Conservation work at Petra: What had been done and what is needed

[1]Fadi Bala'awi*, [1]Firas Alawneh, [1]Yahya Alshawabkeh and [1]Mohammed Waheeb

[1]Queen Rania's Institute of Tourism and Heritage, Hashemite University

Abstract

[1]Fadi Bala'awi*, [1]Firas Alawneh, [1]Yahya Alshawabkeh and [1]Mohammed Waheeb
[1]Queen Rania's Institute of Tourism and Heritage
Hashemite University

Abstract

The conception of conserving and managing an archaeological site is usually challenging. These issues become more challenging when dealing with archaeological sites in the scale of the world heritage site of Petra, Jordan. The current paper presents a critical evaluation on some of the conservation work at one of the world new seven wonders, the World Heritage Site of Petra. The research extended to discuss and evaluate the historical, structural and current condition of Petra monuments. The study has revealed that the conservation work at the city had been done by different international organization with a different concepts and standards for each work. The study had concluded that a national conservation standard is highly needed for the conservation work at the city of Petra.

Keywords: Petra, Conservation project, critical evaluation, Rockcut Tomb Facades, weathering forms, decay features and national conservation strategy.

1 Introduction

Conservation of archaeological sites is one of the most contradictory topics in heritage protection. This could be related to the complexity and sensitivity of

conservation issues as well as the wide range of groups who are interested in these issues. In addition, conservation of the archaeological sites should be interdependent work, which takes into consideration any previous work before starting a new project. The discussion and evaluation of the previous conservation work on a site is without any doubt an essential and primary task, since it gives the conservator the areas where the previous work had failed or the areas that need to be studied more.

One of the most important sites in Jordan is the Red Rose City, Petra. In this unique Nabatean city a considerable amount of conservation work has been carried out. Some of these works failed totally, others affected the authenticity of the city, and others were successful. Recently, the deterioration and the decay of Petra irreplaceable monuments are increasing at noticeable levels. In order to demonstrate the main needed conservation work at the city of Petra, the current research will discuss and evaluate some of the main previous conservation projects that had been carried out in the archaeological city of Petra. Moreover, the research will highlight the main conservation researches in Petra. The paper will extend to main problems that facing the Petra monuments. Finally, the conclusion will summarize the current survey result and propose what is really needed for the conservation and protection of the World Heritage Site of Petra.

2 Petra: The site

2.1. General

Jordan lies at the heart of one of the most historically important and intellectually intriguing regions on earth. The Kingdom has more than 10,000 known archaeological sites with many yet to be discovered. One of the most famous sites in Jordan is the World Heritage Site of Petra. The archaeological city of Petra with its 2000 sandstone rock cut façades is considered by many to be the eighth wonder of the world. It is a Nabatean city that was hewed into coloured sandstone and Limestone Mountains. The Nabateans were nomadic Arabic people who ranged between Syria and Arabia from the 7th century before the Christian era to the 2nd century after the Christian. Petra in Greek means the rock or the stone, and it is also repeatedly mentioned in the Bible as “Sela”, which means the rock in Hebrew (Bourbon 1999). However, some authors such as Naoum (1993) said the name of Petra had an Arabic origin from the world “batara”, which means cut or hew. Also, it used to be called Wadi Mousa or the Valley of Mousa, which is now the modern village around the ancient city. Additionally, the city is famous for its name The Red Rose City, because of its wonderful sandstone colours. Petra is the biggest tourist attraction in Jordan; however the city suffers from weathering and erosion problems, both natural and human in origin.

2.2. The location

The city of Petra lies hidden in the Desert Mountains in the southern part of Jordan, half way between the Dead Sea and the Gulf of Aqaba. It is 255 km away from Amman (the capital of Jordan) (Figure.1). The international

coordinates for the city are 35º 25′ E - 35º 28′ E and 30º 19′ N - 30º 21′ N. The archaeological city of Petra occupies about 15 km2 and is 900 to 1500 m above sea level.

Figure 1: Map of Jordan and its main archaeological sites. (Lonely Planet 2004)

2.3 The climate

According to a report by the Jordan Meteorological Department (JMD 2003), the climate in Jordan is predominantly Mediterranean. This means hot, dry summers and cool, wet winters with two short transitional periods in autumn and spring. More than 80 % of Jordanian land is considered to be arid.

Average rainfall ranges from 600 mm/year in the north to less than 50 mm/year in the south. The rainy season is between October and May. Eighty percent of the annual rainfall occurs from December to March.

The study area, Petra, is a rather semi-arid, steppe-like region in which small plants survive in winter and spring. Generally, dry hot summers and relatively cold dry winters characterise it.

2.4 The economic context of Petra

As well as being of vital historical value, Petra has also been of the most crucial economic value both for the Nabataeans and Jordanians. For the Nabataeans, Petra was not only the capital of their Kingdom but also the central position of their trade. For example, communications between the Hejaz and Mediterranean ports usually used Petra as a transit point due to its strategic position on the ancient trade routes. In addition, the natural defensible location of Petra made the trade easier and safer. According to Bienkowski (1992), the great civilization in Petra was related directly to the economic profits from trade. It is certainly true that the trade of the Nabataeans with many nations, and especially the trade with Roman Empire, improved their economic situation, which gave them the money to construct their Eighth Wonder of the World. In addition, Petra is a crucial feature of the Jordanian economy. For instance, in 1998 it generated about 755 million US dollars, which accounted for about four percent

of the Gross National Product (GNP) (ACOR 1999). In 2007 record number of tourists visited Petra with arrivals topping 580,000. Moreover, job opportunities were increased after tourist constructions in Petra.

2.5 The Monuments of Petra

Petra monuments and ruins are unique in their architecture, distribution, and variety as well as their durability. To understand the general situation of Petra monuments, which is the core elements in understanding the conservation work in Petra, it essential to understand the monument history, structure and importance. It is worthwhile to remember that the archaeological site in Petra contains more than 3000 monument and only one the monuments which had a major conservation work will be presented at this paper, Tomb 825 as well as three others monuments that are deteriorated badly and considered as monuments at high risk.

2.5.1 Tomb 825

Tomb 825 (Figure 2) according to Brunnow"s classification and sometimes it is known as The Tomb of the 17 Graves, since it has fourteen graves cut into its floor and three more in large rectangular recess in the back wall (Khouri 1986). Shaer and Aslan 2000 reported that this tomb is consisted of two sets of large steps, a cavetto cornice, an attic storey and a classical cornice. The importance of this tomb can be summarized in its typical Nabateans architecture style, representatively to the Nabateans family tomb and in the conservation work that took place in this tomb.

2.5.4. The Palace tomb

The Palace Tomb is one of the three large façades at the eastern side of the city, known as The Royal Tombs. It is so-called because it is a copy of the design of a Roman palace (Ulama 1997, Khouri 1986, Kennedy 1925) (figure 3). It consists of three different levels, the first level being completely inconsistent with the upper two levels. The lower part is a rock-cut façade, while the two upper parts are built as freestanding façades (Markoe 2003). In front of the tomb is a large stage and in front of that a large courtyard. The Palace Tomb is one of the most impressive monuments in Petra, as it is located at the edge of a mountain cliff, has a complicated architectural structure and is unusual in appearance. Many writers such as Taylor (2001), Vivekanand (1995) and Maqsood (1994) have suggested that the Palace Tomb housed the last Nabatean kings (King Rabbel II, 75-106 AD).

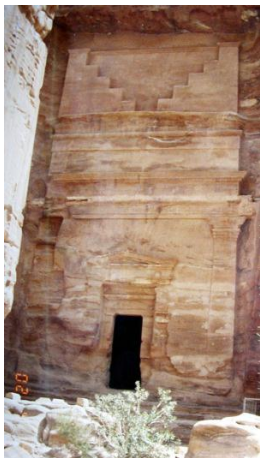

Figure 2: Tomb 825,

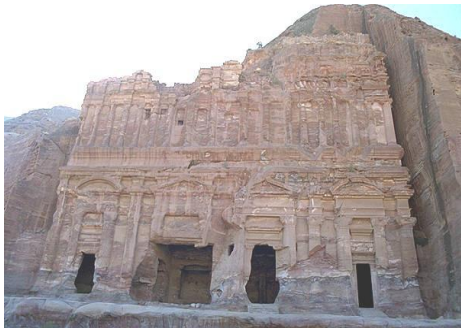

Figure 3: The Palace Tomb

2.5.5 The Corinthian Tomb

The Corinthian Tomb (figure 4) is 27.5 m wide and 28 m high. It is one of the most beautiful tombs in Petra, but unfortunately has lost most of its features due to deterioration. The upper part of this tomb shows the clear influence of Hellenistic architecture, while the lower part is a typical Nabatean style. As with most of the Nabatean monuments, there is no historical record of the absolute date of its construction. Many authors such as Bourbon (1999) and Maqsood (1994) reported that this tomb was built for either Aretas II (120-110 BC) or Malchus II (40-70 AD). In contrast, Vivekananda (1995) suggested that it is more likely that Aretas III (84-62 BC) constructed the Corinthian Tomb, because its structure is similar to his famous monument in Petra, The Treasury (The Khazneh). The Corinthian Tomb is the most deteriorated carved monument on the archaeological site of Petra.

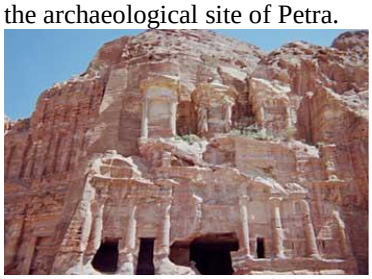

Figure 4: The Corinthian tomb.

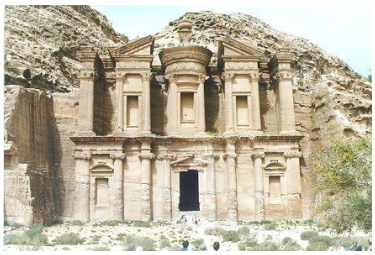

Figure 5: The Deir tomb.

2.5.6 The Deir Tomb (The Monastery)

The Deir (figure 5) (meaning monastery in Arabic) received its name from the cave that is known as the Hermit's Cell. No one knows where this name comes from, and it may have only come into use after the Middle Ages. The journey to the Deir Tomb requires the climbing of more than 2000 steps carved

into the mountain. It is the largest and most impressive façade in Petra. The façade is about 50 m wide and 45 m high (Khouri 1986). It is divided into two storeys; the lower one has a simple doorway (8 m high) with six columns topped by Nabatean capitals, the upper storey, which is better preserved, has eight columns with a conical central roof crowned with an urn. The main chamber in the Deir is huge (11.5 m by 10 m). A small part of it was used as a meeting room (symposium), whereas the main part was a mausoleum for the king. A huge area in front of the monument was levelled, and seems to have been used for great congregations of people. There is no actual dating for the Deir. However, many writers such as Bourbon (1999), Taylor (2001) and Khouri (1986) suggest the middle of the first century (44-70 A.D.).

3 Summary of the main conservation Project in Petra

The conservation of Petra monuments is a very old dilemma in Jordan. Unfortunately, most of conservation projects in the city were a by-product of tourism development. In the following section some of the important conservation project in Petra will be presented and evaluated briefly.

One of the earliest conservation projects in Petra is the repaired of the third pillar of the Treasury building in 1958. United State Agency for International development (USAID) founded this project. The project succeeds in restore and enhances the view of the most attractive monument in Petra (The Treasury or what is called in Arabic Al Khazneh) by reconstruct the third column of the monument. However, it is hardly to notice this column from the others columns, especially if you did not know the conservation background of the site. Also, unfortunately, in the site there are no signs or boards that describe the conservation work in this site, or even just a brief mention of it. It is worthwhile to remember that the reconstitution of this column took place in 1958, which is before the Venice Charter 1964 or the Nara document on authenticity 1994. However, one can say that this project adhered the principles of Athens Charter for restoration of historical Monuments (1931) that emphasized in the aesthetic appearance of the monuments. From my point of view, the conserving of third column of the treasury is a part of the site history in these days and the project achievements should be appreciate, since the work had been documented and the its work carried out with highly accuracy. In contrast, the project did not take in consideration many modern conservation principles such as the minim intervention and the authenticity of the place.

During the excavation of the main theatre in the early 1960s, a few conservation works took place on the site. During the late 1960s, the USAID provided funding to complete a master plan to guide future development of Petra site (United State Support for the World Heritage Sites 2001). The plan identify the flooding in the Siq area as a major problem on the city, as a consequence it had been recommend to reconstruct the Nabataeans dam in the entrance of the site. The restoration of the Nabataeans dam was not only a solution for a problem exist, but extend to cover a wider issues in presenting the intelligently of the Nabataeans engineers, which aid another significant to the place. In addition,

during the excavation campaigns in the temple of the Winged Lion (1974-1990) a sequence of conservation work took place in the excavated areas. The Department of Antiquity –Jordan carried out a clearance campaign in Urn Tomb in 1975.

In 1981 a restoration campaign was held the Department of Antiquity in the city. The work of this campaign includes the Siq clearance from the accumulated debris, the clearance of the entrance to tomb 64, the restoration of the city gate, clearance in Qasr Al Bint, and the restoration of some Fresco in the rock carved cave with the co-operation with the National Museum of Madrid (Zayadine 1981). Another excavation and restoration campaign was resumed in the Qasr Al Bint from the 3rd of October to December 20th, 1983 and in May 1984 (Zayadine 1986). In 1991, and in order to compensate the total absence of income from tourism, which affect more than 300 family from the local community, a clearance and excavation campaign was carried out in Petra by Petra National Trust (Zayadine and Farajat 1991). Moreover, in 1993 a Jordanian - German group started a very important conservation project in the rockcut facades in the city. Brown University carried out another important excavation and conservation project in the Great Temple in 1993 and the project still carrying on. Beside that, and through USAID funding, a second master plan for Petra and the surrounding region was completed in 1994. Unfortunately, this plan does not put in work. In 1993 the American Centre for Oriental Research (ACOR) started a conservation project in the Byzantine Church.

Besides that, in 1994 the ACOR with the co-operation Helsinki University started a conservation project in some papyri scrolls that had been founded in the Byzantine Church. In addition, a Swiss- Liechtenstein excavation group carried out a restoration and consolidation campaign in the zanture area in 1994. Fitzner and Heinrichs evaluated the weathering damage monuments carved from rock in the city (1996-1999). It is worthwhile that UNSECO with the co-operation the Jordanian government and a wide range of archaeological expertise complete a new management plan for Petra area, which include a conservation plan for the city, but this plan dos not published yet.

To conclude, one can say the conservation work in Petra in concerning a wide range of authorities inside and outside Jordan. The evaluation of all of these projects is very important to demonstrate the future needs, however, and due to the limitation of this paper, the author proposed to discuss and evaluate one of the main conservation projects, which is the German- Jordanian preservation Project (1993-2000).

4 Petra Stone Preservation Project (Jordanian – German Conservation Project [1993-2000]

A Jordanian-German group carried out a conservation project in the rockcut façades in Petra from 1993 till 2000, which is certainly one of the most unique

and valuable conservation projects in Jordan. This is related not only to its successful practical work in stone conservation in the city, but also to the wider issues and principles the project tried to establish in the conservation field in a country which really had no experience in these basic and essential issues.

The establishment of this stone preservation project in Petra, which became known later as the Jordanian-German Project for the Establishment of Conservation and Restoration Centre in Petra (CARCIP), could be considered as a special start in the conservation field in Jordan.

According to Fisher (2000), the main goal of the (CARCIP) project was to implement and institutionalize internationally accepted conservation and restoration practice and procedures in Jordan.

The establishment of specialized and fully equipped conservation and restoration centre in Petra was the starting point for this tremendous goal. The centre had to be able to plan, support, supervise and execute entire conservation and restoration projects in Petra at the end of this project (Greipal 2000). It is important to notice that the project plan mentioned that the Centre should be operated and managed by Jordanian hands at the end of the project.

The tasks the project aims to achieve are quite complicated and will take an enormous time and effort to be achieved. However, the project in its first six years (1993-1999) is, by and large, gone in the right direction. According to project procedures, the duration of the project is about nine years, three years for each step of its three previously mentioned steps. The project"s achievements in its first six years (i.e. in the first two stages of the project) were enormous and valuable. First of all, most of the technical issues were completed. This includes the setting of the essential tools and structures for the coming conservation work, for instance, metal scaffolding, hammers, photographic equipment and truck with hydraulic crane. According to Fischer (2000), the necessary support structure has been successfully established, especially due to the important backing from BLfD. Secondly, the conservation Laboratory in Yarmouk University was upgraded in order to improve field testing and the evaluation of the materials and methods of conservation in Petra"s monuments (Fisher 2000). Moreover, a database centre for field image analysis and data collection have been established in the Hashemite University. Akasheh (2000) mentioned that with the construction of such comprehensive centre, its activities of documentation extend beyond the monuments themselves to all aspects related to Petra, and will be an extremely useful source of information needed for conservation work in Petra. In addition, one of the most important achievements of the project is the development of the concepts of conservation and restoration, not only in Petra but also in the whole country (Fisher 2000). The author believed that the CARCIP project elaborated the conservation and restoration aspects to international standards not only to the people who are interested in these topics, but more importantly to the local community. On the practical side, a very important success was attained, through the restoration of a complete tomb facade (Tomb 825). The restoration of this tomb is considered as extraordinary work, even though it took time, stopped many times and was done mainly by the German experts. This is related to the fact the this practical work

is different from the ordinary restoration work in the city, since it was done within international conservation principles, provided the local community with considerable field work experience and set up the bases for the coming conservation work). Besides that, the project started research links in conservation work with different campaigns. For example, it is reported that a research link has been agreed with University College London to explore and address the obvious problem of salt contamination in the monuments and its effects on the deterioration process (Fisher 2000). On the other hand, a wide range of challenges face the project. First and most important, is the funding problem. The CARCIP project, like many development programmers in developing countries, has a problem of bringing on funding resources after the end of the foreign support. Operating and developing the centre is more important than establishing it. One of the proposed solutions is to establish a trust fund (Fisher 2000). Secondly, the process of project institutionalization (i.e. transferring into a non-government organization [NGO]) still needs a lot of work. In my view, even though I agreed with the fact that an NGO has more flexibility and independence in its designs, it is really difficult for such a project in a country like Jordan to become completely independent from the governmental side. Other challenges include doubts about the continuity of creating a skilled generation who will be able to operate the centre for the coming times.

In summary, the achievements of the CARCIP project are really valuable in the conservation field in Petra. The introduction of essential conservation tools, the creation & development of laboratories, research field linking with renowned campaigns, training of the local community and the restoration of a complete tomb façade are the project"s main achievements. However, project institutionalization, funding and the continuous availability of skilled persons are challenges of the project.

5 A Summary of the main Conservation Researches in Petra

In order to conclude the discussion of the conservation work that had been done in Petra, a summary of the main conservation research that carried out in the city will be presented briefly. It is worthwhile remembering that the presentation of these researches will include research topic and results not its technical part.

5. 1 The Evaluation of Weathering Damages on Monuments Carved from Rock in Petra-Jordan (Fitzner and Heinrichs 1996-1999)

For better understanding of the stone weathering in Petra and the damage to its monuments, a research project were carried out by B. Fitzner and K. Heinrichs between 1996 and 1999. The project aimed to document and evaluate the actual state of the monument carved from the bedrock, approach the results in weathering model and finally evaluate the survey results for the monuments preservation needs (Fitzner and Heinrichs 1998). To achieve the above goals 22

monuments were selected. It is should be noted that the selection of monument considered the variety of stone type and characteristic as well as the feedback from the Jordanian scientist (Fitzner and Heinrichs 1998). The project investigation program consisted from in situ and laboratory tests. The fieldwork consisted of the lithotypes description, monument description, monument mapping, measurement sampling and photodocumentation. On the other hand, the laboratory work compromised mainly of petrographical classification, characterization of stone properties, chronology of stone alteration, identification of the weathering products and characterization of weathering behavior of stone properties (Fitzner & Heinrichs 1998). On the other hand, the laboratory work compromised mainly of petrographical classification, characterization of stone properties, chronology of stone alteration, identification of the weathering products and characterization of weathering behavior of stone properties (Fitzner & Heinrichs 1998).

To conclude, one can say that the above research project is a comprehensive study of the weathering forms in Petra monuments, which is the primary stage in conserving them.

It can be stated that the problem of identification is the most important stage in the conservation work, therefore the demonstrating and evaluation of the weathering form in Petra monument is an essential work that should be carried before taken any conservation intervention.

5.2 Analysis of Sandstone Weathering of the Roman Theater in Petra, Jordan (T. Paradise 1995).

In 1995, T. Paradise from Hawaii and Hilo University started a conservation research project in the main theatre in Petra. The project aims to understand the theoretical weathering principles in the theatre in order to assist the future chemical solution for the weathering problem (Paradise1995). The research based on the the determination of the sandstone weathered and eroded since the data of its construction by the determination of the pre-weathered dresses sandstone surface11 and correlate with the actual state. The research conclude that both the variation in rock matrix chemistry as well as the aspect and its related annual solar flux were the main factors that influence the deterioration of sandstone surface in the theatre (Paradise 1999).

From the above study, one can observe the vast challenge in the conservation issues in a site such as Petra, since the factors that influenced the deteoriation of the city monuments are numerous and varied from place to another even in the same monument.

5.3. The Chemical and physical evaluation of Petra building materials

A number of studies had evaluated the physical and chemical properties of Petra stone building materials, which is an wensstial step in any conservation work. For example, The porosity properties of Petra sandstone were studied by many researchers such as Jaser and Bargous (1992), Heinrichs and Fitzner (2000) and Al Naddaf (2002).

The main porosity was in ranges of moderate to high in the Middle Umm Ishrin Sandstone Formation and high to very high in the Upper Umm Ishrin Sandstone Formation and the Disi Sandstone Formation.

Jaser and Bargous (1992) examined the permeability of the different sandstone formations of Petra monuments in terms of the coefficient of permeability.

Jaser and Bargous' (1992) data showed that most Petra sandstone permeability measurements ranged between slight (class 4) in Disi, Upper Umm Ishrin and Middle Umm Ishrin Sandstone and very slight (class 5) in Lower Umm Ishrin Sandstone.

Al Naddaf's (2002) carried a comprehensive study on Petra stone materials where the mineralogical content, stone hardness, water absorption capacity, water uptake capacity and stone drilling tests had been carried on a number of samples from Petra building materials.

5.4. Salt Damage at Petra, Jordan: A Study of the Effects of Wind on Salt Distribution and Crystallisation (Bala'awi 2006).

The study had examined the scale of salt damage on the city of Petra. Also, the role of the environmental conditions around the monuments in the activation of salt damage had been evaluated. In particular, the role of wind speed in distribution and crystallization of salt had been explored. The results have shown that wind speed has a significant impact on salt crystallisation and distribution in porous materials, and thus on decay rates, and that fluctuating wind speed enhances salt damage more than steady speeds. In addition, the research has suggested an unexpected relationship between pore structure and the behaviour of salts under different environmental conditions.

The study concluded with recommendations for the conservation of the site of Petra. These include proposals for reducing the salt content of certain monuments and for protection against the effects of wind.

To conclude, one can say that the conservation work and research in Petra a wide range of issues, meanwhile the city and due to its high level of deterioration is still need an enormous effort in both the practical and research approaches in the conservation field.

6 Petra: The Problem

Most Petra monuments are endangered due to weathering processes (Heinrichs and Fitzner 2000). Fischer (1997) claims that more than 80 % of the sandstone façades in Petra have been eroded beyond recognition. It is worth remembering that in 1995 the World Monuments Fund inscribed Petra on its list of 100 Most Endangered Sites (Fitzner and Heinrichs 1998).

6.1 The weathering agents in Petra monuments

Natural processes and human activities as well as lack of maintenance in the ancient city are all involved in the weathering process. The natural causes of weathering are summarised below:

6.1.1 Tectonic movements (earthquakes)

According to a UNESCO Report (1992) and Jaser and Barjous (1992), Petra is located in a tectonically active region.

Due to the high seismic slip between these faults, the area has suffered a series of serious earthquakes. The monuments of Petra have suffered from a

wide range of destructive earthquakes, such as the earthquake of 363 AD that destroyed most of the Theatre, and the earthquake of 747 AD that destroyed most of the monuments in the centre of the city. Generally, statistics showed that an earthquake with a magnitude above 6 on the Richter scale occurs every 100 years or so in the area of Petra (UNESCO Report 1992).

6.1.2 Water erosion

As mentioned earlier, the rainfall in Petra is very low, but happens in a very short period. Subsequently, water erosion is a very active agent in such an environment. The Nabatean hydrological systems prove that the Nabateans were very much aware of the water erosion problem in their area; they constructed ceramic pipes along the bedrock and the face of the monuments to protect them from the running water. Moreover, the horizontal surfaces were covered with multilayered mortar to minimise the effect of running water on these features (Shaer and Aslan 2000).

Unfortunately, nowadays, the Nabatean water system is the main cause of water erosion at the site. Joints and cracks that were created by earthquakes as well as the clogging of the Nabatean water channels allow the water to attack the Petra monuments from within and from outside (Fischer 2000).

In short, the water is a major factor in the deterioration process in the city of Petra through flood damage, rainwater, runoff water, and capillary action (and their subsequent effects).

6.1.3 Wind erosion

Wind is another important weathering agent for the Petra monuments. Not only does it cause the destruction of monuments due to wind-blown sand (UNESCO Report 1992), but it also enhances other weathering agents, such as salt crystallisation (which is the main scope of this study). The effect of the wind-blown sand is mainly restricted to the lower parts of the monuments (1-2 m height), as these parts come into contact with sand particles (UNESCO Report 1992).

6.1.4 Salt crystallisation process

Salt crystallisation is another, if not the major, weathering agent in Petra monuments. Previous studies, such as Al Naddaf's (2002), showed that drilled samples from the Petra monuments are rich in sodium chloride and calcium sulfate, while the scraped samples were dominated by calcium sulfate. Bala'awi (2006) carried out a detailed survey of the salt types, locations and variations within selected monuments in Petra. This research was undertaken in order to examine the role of wind speed in the salt damage process in general, and in the world heritage site of Petra in particular. The study evaluated the role of wind speed in salt crystallisation and distribution. The research presented a detailed monitoring of the microclimate conditions and its role in the salt distribution at selected monuments in Petra, in order to understand the extent and mechanism of salt damage at these monuments. The research developed a salt simulation test that would include the effects of wind. The results have shown that wind speed has a significant impact on salt crystallisation and distribution in porous materials, and thus on decay rates, and that fluctuating wind speed enhances salt damage more than steady speeds.

6.1.5 Thermal shock

Due to wide variations in temperature, both daily and seasonally, the monuments in Petra suffer from what is known as 'thermal shock'. This kind of weathering is related to the fact that some minerals expand more than others at high temperatures and contract at low temperatures. A study of the temperature variations within a 24-hour cycle in Petra carried out by Fitzner and Heinrichs (1991) showed a difference of 20 ºC in the stone temperature and a difference of 21.1 ºC in the air temperature. In another study of the effect of thermal shock, Paradise (1999) concluded that, as a weathering agent, thermal shock was more effective in calcite-cemented sandstones due to the fact that calcite expands 25x10-6 µm/ºC parallel to the C-axis and contracts 4.9x106 µm/ºC normal to the same axis in temperatures between 18 and 50 ºC.

The evaluation of the effect of the thermal shock in the mechanical degradation of Petra monuments varies between scholars. Franchi and Pallecchi (1996) concluded that this is the main cause of stone deterioration in the Petra monuments, while others, such as a UNESCO Report (1992) considered it to be a minor cause. In accordance with this, this research supports the idea of the temperature variation having a minor effect and does not consider it to be a main cause of stone deterioration in Petra.

6.1.6 Biological weathering

The main biological weathering feature in Petra is the overgrowth of grass in and around the monuments. The availability of water allows vegetation to grow on some of the façades, such as the Corinthian Tomb causing considerable destruction of the façades' structure. Insect colonisation in certain monuments also enhances the damage by trapping the water under their nests and blocking its evaporation (Al Naddaf 2002). It should be stated that the impact, if any, of micro-organisms on stone decay in Petra, which could have a significant role in the biological weathering of the monuments, has not been studied.

6.1.7 Human activities

The human activities in the city make a considerable contribution to the deterioration of the monuments. Tourism is one of the main destructive factors. For example, Paradise (1999, 355) estimated that '20 percent of the original masonry marks were visible on the amphitheatre in 1990; however, only 5-10 remained in 1999 due to traffic pollution as well as the type of footwear tourists used at the turn of the century'. Moreover, the uncontrolled urban developments, in and around the archaeological site affect it negatively. This includes the hotel development, as well as the uncontrolled expansion of the villages around the site (Umm Sayhun and Wadi Mousa). This unrestrained development has not only impacted on the aesthetic integrity of the site, but has also increased the rate of pollution in the area.

7 Conclusion: What is really needed now?

Based on what had been presented, it can be concluded that the conservation work on the archaeological city of Petra had succeeded in many aspects. At the

same time, the study did revel clearly a number of issues that needed to be considered in any future conservation work with the city.

The lack of national conservation policy resulted in many conservation actions with different standard within the same site. Some of the projects focused on the aesthetic part and restoration were highly applied, while the others preferred prevent action dispute its disturbance to the context of the city. The establishment of national conservation policy is a must action and it should be a priority prior carrying out any further conservation projects. The policy should be based on the understanding of the site nature and needs. The policy should also consider the local community involvement in any future work. The policy will reduce the variations between the conservation projects standards the city of Petra and it will establish a well-defined system for prioritizing the conservation work on the city and how each project should be approached. The system should be simple and based on international with special considerations to nature of the city.

Also, the city of Petra did suffer from the large number of scientific research that had been carried out for conservation purposes. Dispute the fact, that all these researches were considerably informative, they were too many and the affect the authenticity of the site. The lack of co-ordination between these researches made some of the work repetitive, were the work in such site should be minimized. The formation of a scientific community with the city of Petra to supervise and coordinate the scientific research is a necessity. The community will be able to minimize the intervention of the scientist on the monument of the city and will have a data base that could provide the core information for any future conservation work.

The study had also showed that the conservation works brought up as immediate a necessity while a large number of excavations are taking place in the city. From the authors' point of view, the excavation should be stop in the city of Petra until the excavated monuments and archaeological remains are conserved.

Moreover, the current study had showed that the local involvement in the conservation projects were limited to seasonal conservation work. This had been resulted in a loss of the efforts that had been carried out to train the local and in establishing a national qualified center which could be able to carry out the responsibilities of the conservation work in the city.

In addition, it was quite clear that many of the conservation decision were made on personal judgments. In such unique city the decision should be collaborative and especially in the huge intervention all the stakeholders within the site should be consulted.

It has been also noted, that a little documentation had been provided for the conservation work within the city. The use of a comprehensive documentation system for any conservation work or research should be main concern in any future projects.

All in all, it could be summarized that the scale of conservation work that is needed for the city of Petra is enormous, and the critical review of what had been done before in conservation sector in Petra had revealed how the future work can

be approached. The establishing of a national conservation policy in Petra and the monitoring of the scientific research programmers as well as the focus on the conservation of the excavated monuments rather the excavating new ones are the main priority of the conservation work in the Nabetean city of Petra.

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