the monument. Mapping of the damage was finally done using common software such as Autocad or ArcGis using field observations and photographic images. Finally a number of consolidants were used both in the laboratory and in the field to test their properties. Apart from the NRA tests, stone cubes were subjected to the salt test in 5% sodum sulphate solution. The consolidants used were Polaroid B72 (Talas – USA) in acetone (5%), Funcosil 100, Funcosil 300, and Tetraethoxy Silane solutions as provided by Reimmers – Germany.

3-Results and Discussion:

3.1 Weathering Forms and Damage

3.1.1 Previous Work

In Table 1 the results of Fitzner and Heinrichs (2003) are summarized giving the extent of damage that each of the four sides of the Djin Block has suffered. The data is represented by the percent area that has suffered a certain amount of damage categorized between 0 and 5, where 0 stands for no damage while 5 stands for very severe damage. We have drawn a chart showing the extent of damage in figure 4. It is clear that the southern façade is the hardest hit surface, and the sequence follows the order South>East>North>West. The difference between North and West is only slight.

Figure 1: East side of Djin Block 9. Right represents the Southern side

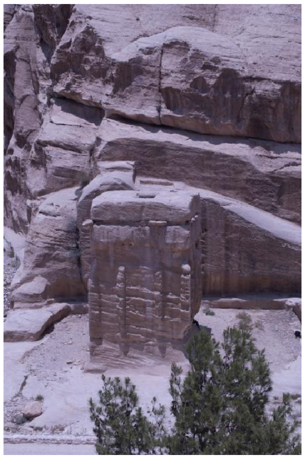


Figure 2(a) Grave at rooftop with sandstone ridge behind. The ridge has a carved channel that used to carry a clay pipe behind the monuments. (b) On the right a closer view of the rooftop shows the surface that was carved into a grave.

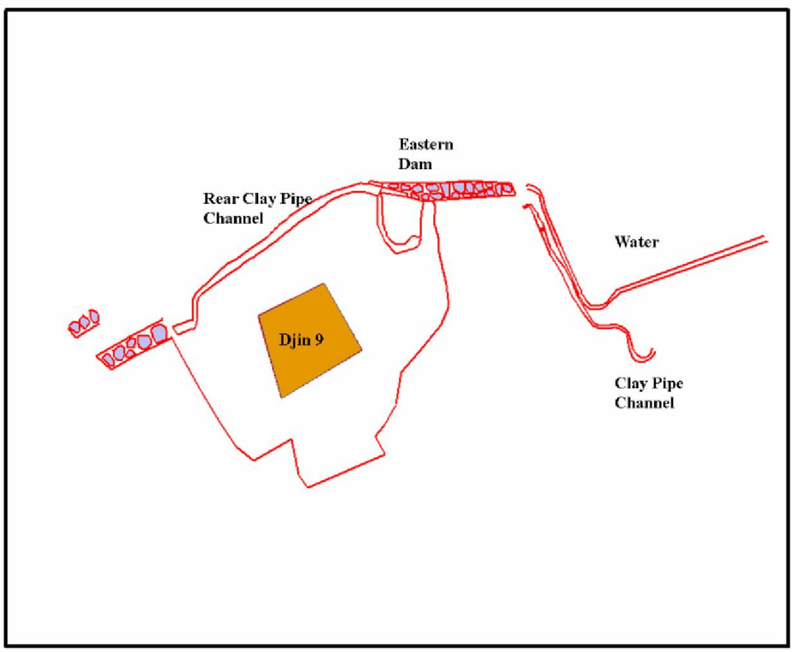
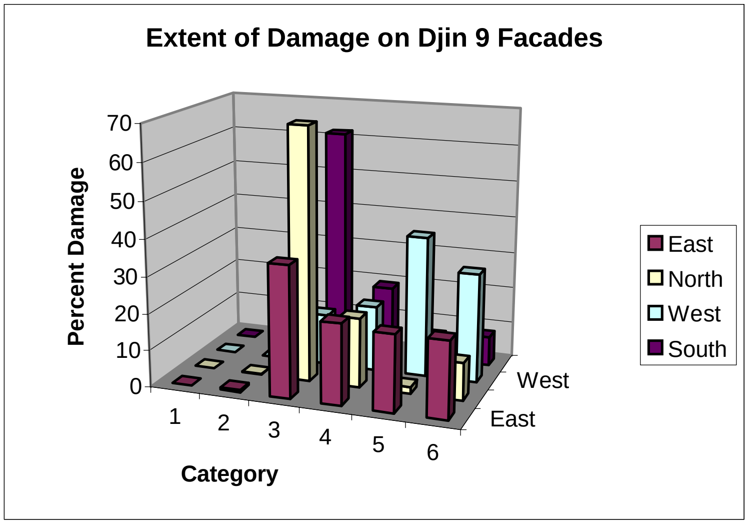


Figure 3: Water Management Layout around the Djin Block

Table 1 and Figure 4: Damage extent due to weathering on the four sides of the Djin Block No. 9
Data kindly provided by Ing Bernd Fitzner and Kurt Heinrichs (2003) from the Aachen Geologische Institut – Aachen Technical University Germany

Category	No damage	Very slight	Slight	Moderate	Severe	Severe		

Facade	0	1	2	3	4	5	First Three	Second Three
East	0	0.6	35.8	22	20.8	20.8	36.4	63.6
North	0	0.1	68.8	18.9	1.9	10.3	68.9	31.1
South	0	0	14	17.8	38.4	29.8	14	86
West	0	4.8	61.8	19.1	6.5	8.1	66.6	33.7



According to studies already developed on the Djin Block, the following description was kindly supplied in a private communication by Dr. Ing. Bernd Fitzner from The Geologic Institute at Aachen University .

Properties of Petra Ordovician sandstone

"*White, medium-grained sandstone, moderate sorting, grain-supported fabric, very high grain-matrix-ratio, clayish and carbonatic matrix, mainly long or point contacts of grains, low number of grain contacts, very high total porosity, very large pores with large pore entries, very small pore surface, high water uptake at atmospheric pressure, very high water uptake at pressure, capillary soaking: high water uptake coefficient and high water penetration coefficient, very low water vapour diffusion resistance, quick water desorption, low ultrasonic velocity, low hardness." (after Heinrichs and Fitzner)*

From the chart it is clear that the damage extent follows the sequence: South>East>North>West. The difference between North and West being slight. To understand this it must be mentioned that the real orientation of the facades is actually about twenty degrees off. In other words the east facade is twenty degrees off East. The Western side of the monument receives the highest solar radiation. A study conducted by Tom Paradise (2005) shows that for Djin block number 5, sun exposure is an important factor in determining damage extent. The higher the exposure the more damage that occurs. In Djin number 9, the North side is totally hidden from sunlight during the whole day (by the small cliff behind the monument). In fact the surface of the northern facade was seen to be wet during April and June 2005, long after the rainy season was over. The exposure to hard sun results in evaporation of water in the rock pores thus causing salt deposition with more dramatic results than for the unexposed facades. Temperature cycles and temperature variations during the day-night cycles are also more pronounced in exposed surfaces. In a private communication the actual temperature measurements performed by Heinrichs and Fitzner indicate that the Western side has the highest temperatures on the stone surface. Thus according to Paradise this side should exhibit the highest damage extent, thus contradicting the present findings. The true reason for the extent of damage can be sought in the higher wind effects that are hitting the Southern and Eastern sides. Thus, alveolar weathering due to eolian effects, intensified by water seems to be a very important factor. Here, water down flow, and capillary rise, are the **t**main mechanisms of weathering, rather than sun exposure.

3.1.2 Current Work

3.1.2.1 Field Description of Weathering and Damage

The documentation process involved several techniques involving surface profiling with a 3D laser Scanner, photogrammetry, manual engineering surveying, corrected digital photography, as well as visual description of the various weathering forms that plague the monument. The first technique serves to document with accuracy the surface profile as well as the Architectural characteristics that are still observable. This will serve as a benchmark for periodic assessment of the state of weathering. Manual surveys serve to correct photos and reduce camera distortions, again an important factor in accurate documentation of the monument. Elevations and plans are also obtainable from a combination of photogrammetry and 3D scanning. Visual inspection lead to the diagrams shown below for façades South and East, where the forms of weathering are mapped. These are helpful in making appropriate plans for cleaning and consolidating the friable surfaces of the facades.

Careful inspection of the monuments leads to the following observations:

1- The Roof: In general the roof is in good shape. However some scaling and exfoliation is observed. Edges are rounded thus allowing for easy water runoff along the façade faces. The edges of the tomb are pitted, and a recess to hold the tomb cover is heavily rounded. Since the tomb is open, it is liable to collect water during rainfall thus establishing long contact times between water and stone, and causing more water impregnation into the rock. The outcome is of course more salt dissolution and re-deposition of salts on the surfaces.
2- The upper Entablature of all facades is subjected to heavy water runoff, thus causing edge rounding and some exfoliation along the bedding planes of the rock (almost horizontal)
3- The groove below the Entablature has lost most of its masonry insets, and most of the remaining sandstone insets are rounded and sandy, or exfoliated. The insets were held in place with mortar and due the heavy water washdown, the mortar has dissolved, washed down the façade, and re-deposited as scales. Naturally the impregnation of the rock fabric with mortar salts is extensive.

4- In the area where the four pilasters lie, heavy alveolar weathering, especially in the East and South facades, often causing a loss of architectural detail as well as deep pits and holes as well as cracks (mostly in the horizontal direction).
5- Backweathering, outbreaks, salt effluorescences and sub-effluorescences are very common.
6- The bottom of the façades is heavily weathered and on the east façade it is possible that a staircase was built but the details have been lost that it is not easy to a make a definite conclusion about this side. The South and West façade do not give the impression of a staircase. Rather there is a definite architectural detail in the form of a base structure (similar to an rectangular entablature). Heavy weathering at the bottom of facades is very common on Petra. The collection of rainwater in the form of pools with improper drainage leads to capillary rise of humidity in the façade, leading to detrimental results with heavy damage and salt effluoresecnces.
7- A deep and wide crack with holes lies along the bedding plane in the lower part of the façade. This runs from the East side to the South to the West, and does not show very clearly on the North side. Since horizontal cracks are considered more dangerous than vertical ones, this is a serious weakness that could cause the whole block to slide and topple leaving only less than a meter high structure. This has been known to happen in Petra during a serious flashflood. An earthquake could also have serious damaging effects.

The following figure on the next page shows the weathering forms that have been observed on the Eastern and Southern sides of the Block. Alveolar weathering seems to hit the highest surface area amongst all weathering forms if one ignores backweathering and outbreaks where the loss of material does have an obvious mechanism of deterioration. It must be stated that all factors of weathering operate jointly on the surface and it would not be possible to always identify which weathering form is predominant on a particular region or spot on the façade.

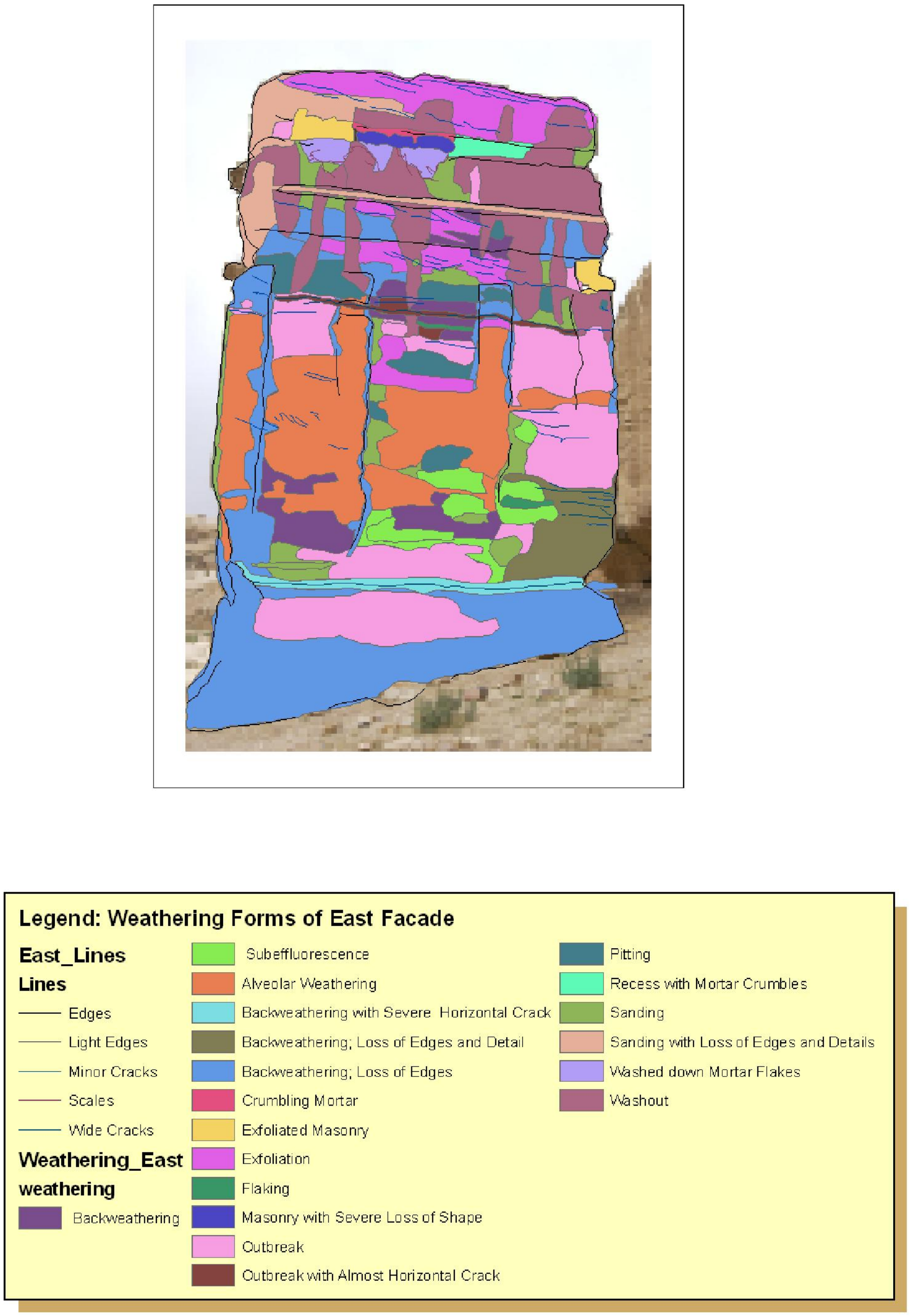


Figure 5: Mapping of Weathering forms for the Eastern Facade

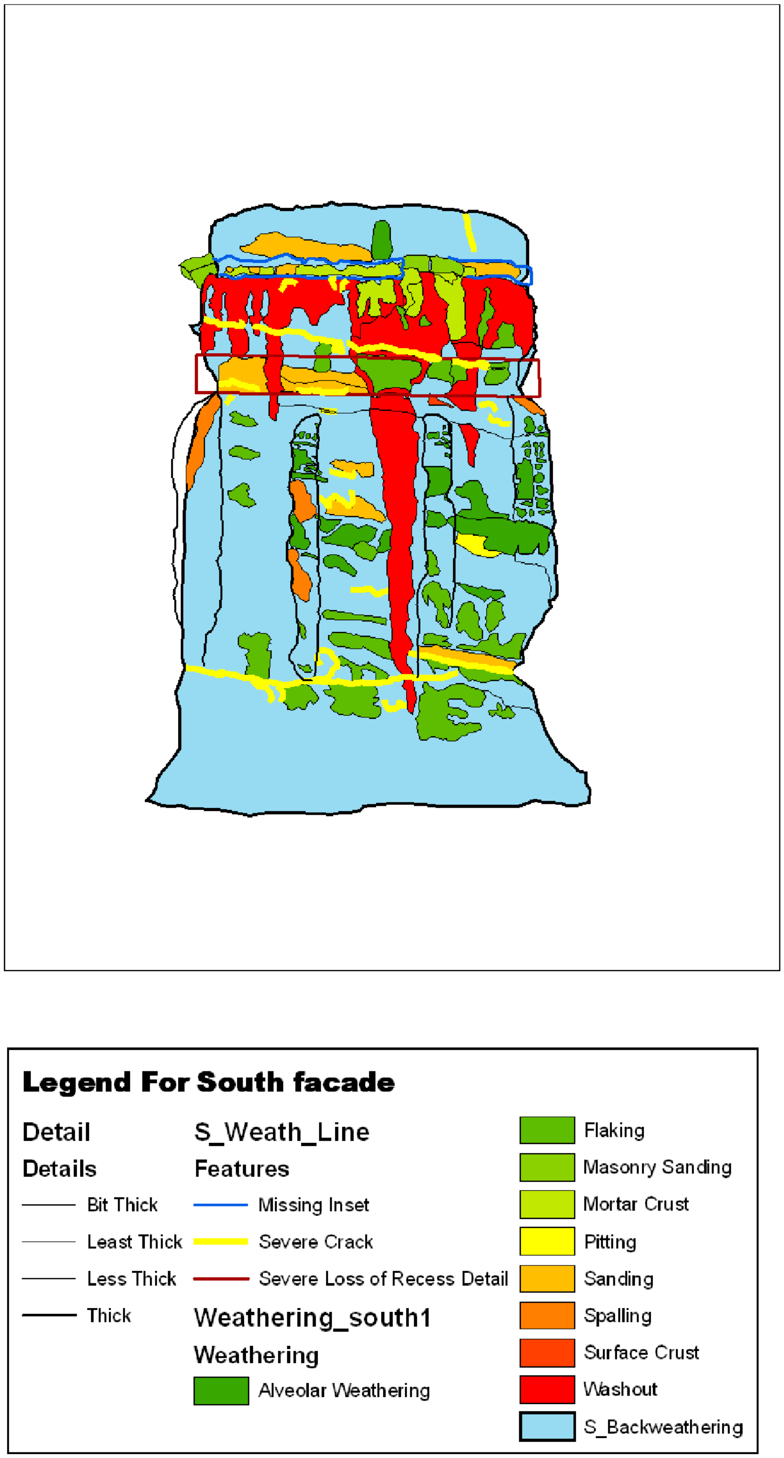


Figure 6: Weathering Forms on the Southern Facade

3.1.2.2 In Situ XRF Tests

As a special field diagnostic tool we have utilized a portable XRF instrument to test a small surface of the façade on the East side for salts.

Figure 7: Distribution of XRF testing points on the lower part of the Eastern Façade

The XRF tests were analyzed by a semi-quantitative analysis of the data using home made elemental standards. About 130 points were measured and the data for the elements or their ratios were entered into a GIS and the image of the monument was rectified so that the exact location of the points could be located on it (as in the figure above). Using spatial analysis techniques, the elemental distribution of the points was transformed into a grid distribution, from which contour lines for each element could be drawn. This is probably the first time ever such an approach is used where non destructive techniques are used in situ and spatial analysis is utilized. The value of such a method is that it shows promise of following salt migration and salt concentration without the need for destructive sampling. Furthermore, there is a very good chance that the elemental grids and contours or those derived from elemental pair ratios, could be correlated with the weathering forms or extent of damage. However, due to budget limitations and time constraints, and as shown in the points distribution diagram, there is need for maybe twice the number of points to get more significant correlations than is apparent currently. This work is currently in progress. The grids and contours of some elements are shown below to illustrate the results. For Calcium the highest concentrations are seen to occur at the bottom of the monument, possibly due to down flow of salts by washdown during the rainy season as well as capillary rise due to water pools.

Figure 8: Calcium Grid Distribution and Contours (Contour labels are in %)

Figure 9: Chlorine Distribution

3.1.2.3 Field tests of Consolidants

In situ testing of consolidants in the field was conducted on a natural Ordovician rock in Petra. This was the only available option as any intervention on the monument itself is not allowed until a full investigation and a full plan is prepared and approved by the Department of Antiquities. Furthermore, a meaningful intervention on this monument requires more financing and time that is allowed by the project, Prodomea. Four consolidants or adhesives were chosen. Palaroid B72 is an acrylic resin that is often used in the conservation of artifacts. Funcsil 100, Funcosil 300, and Tetraethoxysilane are silicic acid esters, that were chosen because of their successful application at monument 825 (see map). The only difference is that 825 is of Precambrian sandstone origin. In the case of Palaroid B72, a solution of the solid in acetone was prepared at a concentration of 5%. The other solutions were used as received from Riemmers – Germany. A square area of 10 by 10 cm was cleaned by carving a thin layer to clean the outer dirty surface of varnish that covers the rock. A brush was used to apply the solution over a period of an hour allowing the surface to completely absorb each application and the amount of liquid used for each test area was about 250 ml. One of the areas was broken to unravel the depth of penetration of the solution. Palaroid B 72 could only penetrate to a maximum of three cm. The other solutions exceeded 10 cm. On the other hand, Palaroid, while being absorbed well in the beginning of the application, it was noticed that it started to accumulate at the surface leaving an unpleasant resin layer, that would be esthetically unacceptable. While it might be argued that other workers, have successfully used this resin in 1% solutions, it is generally accepted only as a replacement for jointing mortars between stones rather than as a consolidant for stone. Its high water repellency is also undesirable. A further discussion will be given on this point after describing the laboratory tests. Figures 10-13 shows the applications on the same day as well as one month after application.

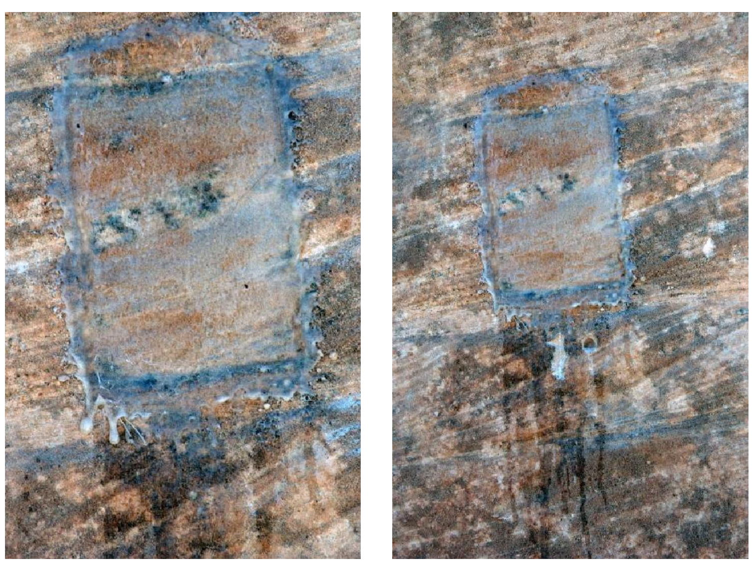


Figure 10: Application of Palaroid B72 in the field

Figure 11: Application of Funcosil 100 in the Field

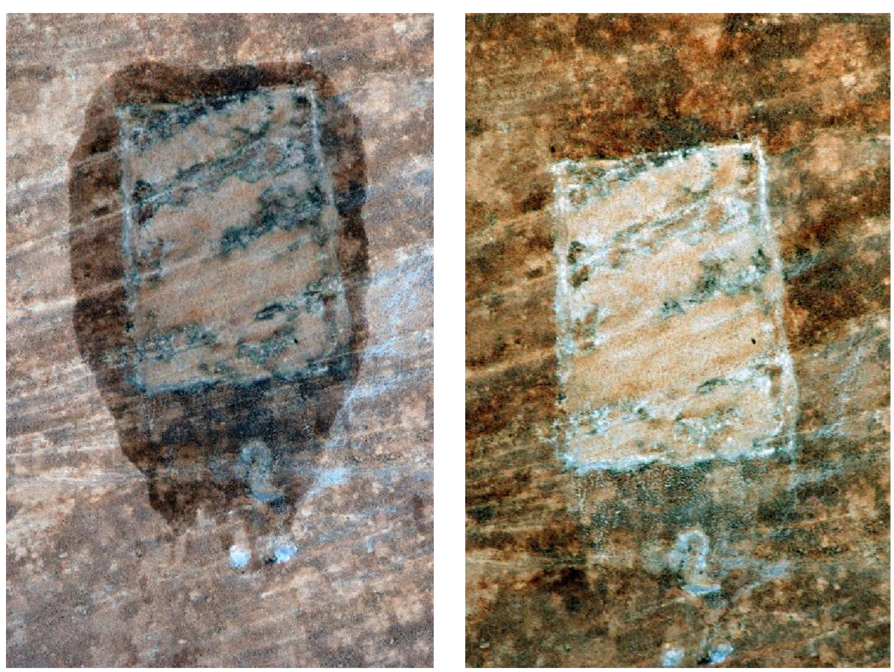


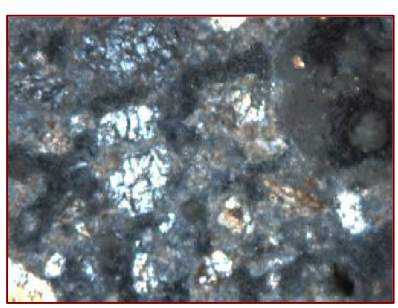
Figure 12: Application of Funcosil 300 in the Field

Application of Tetraethoxy Silane in the Field

The results in the figures above show that in time the wet impression that the surface exhibits, clears up in time in the case of the application of Funcosils and Tetraethoxy Silane. Esthetically Palaroid is unacceptable. Furthermore the fact that Palaroid B72 is highly water repellant makes it a very poor candidate because of the possibility of water accumulation behind the treated surface. This can have detrimental effects on the monuments and its façade.. The surfaces are consolidated in all cases, although the extent was not determined because it is too early to judge and it is too early to take core samples for laboratory testing of the application. It is also expected that in the case of the silicic acid esters the stain will disappear. This is the observation made during the consolidation of monument 825 by these materials. It remains to be said that a better product has been utilized on monument 825. This is Funcosil 510, which seems to be a better consolidant.

3.1.2.3 Experimental Analysis of Stone Samples

Figure 14: Polarizing microscopy of Stone Sample



All samples were studied under the polarizing microscope and a typical result is shown in Figure 14 where the presence of quartz arenite was confirmed.

The Following tables include some the tests that we were conducted at The National Resources Authority Amman Jordan.

Table (2): Results of Physical Properties for Petra Ordovician Sandstone Samples for Consolidant Palaroid B72

Sample No	Dry weight	Saturation weight	Specific weight	bulk Density) (g /cm3) (ASTM C127)	Saturated specific gravity (ASTM C127)	Apparent Specific gravity (ASTM C127)	Absorption % (ASTM C127)	Porosity % (ASTM C127)	Compressive strength (Kg/ cm^2) (ASTM D1074)
1A*	1032	1101	605	2.08	2.22	2.42	6.69	13.91	25
2A	233	248.8	137	2.08	2.23	2.43	6.78	14.13	3.7
1B**	1033	1132	622	2.03	2.22	2.15	9.88	19.41	25.4
2B	985	1037	592	2.21	2.33	2.15	5.28	11.68	31.4
3B	1048	1143	627	2.08	2.22	2.49	9.06	18.41	45.5
4B	231	243	135	2.14	2.25	2.41	5.19	11.11	15.9
5B	225	237	131	2.13	2.24	2.39	5.33	11.32	18.3
6B	240	253	141	2.14	2.26	2.42	5.42	11.6	21.2

*A: without consolidant
**B: with consolidant (Palaroid B72)

Table (3) Density and strength

sample No	length	wedth	hight	area	volume	load(kn)	weight(g)	density	strength(kg/cm2)
A1	9.9	10.1	9.9	99.99	989.90		2198	2.220	
A2	9.9	9.07	9.7	89.79	870.99	109	2064	2.370	123.818
A3	9.8	9.8	10	96.04	960.40	157	2088	2.174	166.743
A4	9.85	9.8	10	96.53	965.30	103	2131	2.208	108.837
B2	9.8	10	10	98.00	980.00	180	2179	2.223	187.347
B3	9.9	9.8	9.9	97.02	960.50		2137	2.225	
B4	10	9.9	9.9	99.00	980.10	130	2214	2.259	133.939
B5	10	9.8	9.9	98.00	970.20	126	2169	2.236	131.143
C1	10	9.9	10.1	99.00	999.90		2245	2.245	
C3	9.9	9.9	9.9	98.01	970.30	114	2246	2.315	118.641
C4	9.6	9.9	9.9	95.04	940.90	117	2128	2.262	125.568

C5	10	9.9	9.9	99.00	980.10	87	2098	2.141	89.636
D1	9.9	9.85	9.92	97.52	967.35	36	1965	2.031	37.656
D2	9.92	9.95	9.92	98.70	979.14	99	2177	2.223	102.306
D3	9.85	9.9	10	97.52	975.15		2086	2.139	
D4	10.3	10.3	10.3	106.09	1092.73	68	2511	2.298	65.378
D5	9.85	10.1	9.9	99.49	984.90	139	2191	2.225	142.514

Table(4): Specific gravity and absorption results

sample No	dry wt.	sat. wt.	sub.wt.	dry Gs	sat.Gs	App.Gs.	% Absoption	porosity
A1	2198	2281	1305	2.252	2.337	2.461	3.776	0.085
B3	2137	2176	1237	2.276	2.317	2.374	1.825	0.042
C1	2245	2249	1290	2.341	2.345	2.351	0.178	0.004
D3	2086	2162	1225	2.226	2.307	2.423	3.643	0.081

BULK DENSITY	**(g/cm2)**	**(ASTM C 127)**
SPECIFIC GRAVITY	*************	**(ASTM 127)**
COMPRESIVE STRENGTH	**(kg/cm2)**	**(ASTM D1074)**

A: Founcosil 100
B: Founcosil 300
C : Tetraethoxy saline
D: Without Consolidant

The stone samples were cut into cubes of varying sizes. This was due to the difficulty in cutting the friable Ordovician stone into regular geometric shapes. Thus dry sawing was necessary. Often the use of a manual or an electric saw would disintegrate the sample especially when using liquid cooling. The stone sample was immersed in the solution of consolidant (5% in acetone for Palaroid B872, and as provided by the manufacturer for the silicic acid esters) to three centimeters height and the liquid was allowed to flow up the stone by capillary rise. After a couple of hours, the liquid was also applied dropwise from the top to assist in reaching complete penetration. In the case of Palaroid B72, complete penetration was never achieved, as was observed after crushing by the compressive strength test, even after a 24 hour immersion. The results show that the compressive strength of the stone samples is generally increased by using consolidants. No comparison could be made between one consolidant and the other because one could not guarantee the same overall properties between one cube and the other, even if they were cut from the same original bedrock or rough stone sample. In the same manner the porousity of the samples was reduced with consolidation. Generally the raw stone porousity we obtained were similar to those obtained by polarized optical microscopy with a maximum of about 20%. Similar results were reported by Fitzner and Heinrichs.

3.1.2.4 The Salt Tests

The salt tests were carried out on 10x10x10 cm stone cubes. These were immersed to a height of two centimeters of a 5% sodium sulphate solution and left for up to 20 days while keeping the liquid constant by replenshing any losses. The figure below show four samples. One was not treated to be used as a reference while the other three were each treated by one of the silicic acid esters respectively. Obviously the salt rise was effectively hindered for a period of 20 days by the adhesives, while the untreated sample was filled with salt to its top even within five days of application.

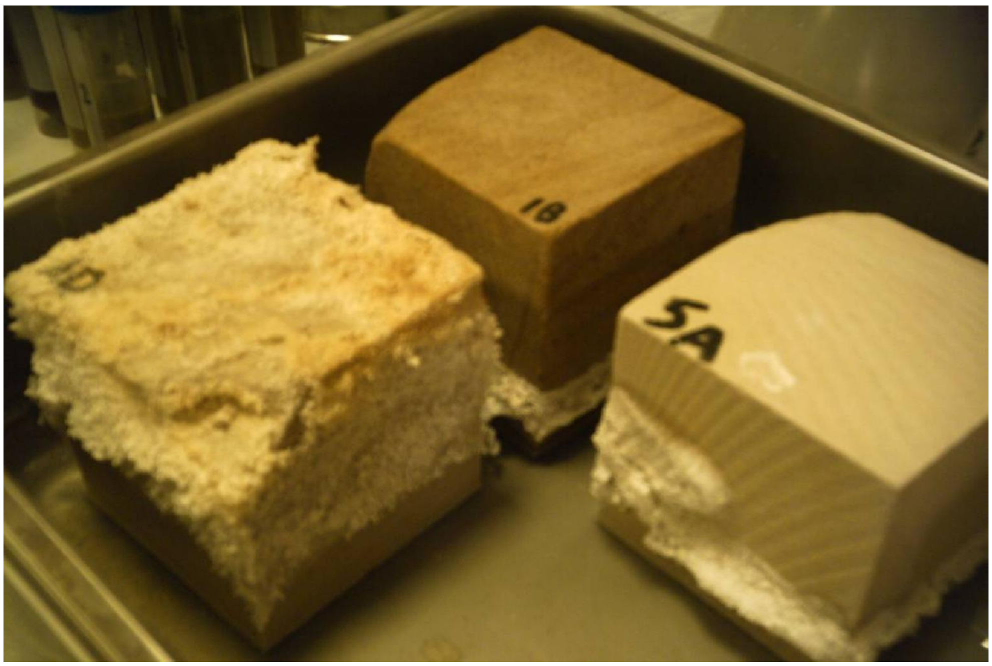
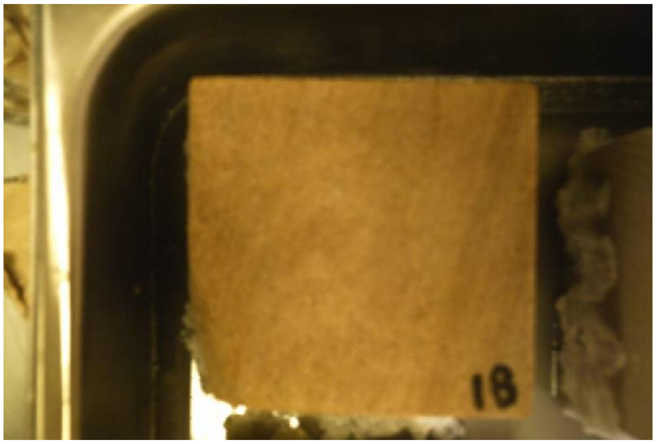
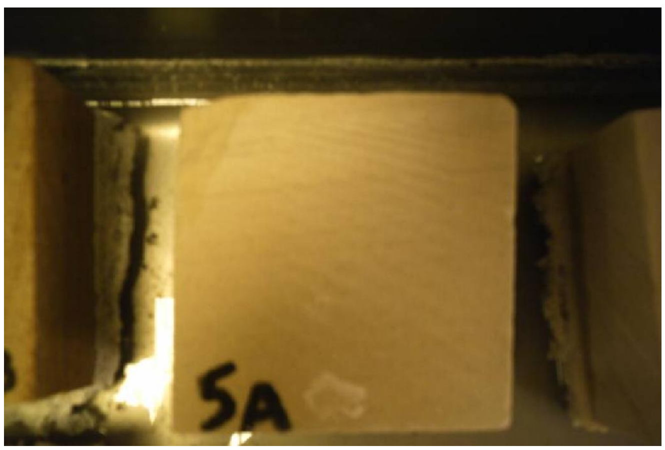


Figure 15: The salt test after 20 days. 1D on the left was untreated. 5A was treated with funcosil100, while 1B was treated with Funcosil 300. The latter seems to yield better protection against salt rise. In the following pictures the stone samples are also shown individually and from the top.





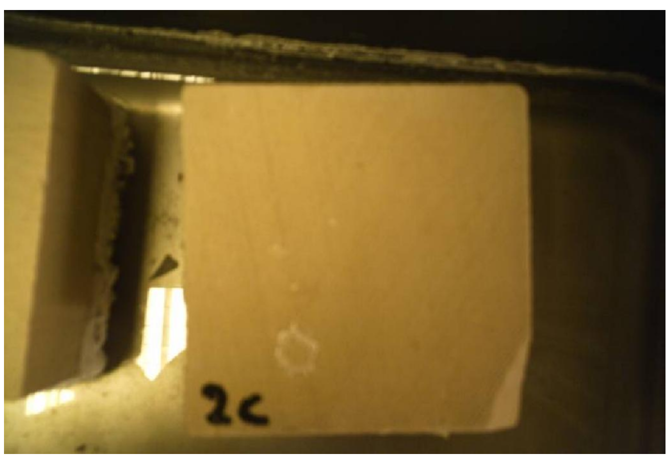


Figure 16: Stone samples and the salt test shown individually (2c is for tetraethosxy silane)

4- Conclusions and Recommendations

The Ordovician sandstones we tested have a relatively high mean porousity, with the highest observed being about 20% as evidenced from the optical microscopic examination and other laboratory tests. They are very friable and our in situ XRF tests indicate high salt content as expected for heavily weathered stone, especially with the deteriorated lime mortar of the inset stones. Consolidants improve substantially the physical properties of the stone reducing the porousity and enhancing compressibility strength. The main weathering mechanism observed id due to water down flow down the facades and capillary rise at the base, where the staircase is completely damaged. This assisted by Eolian weathering by wind, thus accounting for the heavier damage observed on the Southern and Eastern facades. The heavy solar exposure on the Western side does not account as main factor of weathering.

A good conservation plan must take into account the following main principles:

1- The treatment should be able to reduce the adverse effects of weathering.
2- Since it is impossible to conduct any effective intervention while maintaining the principle of reversibility, one must ensure that retreatability is still possible.

The following steps must be considered in any conservation intervention:

1- The removal of the damaged mortar below the stone insets is of utmost importane. The stones must be cleaned after removal and must be consolidated before reattachment. New stone insests may be put in place in order to protect the groove in which they are held. A special mortar mix using Silica Sol can be used in a manner similar to that used in monument 825.
2- Salt removal may be done using a poultice of kaolinite, clay and cellulose with water (2:1:1:2).
3- The grave on top should be closed to prevent rainwater storage during winter time and to prevent any prolonged contact with water. This is probably the main reason for the mortar damage at the top of the monument.
4- The rooftop should have adequate water drainage as water flow down the facades is detrimental. Water repellants and consolidants for the roof could be very useful.
5- Consolidation of friable areas of the monument should follow.
6- Drainage at the base is also important to reduce water pools in winter and avoid prolonged contact with water.
7- Injection mortars should be used to fill holes and cracks.
8- Finally, a sacrificial mortar should be used in places where heavy gaps and alveolar weathering have occurred.

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