The ancient rock city of Petra, which lies south of the Dead Sea in the Hashemite Kingdom of Jordan, displays with its unusual sandstone architecture an abundance of evidence of the Nabatean culture. For this reason, Petra and its almost 4000 individual monuments was included in the World Heritage List of the UNESCO (United Nations Education, Scientific and Cultural Organisation) in 1985.

Petra has gained special recognition for its hundreds of rock facades carved out of the sandstone rock found there. Among the other monuments are the stone chambers without front facades termed shrines as well as sacrificial places and altars, inscriptions and scripture walls, stairs, roads, statues and relief’s, temples, simple homes and opulantly furnished villas.

The ancient stone city was the capital for the Nabateans from about 400 BCE until the fourth century CE and housed 30,000-40,000 people during its heyday. The Arabic tribe of Nabateans achieved great wealth and political-economic significance through caravan trading on the Silk and Incense Routes. In 106 CE, the Nabatean kingdom lost its independence and was incorporated into the Roman Empire as Provincia Arabia. It was an earthquake in 363 CE that dealt a decisive blow to the still important and extremely wealthy city and Petra increasingly lost importance as a metropolis.

As their territorial independence came to an end, the Nabateans lost the economic and political influence they once had. The Nabatean Era had come to an end.

Petra first recovered to some extent again in the middle of the 5th century CE. Although the majority of the residential city carved out of ashlar lies literally in ruins due to earthquakes, the facades chiseled in the rock leave a lasting impression of the wealth and importance of this former Arabic metropolis.

Today, the existence of the unique rock architecture of these monuments are in danger due decomposition, poor maintenance and lack of conservation. Due to the abundance of tasks to complete and the large number of monuments, appropriate concepts for possible protection and lasting conservation of these antique places are in question.

Within the scope of a dissertation in the field of Restoration and Stone Objects under the guidance of Professor Jan Schubert at the University of Applied Arts and Sciences in Hildesheim, Germany...
(HAWK), a care and conservation plan has been developed that aims at the lasting protection of the stone facades\(^2\).

During three years of on-site work and concrete field research in collaboration with the CARCIP (Conservation and Restoration Center in Petra), findings about the geology and geomorphology of the cambric sandstone could be gathered, acute safety repairs and restoration of the stone facades and temple grounds could be undertaken and new techniques for conservation could be developed and employed\(^3\).

In a series of articles in future issues, the results of individual focal points within these work areas will be presented.

Strong rains and sudden floods: a curse and a blessing in one

With few exceptions, all experts agree that the uncontrolled drainage of rainwater is the main cause for damage to the monuments\(^4\). Due to strong rains in February and March, every year heavy sudden floods occur through the narrow Wadis, which can swell up to torrential mountain rivers within minutes. These floods present the largest danger to the monuments\(^5\). The Nabateans, the builders and engineers of Petra, were well aware of the destructive strength of the waters. For this reason, the majority of the monuments are equipped with drainage canals. Today, these canals are blocked by fallen rubble or are partially destroyed, which has led to damage to many parts of the facades\(^6\). On the other hand, the water was a necessary life source and a blessing for the city and its agriculture. Numerous dams, canals and cisterns were capable of storing enough water to make the desert come to bloom. Even in remote valleys surrounding Petra, the many stone wine presses and irrigation facilities are evidence of the strongly developed agricultural usage of the entire region. The drainage canals upon the mountain tops and around the monuments were integrated into this system.

Inventory and Results

To date, no comprehensive inventory has been taken of the monuments in Petra. The German
building researchers, Brünnow and Domaszewski (1904), published the first survey of the monuments of Petra and proposed a numbering system that is still used today. A second survey attempt was made by the former director of the Institute for Antiquity and Christianity of the Holy Land, Gustaf Dalman (1912), who also created a numbering system for the buildings and extended the list to approximately 1000 monuments.

According to our inspections, of the 831 monuments that Brünnow and Domaszewski took inventory of in Petra, 539 were cataloged as stone facades. During the on-site field research, an inventory was created and exemplary photographs and written documentation were taken of the condition of 211 monuments, or one third of all the tomb facades. The inspections showed that over one-half of all the stone facades were equipped with drainage systems. These gutters and canals supplied the cisterns with rainwater and formed part of the water supply. In most cases however, these canals are blocked by rubble or are damaged so that the water now drains uncontrolled over the rock facades and damages them. The Corinthian Tomb, the Renaissance Tomb and the Urn Tomb along the Kings Wall in the city center are particularly prominent examples of this phenomenon.

To take inventory, a form sheet was created for each monument, which were then inspected according to a catalogue of different criteria. Special attention was paid to drainage systems, static tension cracks, loose ashlar and rock slabs, rubble and dilapidation. Furthermore, plastic decoration art and frame remains were searched for. Former and present use of the tomb interiors by the Bedouin Tribe, which inhabited Petra into the 1980s, was recorded. In order to create a quick overview of the condition of each particular monument,
to assure easy and understandable use and to fa-
cilitate communication between colleagues, sim-
ple checklists and symbols were used.

After evaluation of the inspection sheets, it became
clear that over one-half of all the stone monu-
ments dispose of drainage canals in the eaves and
at present many of these are blocked with rubble
or partially destructed or damaged.
The lack of care and maintenance can be seen
clearly in the situation in front of the monuments
and in the tomb and cult chambers. Over 70% of
the examined buildings are covered in rubble. At
the time of inspections, over 30% were polluted by
human or animal excrements or by garbage and
rubbish. Over 20% of the inspected cult buildings
showed remains of mortar, paint or stucco.
Almost 30% of the monuments were built of ashlar
that are presently in danger of collapsing. Also
threatening to collapse are the larger sandstone
blocks that were also used. The situation at the
Palast Tomb, which presently consists of 8% ash-
lar, at the beginning of the King’s Wall is particu-
larly alarming.
Approximately 30% of all monuments are covered
in cracks and crevices, which poses a danger to
both the building stability and visitors.
Only three tomb vaults, i.e. 1.4%, in the inspection
area are still inhabited by a Bedouin family.
In general, the centuries of Bedouin settlement in
the monuments did not cause much damage. The
Bedouins made very few constructional changes to
the monuments, and those that they did are re-
versible. Also, only few changes were made in the
tomb chambers.
However, open fires for cooking and heating left
visible marks in the rock vaults. The dense, black
soot on the sandstone surface is very difficult to
remove.
The rooftop of the central round building has an waterfall at the end of the plateau. The water flow continues into another facade creating a waterfall onto a small adjacent facade and flows along the back, right side of the monument far back in the Wadi to the left of the mountainside. The canal originates above the canals from the rainwater of the surrounding others, this monument was protected by drainage systems functional again and to reactivate their protective functions.

The drainage system of the Ad Dayr monument

All of the large, outstanding tomb facades in Petra dispose of a drainage system. As an example, the drainage system of the Ad Dayr monument will be presented here. Monument Nr. 462 on the high plateau of Ad Dayr is one of the most important and grandiose constructions in Petra. The impressive rock facade is one of the biggest cult constructions measuring 45.5 meters in height and width. Like many others, this monument was protected by drainage canals from the rainwater of the surrounding mountainside. The canal originates above the monument far back in the Wadi to the left of the facade and flows along the back, right side of the facade creating a waterfall onto a small adjacent plateau. The water flow continues into another waterfall at the end of the plateau.

The rooftop of both building wings to the left and right of the Pavilion were not worked on. They exhibit gutters that could in part be identified as canals, yet they could also be attributed to broken off ashlar. Several of these canals direct water onto the monument which has led to alveolar weathering on these contact surfaces.

Investigations of the intensity of weathering

Maps of the weathering rate and the weathering intensity were made based on photographs true to the architectural dimensions of 14 other monuments along the King’s Wall. The aim was to evaluate which weathering forms are predominant and to assess the condition of the tomb facades. Backwaterring of varying intensity and form are found on the monuments. The solid rock of Petra’s cambric sandstone is characterized by alveolar and tafoni weathering. Holes, hollows and erosion varying from a few centimeters to several meters in size. Due to the strong rains in February and March, heavy sudden floods occur through the narrow Wadis every year. As mentioned above, these floods are the biggest danger to the monuments. The eruptive impact of the water, however, plays a subordinate role. Instead, the water serves as a transport medium for the damaging salts dissolved some of the salt out of the rock structure. This salt deposits on the surface of the rock and leads to damages. This destructive salt is Halit (NaCl), or rock salt as our investigations and investigations of numerous authors have proven.

Aside from this surface weathering, the so-called alveolar and tafoni weathering defines the stone relief of Petra, causing holes and hollows varying from a few centimeters to several meters in size. Investigations showed two forms of weathering, the surface, relief-like weathering and the spatially limited backwatering (tafoni weathering). The differentiation between the two forms is difficult in places, because one type often transitions into another.

In addition, today many buildings are covered in cracks and crevices, stones threaten to crash down and entire areas, especially on the building corners, are fractured surfaces.

The results of the damage mapping show that most data among the defined categories differed greatly from monument to monument. The most similar data was gathered for the obtainment of building outlines, varying between 85.5% and 99.1%. This correlates with the perception of the large buildings from afar. Of the 14 mapped monuments, 95.9% of the buildings still retain their original form. The rate of weathering differs greatly between 18.1% and 99.9% with an average of 50.9%. The surface type of weathering dominates and averages 47.9%, the alveolar and tafoni weathering shows an average of 11.7%.

The uncontrolled drainage of rainwater must be made primarily responsible for the extreme weathering of all the monuments investigated in this expedition. The King’s Wall and most of the other
large tomb ensembles were protected by an effective drainage system which was an integral part of an ingenious irrigation system creating the groundwork to make Petra a blooming oasis for tens of thousands of people. The reactivation of certain parts of this system would be a lasting step toward the preventative conservation of the sandstone facades in Petra.

Acknowledgments

For their cooperative collaboration on-site, I would like to especially thank the director of the "Petra Stone Preservation-Project", Dr. Helge Fischer, the former director of CARCIP, Dr. May Shear, as well as the director of the Petra Archeological Park, Suleiman Farajat. For the permission to conduct field research on-site, I thank the general director of the Department of Antiquities of Jordan (DOA), Dr. Fawwas AlKhreyshah.

References

5. B. Lane, B. Boussquet, op.cit., p. 111.