

## CHAPTER SIX: CASE STUDY #3

### From Rock Art to Edifices:

*A Preliminary Adaptation of Pre-existing Field Techniques to Assess*

*Cultural Stone Stability in Petra, Jordan*

#### 6.1 – INTRODUCTION

The ancient city of Petra, hidden in the colorful sandstone cliffs of southern Jordan, has become one of the Kingdom's most popular tourist destinations and attracts visitors from all over the globe—but at what cost? Similar to many other popular destinations, widespread tourism was not prevalent in Petra until post World War II, when international travel became more accessible to the average consumer. Nominated by the International Council on Monuments and Sites (ICOMOS) as an irreplaceable archaeological site, Petra gained the esteemed distinction “Cultural Heritage Site” in December of 1985, effectively turning the once lost Nabataean Capital and its gateway town of Wadi Musa into the country's most visited tourist attraction with nearly a million visitors in 2010 (PNT, 2013). Within less than a century, the city of Petra went from a forgotten desert refuge to a booming tourist destination witnessing hundreds of thousands of visitors each year. Understanding the effects of this radical transformation—both the risks and benefits—is imperative to the city's long-term survival. While some monuments have begun to deteriorate more intensely under the strain of continual tourist activity (Paradise, 2010), others have experienced revitalization and restoration due to boosts in the local economy and notoriety that comes with global tourism.

As with rock art, the management of cultural stone sites, such as Petra, can benefit significantly from rapid field assessment techniques of stone decay and landscape change. Knowing how and where change is occurring can lead to more informed and effective management policies. An example of this process in Petra is the UNESCO-initiated “Siq Stability Project” where researchers identify potentially dangerous sections of the Siq, Petra's main entrance, allowing engineers and geologists to preemptively remove loose material before it falls or causes mass wasting (see [www.unesco.org](http://www.unesco.org) for more). This project has been relatively successful but it only addresses one specific area. Similar work has been conducted

in various parts of Petra (e.g. (Paolini et al., 2012), but more research is needed to truly understand the extent and cause of rock decay and landscape change throughout the ancient city. The other two case studies in this dissertation have illustrated how rapid field assessment techniques are efficient tools for providing cost effective and timely analyses of rock art stability—the same kind of analyses that could greatly benefit culturally and environmentally fragile places such as Petra. To that end, this chapter explores the merits of adapting existing rock art research methods to assess other forms of cultural stone via a preliminary analysis of monument stability in Petra, Jordan.

### **6.1.1 – Site Setting**

Located in southeast Jordan, the ancient city of Petra lies in the mountainous region between the highlands of the Wadi Araba and the vast eastern desert. The now-vacant monuments along the cliff faces and valley floor represent a long occupational history fostered by the steep protective cliffs and unique environmental conditions (Groom, n.d.). Part of the Northern Araba Drainage Basin, Petra's complex physical landscape contains dramatic cliffs, slot canyons called siqs, and a myriad of wadis (ephemeral streams) that run through the city (Figure 6.1). Poetically titled "The Valley of the Crescent Moon", the main valley of Petra resembles a crescent moon when seen from above. With an elevation ranging 900-1000m, the city exists within the transitional zone between the temperate Highlands and the arid Wadi Araba. While Petra's climate is technically a Mid-Latitude Dry Semiarid Steppe (BSk in the Köppen Classification), its cool, wet winters and hot, dry summers are more characteristic of a Mediterranean-type climate (Cordova, 2007). In the valley, average winter temperatures range from 6°-12°C with 15°-32°C in the summer with less than 130 mm average annual precipitation (Jordanian Meteorological Division, 1971). Collection of current long-term meteorological data has been limited due to complications ranging from theft of equipment to lack of sufficient funding. Petra's physical features and rainy winter climate make the valley prone to flash floods—the main valley, Wadi Musa, can be very dangerous during storms, especially in the narrow entrance at the Bab As-Siq (Al-Weshah & El-Khoury, 1999).

The relative abundance of wadis, along with strategic water management systems, has supported life in Petra for thousands of years—both flora and fauna. According to a biodiversity survey conducted in

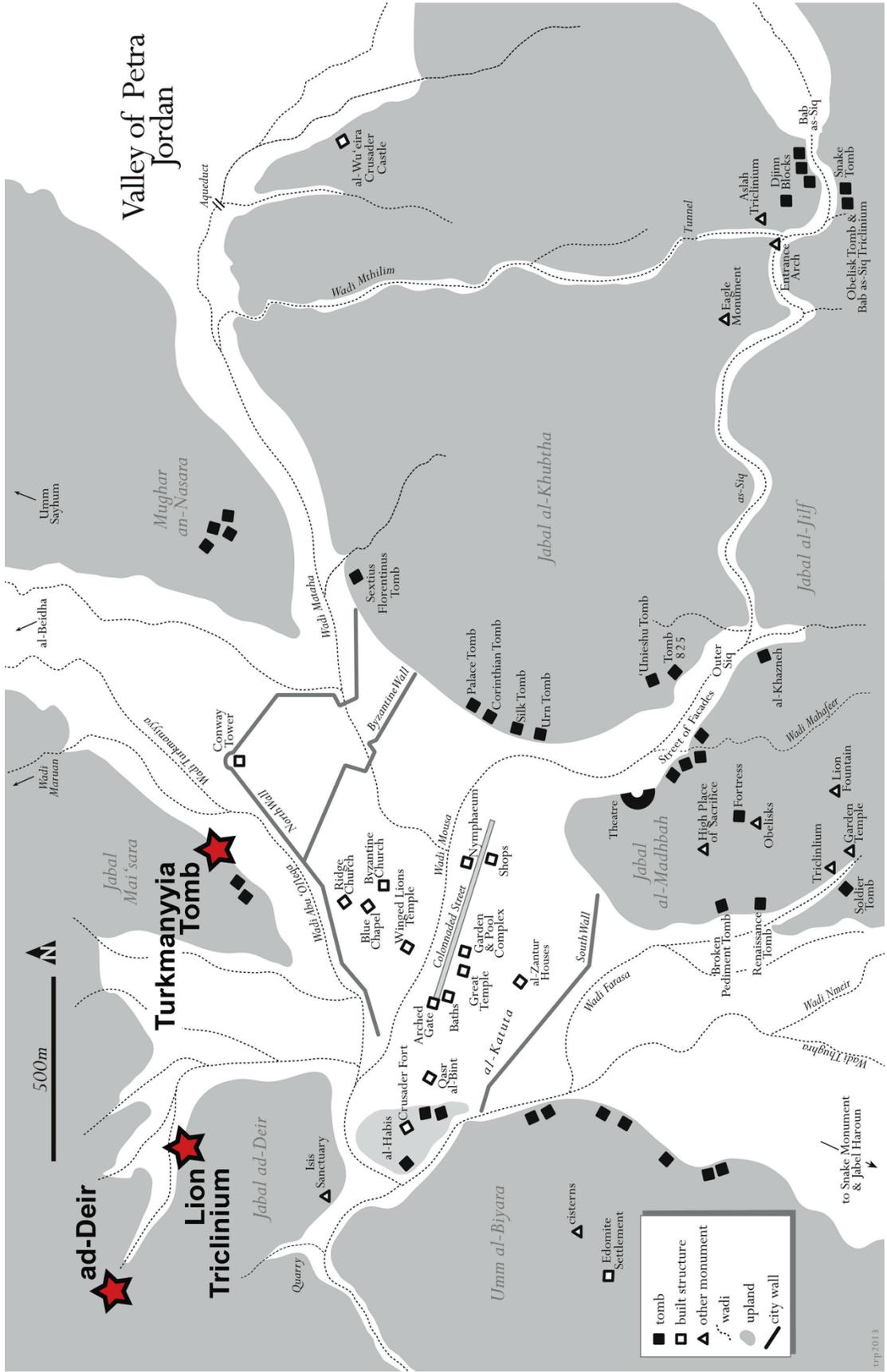


Figure 6.1: Aerial map of the Petra Valley with the three assessed monuments highlighted in red. Cartography by T.R. Paradise from J. Taylor (2001).

the mid-1990s, over 700 different plant species and nearly 400 animal species reside in the valley (Ruben & Disi, 2006). Flora in the valley mostly consists of *Anabasis* shrubs and *ziziphus lotus* with a spattering of *Haloxylon articulatum* and *Salsola villosa* in the saline wadi bottoms (Cordova, 2007). There are patches of greater hardwoods, such as Oaks, found around the area, although these are becoming less common. Native fauna in the valley, besides humans, mainly include various species of reptiles and birds. Most reptiles in Petra are snakes and lizards, such as several species of Fringe-Toed Lizards (*Acanthodactylus* Genus) and Dwarf Racer snakes (*Eirenis* Genus)(Maani, 2010). Petra's bird population, including both permanent residents and migratory species, range from birds of prey, such as European Scops-Owls (*Optus scops*) and Long-Legged Buzzards (*Buteo rufinus*), to small songbirds, such as Rock Martins (*Ptyonoprogne fuligula*) and the Blue Rock-Thrush (*Monticola solitaries*)(Maani, 2010).

However, Petra's most iconic and prominent physical feature is its vibrant sandstone. Accommodating the city's ancient architecture and embedded monuments, the valley's unique geology offers a mesmerizing display of color and texture. The contrasting red and white sandstones, liesegang banding, iron veins and nodules, and rich desert rock coatings have inspired countless poetic monikers for Petra such as "The Rose-Red City" (Burgon, 1845). Exhibiting some of the oldest exposed sandstone on earth, Petra's geology is comprised of two siliciclastic sections of the Ram Group: The Cambrian Umm Ishrin Sandstone and the younger Ordovician Disi Sandstone. The Umm Ishrin Formation is a quartz arenite with cross-bedded components of siltstone and mudstone, feasibly representing the fringe of a fluvial system (Abed & Khaled, 1983). The Umm Ishrin is also the source of the famous "Rose Red" color found throughout the city, although it also exhibits other colors including salmon, chocolate brown, and deep mustard yellow. Alternately, the distinctively white or cream Disi Formation composes much of the city's higher elevations and cap rock. Much courser in texture, the Disi Sandstone lacks horizontal cross bedding and was most likely deposited in a braided stream environment among dunes and sandbars (Alsharhan & Nairn, 1997). While the Disi formation is relatively uniform across much of Jordan, it is more inconsistent in Petra due to irregular contact and large amounts of interdigitation with the as-Shara Limestone on the northeastern edge of the valley near the Bedouin village, Umm Sayhoun (Bernd Fitzner & Heinrichs, 1998).

Since Petra's famous cultural components are, literally, embedded in their natural environment, both physical *and* cultural elements of the city can influence cultural stone decay and landscape change. Therefore, it is necessary to not only address the physical landscape but the archaeological site's historical and cultural context as well. Often called The Lost Kingdom of the Nabataeans, the Nabataeans were the earliest documented civilization to occupy Petra, beginning around 580 BC (Browning, 1973). The Nabataean people are credited with creating some of the most recognizable and inventive features in the city, such as the monolithic tombs of al-Khazneh (the Treasury) and ad-Deir (the Monastery) along with the intricate water retention system. Promising water and protection to caravans and traders traversing the brutal Arabian Desert, the city quickly became a thriving central hub in the region. Much like modern international cities, various cultures and ethnicities became integrated into the landscape, evident in the city's eclectic architecture and artifacts displaying Hellenistic, Roman, Assyrian, and Egyptian influences (Tholbecq, 2007). The city's success made it powerful and Nabataean Kingdom wasn't annexed by the Roman Empire until 106 AD, well into the height of Roman expansion (Fiema, 2003). Renamed "Arabia Petrea", the city was given typical Roman features, such as gardens and grand water features, along with the infrastructure necessary to sustain nearly 30,000 people (Fiema, 2003).

After major trade routes shifted to other Roman cities, such as Jerash and Palmyra, and the development of sea trade around the Arabian Peninsula, Petra's prosperity came to an end. Following gradual economic downfall, Petra was devastated by massive earthquake in 363 AD (Russell, 1980), possibly followed by catastrophic flooding (Paradise, 2012). Byzantine structures and architectural influences suggest at least some degree of human activity in the following centuries, but it is unclear how many people resided in the valley during this time (Fiema et al., 2001). Strategically located, Petra's Crusader occupation in early 1100s AD was limited to a few military outposts, such as the small mountain fort Al-Habis in the main valley and the larger fortress of Al-Wu'aira on the other side of al-Khubthuh mountain (Hammond, 1970). After the Crusader Kingdom dissolved in 1191 AD, Petra fell into obscurity, lost to the western world until Swiss explorer Johann Ludwig Burckhardt (1784 – 1817) "rediscovered" the city in 1812 (Browning, 1973).

While it is often coined a "lost city", many would argue Petra was never completely deserted. Generations of semi-nomadic Bedouins lived among in the ruins, especially members of the Bedul tribe,

making use of the caves and water retention systems. Primarily camel and goat herders, the Bedouins typically resided in large portable tents but the stone sanctuary of Petra was a convenient refuge. However, since the site's 1985 induction in the World Heritage program and exponential tourism growth, Bedouins are no longer permitted to live in the valley and the vast majority of the Bedul Bedouins were involuntarily relocated to the government-built village of Umm Seyhoun outside of the archaeological park (Shoup, 1985). While later installments of roads leading back to Petra allow Beduls a livelihood in the tourism sector, contention remains and the complicated relationship between the locals and the government agencies responsible for their expulsion present a number of heritage management and conservation challenges.

### **6.1.2 – Existing Rock Decay Research in Petra**

The majesty of Petra, and the unique management challenges it poses, has drawn the attention of several academic and scientific research communities—though the vast majority of research in Petra has been archaeological. In fact, Petra's scientific history has been dominated by intensive archaeological endeavors, such as the famous 1897-1898 Brünnow and von Domszewski survey of the Arabian Province during which nearly every monument in Petra was documented and numbered, designations still in use today (Brünnow et al., 1905), and the massive 1993-1997 exhumation of the Great Temple in the city's central valley (Joukowsky, 1998). More recently, areas of the ancient city still being cleared, excavated, and exposed to the thousands of visitors each year include the so-called "Royal Necropolis" on west side of al-Khubthah mountain (Wadeson, 2014) and the Petra Garden and Pool Complex adjacent to the Great Temple (Ramsay & Bedal, 2015).

That said, some archaeologists have recognized the complicated management issues threatening Petra and have focused their work on promoting more sustainable research and conservation methods. For example, in 2009, the lead scholars for the ongoing excavation of the Temple of the Winged Lions, sponsored by the American Center of Oriental Research (ACOR), pioneered the Temple of the Winged Lions Cultural Resource Management Initiative (TWL-CRMI). In junction with ACOR, the Jordanian Department of Antiquities, and the Petra National Trust, the initiative aims to regulate conservation techniques, improve and uphold educational standards for local management personnel,

and compile a comprehensive report of monument conditions and stability (Tuttle, 2013). The very need for such an initiative highlights the some-what chaotic nature of stone conservation efforts in Petra, despite the establishment of the Conservation and Restoration Center in Petra (CARCIP) in 2002.

There have been several preservation-focused studies conducted in Petra, but these are usually limited to disjointed preliminary monument-specific case studies, as many of the techniques employed were either prohibitively expensive or experimental. The focus of these studies have included exploratory pre-intervention examination of structural integrity and building materials (Bani-Hani & Barakat, 2006), laboratory analyses to identify the most appropriate mortar for the reconstruction and restoration of Petra's built monuments (Al-Saad & Abdel-Halim, 2001), multispectral photography and 3D recording for systematic documentation of decay (Haddad et al., 2015) and experimental applications of different conservation techniques on isolated tomb facades to test their effectiveness (Aslan & Shaer, 1996; Wedekind & Ruedrich, 2006). While most of these publications are goal-oriented and focus on the effectiveness of various conservation, restoration, and/or preservation methods and techniques, few address naturally occurring geomorphologic and rock decay processes directly.

Alternatively, Petra's unique stone landforms and geologic anomalies have also attracted academic scholars more science-focused without clear heritage conservation intentions. These studies have included geomorphologic research categorizing rock-fall hazards in the steeper cliffs (Delmonaco et al., 2013), identifying evidence of past catastrophic flood and earthquake events initiating massive landscape changes (Paradise, 2012; Russell, 1980), and investigating sandstone decay thresholds and tafoni development throughout the city (Gomez-Heras et al., 2012; Heinrichs, 2008; Paradise, 1995, 2013). Although historic preservation and heritage management entities could benefit significantly from empirical geomorphologic research such as these, there is surprisingly little discussion between the conservation practitioners and scholarly researchers in Petra—theoretically limiting what each side can accomplish (Smith et al., 2008).

That said, there have been a few scholars that have been able to bridge the gap between rock decay science and heritage/tourism management. In a time and resource intensive study, Bernd Fitzner and Heinrichs (1998) conducted numerous laboratory and in-situ field investigations to identify weathering (rock decay) profiles and decay rates, petrographic characteristics and weaknesses, as well as structural



factors such as porosity, pore-size distribution, water absorption and evaporation rates, etc., with the explicit intention of determining the most promising conservation techniques. While the scientific merits of this work are remarkable, the practicality of such an in-depth investigation for management purposes is questionable, especially for a site as large as Petra. Attempting to establish more timely research techniques, a UNESCO-lead research team recently conducted a preliminary rapid risk assessment meant to identify both natural and anthropogenic threats to Petra's landscapes (Paolini et al., 2012). Working with representatives from the Jordanian Department of Antiquities, the Raymond Lemaire International Center for Conservation (RLICC) at the Katholieke Universiteit Leuven in Belgium, the Getty Conservation Institute (GCI), and the Petra Development and Tourism Regional Authority (PDTRA), the results of the study were impressively detailed considering their limited time in the field. However, despite having experts from archaeology, geology, and engineering, the geophysical and rock decay components of the study were dangerously over-simplified, almost to the point of being counter-productive (Figure 6.2), only serving to further exemplify the debilitating disconnect between conservationists and geoscientists.

A possible solution to this conundrum may be a matter of adaptation. Instead of recreating new disparate methods and avenues of exploration between management and science, perhaps scholars need to focus on adapting components of pre-existing conservation practices with geomorphologic techniques to create more holistic research that can be accessible from both sides. This chapter attempts to do just that. Analyzing the same monuments as the Paolini et al. (2012) UNESCO risk management assessment, the Dier, the Lion Triclinium, and the Turkmanyyia Tomb, this case study illustrates how adapted existing research methods and rapid field assessment techniques can benefit heritage management in scientifically disconnected places such as Petra, Jordan.

## **6.2 – CASE-SPECIFIC METHODS**

As a case study to assess both monument geologic stability, rock decay, and overall landscape change in Petra, elements lacking in the UNESCO study, all three monuments were assessed using an adapted version of the Rock Art Stability Index (RASI) called the Cultural Stone Stability Index (CSSI) along with repeat photography. While more in-depth descriptions of both RASI and repeat photography can be found in Chapters 3.2 and 3.3, respectively, this subchapter outlines specific details pertaining to

this case study, such as RASI's conversion into CSSI and the source of historic photographs for repetition.

### **6.2.1 – Cultural Stone Stability Index**

In most situations, rock decay is ubiquitous. All stones decay, regardless of geologic material, function, or content. The same major geomorphologic processes that damage rock art panels also threaten all other forms of natural and cultural stone. Therefore, with only a few terminological changes, the core index that composes RASI can be adapted to address a broader research topic of cultural stone. Termed the Cultural Stone Stability Index (CSSI), this modified index can be used to assess anything from building facades and statues to bridges and gravestones. The CSSI functions in the same manner as RASI. Practitioners define and sketch the target feature (or panel for RASI), and then rate each rock decay process on the same scale of 0-3 divided into the same six categories, ending with a doubled final score indicating the feature's geologic stability. In fact, the indices are so similar that RASI has been used to assess built monuments well before the conception of CSSI (Groom, 2011).

Within the index itself, only a few changes are needed to transform RASI into CSSI (See Appendix G for a visual comparison). These changes are usually terminological and not related to different rock decay processes—simply broadening the scope from specifically rock art to encompass more general cultural stone subjects. For example, the RASI item “rounding of petroglyph edges” is changed to “rounding and/or blurring of carved edges or inscriptions”—both elements rate loss of detail, just in different terms. Although, there are a few elements added specifically for buildings and cultural stone decay completely unrelated to rock art, such as “anthropogenic fissures” in the Site Setting and “anthropogenic joints/jointing” in Incremental Losses, both focusing on decay processes involving mortar work.

The section that requires the most modification is Rock Coatings, due to the different roles of rock coatings between rock art and other cultural stone (Dorn, 1998). For certain types of rock art, many rock coatings are not only beneficial, but also necessary for their existence. Most petroglyphs, for example, are created by pecking or scraping through rock coatings to reveal the raw stone beneath the surface (Whitley, 2005). The contrast between the coated exterior and newly-exposed interior makes the art

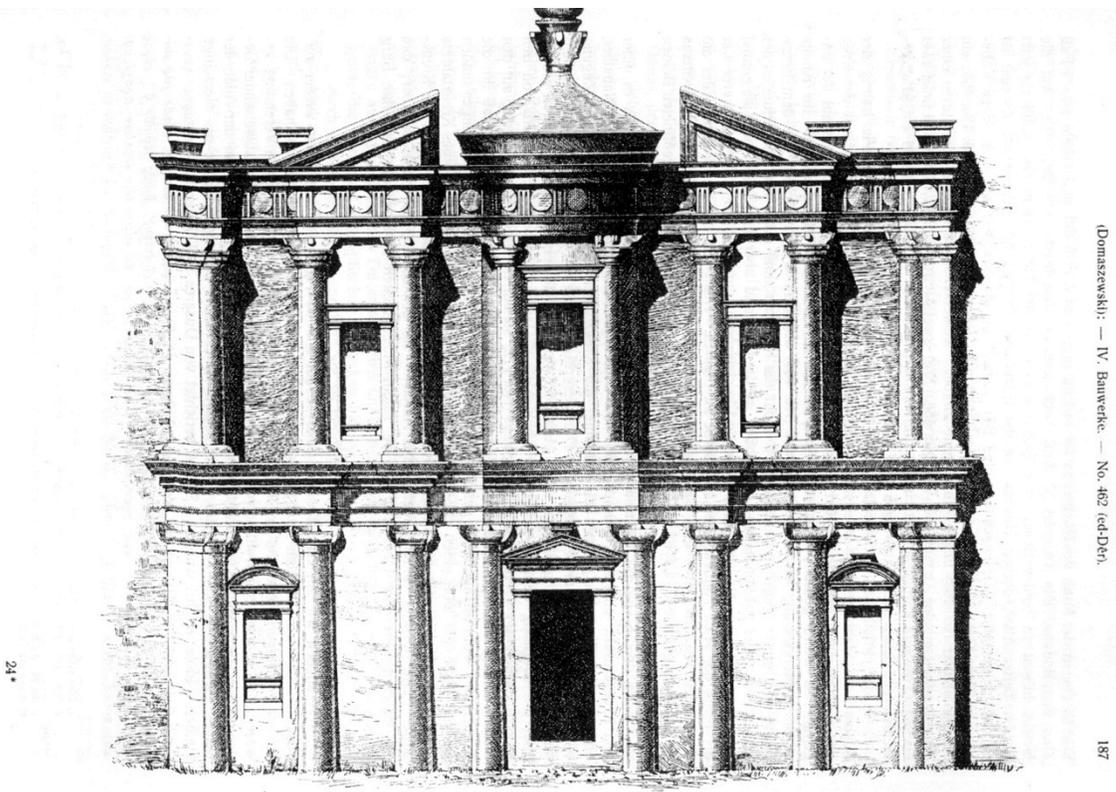
possible. Therefore, in RASI, two of the four rock coating elements have negative scores—indicating them as stabilizing agents. Alternatively, stone building facades and most other cultural stone are created with freshly quarried material, so any rock coating accumulation takes place after the stones are already in situ and beginning to decay. Also, since historic buildings and cultural stone often exist within cities and populated areas, as compared to the relative isolation of rock art sites, they may experience higher exposure to air pollution and urban traffic exhaust, leading to the development of harmful toxic rock coatings (Smith et al., 2005). To accommodate this difference, the CSSI adds two more elements to the Rock Coating section: “carbonate coating” and “oxidation”, each with positive scores reflecting their destabilizing influence. The two Rock Coating elements with negative scores in RASI (“case hardening” and “rock coated present”) still have negative scores in CSSI, but with CSSI the specific coatings associated with pollution and enhanced urban decay (carbonates and oxidation) can be individually evaluated and added to the total score.

While CSSI shares most of RASI’s strengths and weaknesses as a research tool (see Chapter 3.2.1 for review), there are a few new challenges and benefits that come with CSSI specifically. For example, Unlike RASI, CSSI compares current conditional statuses against assumed non-decayed baselines, since most cultural stone resources were created from “new” material. With RASI, researchers need to recognize that there will be a certain degree of “inherited decay”—rock decay that took place before the rock art was created—in their final scores since most rock art exists on pre-exposed surfaces. In contrast, the “virgin surfaces” of built monuments and building facades foster the assumption that all decay present has occurred after the completion of the resource. This assumption provides researchers with a controlled timeline of decay—allowing them to estimate factors such as rates of decay and date of decay initiation, which are much more difficult to calculate in natural settings. That said, the possibility remains that assumed baselines can skew results if the original surface was different than presumed (e.g. if stone dressings imitating textural deterioration were applied intentionally). In surveyed sites, such as Petra, baselines could be structured after archaeological records or sketches created by early scholars in the region (e.g. Figure 6.3).

Another practical difference between RASI and CSSI is one of panel/feature definition. When preparing a rock art site for RASI analysis, individual panels are usually fairly easy to distinguish and are

often already identified via archaeological surveys or site records (e.g. Groom & Poole, 2010; Groom & Thompson, 2011). Rock art panels usually consist of relatively flat and uniform surfaces, such as cliffs or sides of boulders, so division can be based simply on panel aspect or concentration of motifs (e.g. Groom, 2016c). When dealing with large building façades, statues, or other more detailed cultural stone, site mapping and preparation can be a little more complicated, but also more flexible. CSSI researchers have the ability to define panels/features in whatever way best suits allotted field time, available resources, or desired precision. For example, a square building could be divided into four panels by aspect (i.e. “north side”, “east side”, “south side”, “west side”) or the same building could be divided by feature (e.g. “north side window arch 1”, “north side window arch 2”, etc.). That same building could be assessed by aspect first, and then any specific characteristics of particular interest or importance can be analyzed individually. A large building façade could be just as easily divided into a handful of quadrants or dozens of individual elements, depending on the design and intention of the research. While studies with more panels will provide a more detailed analysis, they are much more time intensive and risk becoming counter-productive. The intention of techniques like RASI and CSSI are to provide cost-effective rapid field assessments. If a building were divided into too many elements, a CSSI investigation would be prohibitively slow and potentially defeat the purpose of the work.

In Petra, to best utilize the benefits of CSSI while remaining within its limitations, this case study only includes three monuments, each divided into 8-18 panels each, despite massive differences in monument size and detail. The largest of the monuments, ad-Deir (or the Monastery), could have easily been divided into hundreds of panels but for the sake of time and detail necessity, it was divided into 18 panels based on prominent feature areas and architectural division. The assessment also included two panels on either side of the monument to provide context. The next largest monument, the Turkmanyia Tomb, actually has the smallest number of panels (only 8 panels) due to the relative simplicity of façade décor and hewn features. However, the Turkmanyia Tomb is significant in Petra in that it displays one of the world’s largest Nabataean inscriptions along its mantel. Therefore, after the monument was divided into 6 main panels, including contextual panels on either side of the monument, two more panels were designated to specifically address the area with Nabataean writing: one incorporating surrounding features and one dedicated only to the area with the inscriptions. This kind of flexibility within panel



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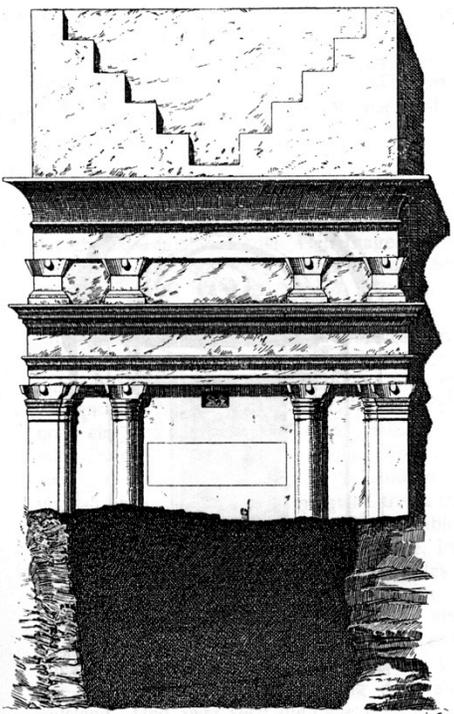


Fig. 172. Petra — Typus: Heḡr — vier kurze Pilaster in der Attika — zwei Halbsäulen und zwei mit den Eckpilastern gekuppelte Viertelsäulen — (Giebeltüre). — No. 633.

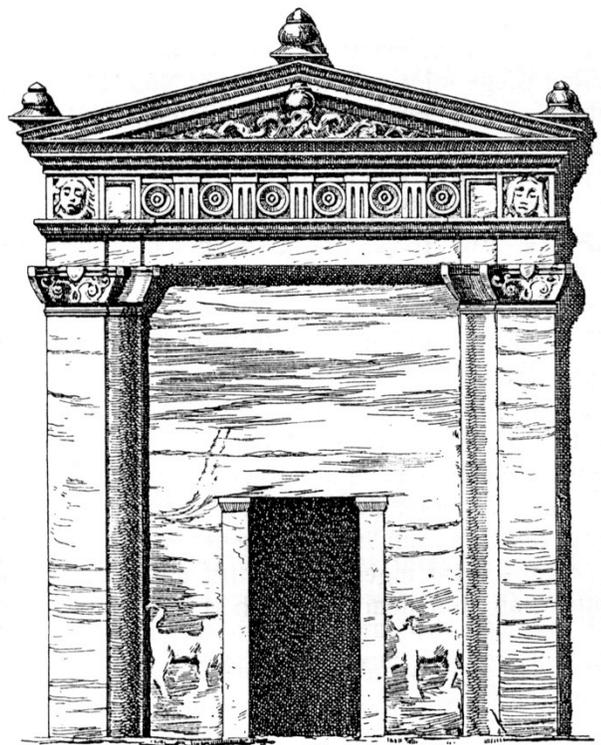


Fig. 190. Petra — Römisches Tempelgrab No. 452.

Figure 6.3: Conceptual sketches of the three assessed monuments from Brünnow et al. (1905)—one of the first extensive surveys/publications addressing Petra.

definition is unique to CSSI, as it allows researchers to put an emphasis on key features of whatever cultural stone is being assessed. The third and smallest monument, the Lion Triclinium, was separated into 12 panels, including 2 contextual panels and a small icon niche to the left of the main monument. Similar to the Turkmanyia Tomb, the Lion Triclinium was divided by general features but then additional panels were dedicated to specific elements unique to the monument: two carved lions on either side of the tomb entrance and two intricately carved faces in the monument's pediment, all assessed individually.

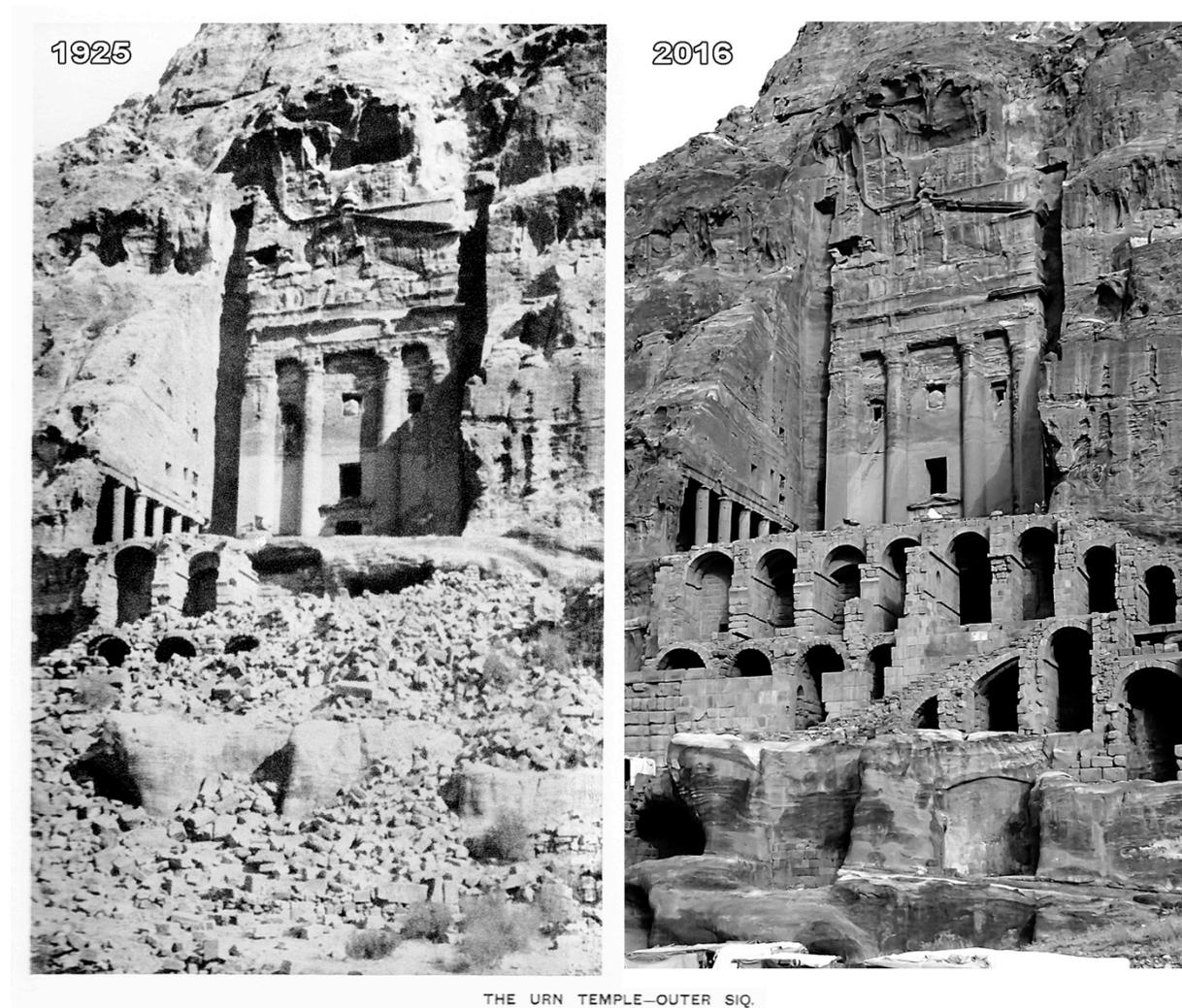
Although CSSI has been in development for years, this is the first time it has been employed as part of a stand-alone research agenda, as opposed to the unpublished academic pedagogical purposes for which it was created. Three researchers, each trained in both RASI and CSSI, evaluated every panel/feature for all three monuments, resulting in 114 total CSSI scores. Each panel's three scores were analyzed to provide a mean score, representing the assessment of all three researchers in one final score. These final scores were also averaged per site to calculate an over-all monument stability score, useful for quick comparisons between sites. Major concerns CSSI identified for both individual panels and sites in general were further investigated temporally using supplemental repeat photography at all three monuments.

### **6.2.2 – Repeat Photography**

Repeat photography is a powerful rapid field assessment technique for quickly identifying landscape change over time (See Chapter 3.4 for more details), making it an ideal supplemental tool to assess Petra's monuments and their surroundings. Just as all stones decay, all landscapes change, it's just a matter of how and why. In Petra, each occupational period in its history left characteristic marks on the landscape: Nabataeans created iconic hewn monuments, such as the Khazneh and the Royal Tombs; the Romans left behind opulent pools, gardens, and temples; the Byzantines converted tombs to churches and marked the landscape with their distinctive mosaics; the Crusaders built forts borrowing stone blocks from previous civilizations' ruins; even the semi-nomadic Bedouins changed the landscape by occupying caves and grazing livestock throughout the city (Taylor, 2001). It, then, stands to reason that the current occupation of Petra, its "touristic occupation", is also influencing Petra's ever-changing

landscape. Monument reconstruction and restoration with modern building materials are just a few examples of this influence (Fig 6.4).

In order to examine the impact of tourism on Petra's landscapes, as well as provide temporal control to CSSI stability analyses, this case study compared current landscapes with historic photographs pre-dating modern tourism in Petra. In 1925, long before international leisure travel was accessible to the average consumer, Sir Alexander B.W. Kennedy published a book titled: "Petra: Its History and Monuments". Contained within this volume are more than 200 high quality photographs of Petra's landscapes, monuments, and archaeological artifacts. The landscapes depicted in these photographs,



*Figure 6.4: Repeat photographs of the Urn Tomb, one of the Royal Tombs. The reconstruction of the stairs and arches with modern materials are among the most notable changes. 1925 photograph from A. B. W. Kennedy (1925). 2016 photograph by author.*

taken nearly a century ago, are raw and practically devoid of tourism, providing an excellent base line for modern comparison—and the differences can be rather stark. While there is immense potential for other tourism research involving Kennedy’s 1925 volume, this case study only repeated three photographs: one of each of the three monuments. These repeat pairs were analyzed alongside the CSSI assessments to provide a more holistic rapid field assessment of both monument stability and contextual landscape change over the last century.

### **6.3 – RESULTS AND ANALYSIS**

Including both CSSI scores and repeat photography pairs, the results of this case study are organized by monument: ad-Deir, the Turkmanyyia Tomb, and the Lion Triclinium. Individual scores, site averages, and major management/decay concerns are identified and discussed. Further exploration of method efficacy and significances, as well as site-to-site comparisons and future avenues of research, takes place in the subsequent sub-chapter.

#### **6.3.1 – *ad-Deir (The Monastery)***

Located high in the western cliffs of Petra, the Deir (or *ad-Deir*, meaning “the Monastery” in Arabic) is among Petra’s most impressive and iconic monuments. Measuring roughly 50m X 45m (165ft X 148ft), the massive double-story façade is one of the largest monuments in Petra and is thought to have been carved in the third century AD, though a number of chiseled crosses on the interior walls suggest it was adapted for Christian purposes several centuries later—thus the designation “Monastery” (Harding, 1990). Heavily influenced by the popular Hellenistic and Classical styles while also maintaining certain distinctive native elements, the Deir is an amalgamation of disparate architectural features characteristic of the Nabataean style (Browning, 1973). With its monolithic pilasters and quintessential split-cornice with subtle crow step decoration, as well as the absence of porticos or overly-intricate ornamentations, some scholars have praised the Deir as representing the height of Nabataean architecture and artisanship (Browning, 1973; Harding, 1990). Browning (1973) describes the design of the Deir as “Hellenism has been brought to heel and made to serve the Nabataean tradition” (p. 97).

Sitting at a higher elevation than the other two assessed monuments, the Deir is hewn from the picturesque golden-white Disi Sandstone formation. The general friability and vulnerability of the Disi formation is exemplified by the myriad of tafoni, sandstone drapery, and other advanced rock decay features on the cliffs surrounding the monument. Decay is also present on the Deir itself, though the sheer size of the façade gives it a deceptively stable appearance. To best evaluate the monument, the Deir was divided into 18 CSSI panels, including four contextual panels—dressed surfaces on either side of the formal monument itself. Because this particular façade is so large, each “panel” was several meters across and included multiple design features that might have benefited from more focused examination. That said, the purpose of rapid field assessments is to gain a quick “snap-shot” of general decay in order to quickly identify problems or areas that require more detailed analysis in the future. Prematurely separating the Deir into smaller sections would have been prohibitively time-intensive and counter-productive to the intention of the study.

#### CSSI

With an average CSSI site score of 59.09, the Deir rests precariously between the second highest and highest descriptive categories for RASI/CSSI—*Great Danger of Erosion* and *Severe Danger of Erosion*, respectively—indicating significant issues with this massive monument (Figure 6.5). Seemingly stable when viewed from a distance, the grandeur of this façade serves to mask the myriad of decay processes negatively impacting the stone. In fact, binoculars were required to assess the upper levels, since the size of the monument limited access and viewing necessary to accurately identify decay features, many of which were indistinguishable with the naked eye from the ground. Upon closer inspection through binoculars, the Deir’s many stability concerns are much more apparent.

These issues are reflected in the site’s CSSI scores, with stone texture and corresponding factors causing the most concern. Incorporated in nearly every category of RASI/CSSI, texture is a physical characteristic of stone reflecting intrinsic lithological features, such as clast/matrix ratios, and can influence decay. For example, Paradise (1995) discovered several thresholds where sandstone matrix compositions, closely related to texture, strongly influenced decay rates. Arguably, rougher textures, manifestations of stone porosity characteristics, may suggest the stone is either more susceptible to or

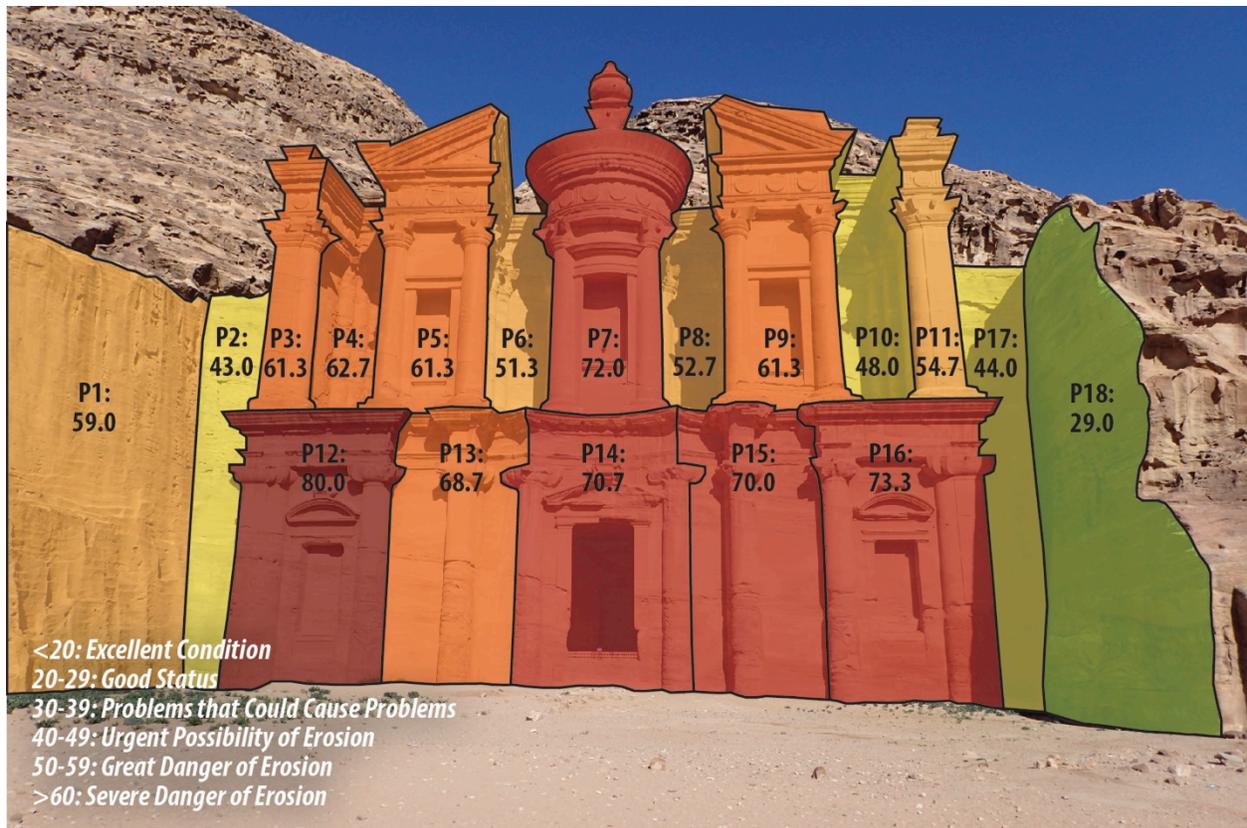


Figure 6.5: The different CSSI panels and scores for the Deir. Colors coordinate with degree of degradation, ranging from green indicating stable conditions to yellow, to orange, to light red, to dark red signifying the highest CSSI scores and most significant decay. Graphic and photograph by author, 2016.

already experiencing decay processes that involve a deterioration of the matrices responsible for holding clasts together, such as flaking (both preparing and detached), granular disintegration, and scaling (McKinley & Warke, 2007; Prikryl & Smith, 2007)—all of which regularly scored high at the Deir. Changes or discrepancies in texture can also affect decay, such as iron banding creating impermeable layers within the stone stopping the movement of water, salts, and dissolved minerals between substrates. This can cause a build up of usually mobile elements, effectively localizing decay along specific textural boundaries (Warke et al., 2006). This is the case for the Deir, as bountiful iron concretions and leisegang banding throughout the monument have channeled decay along specific strata.

Textural anomalies have also created a spatial pattern of decay for the Deir, with the lower levels experiencing relatively higher rates of decay than the upper levels. Decay features commonly associated with salt accumulation, such as flaking and granular disintegration, ranked higher along the ground level



*Figure 6.6: Closer photograph of the textural anomalies on the Deir Panel 12. Much of the horizontal striations and red coloration are exposed areas of the host sandstone where the stone dressing has deteriorated. The green patches are small bushes (roughly 0.5 meters diameter) for scale reference. Some graffiti and vandalism can be found on the lower sections of both columns. Photograph by author, 2016.*

panels than the upper story panels with noticeably different surface textures between levels. This is most likely due to a large iron band dissecting the lower level of the monument, creating a distinctive stopping point for wicking salts and minerals migrating up the stone. The highest scoring panel at the site, panel 12: 80.0, contains the largest section of exposed sandstone below this boundary, exhibiting the immense damage that can be caused by concentrated salts and other expansive minerals (Figure 6.6).

Additionally, anthropogenic textures may also seem to influence decay, as the panels with fewer carved details, such as the inset panels 4,6,8, and 10, as well as the contextual hewn walls on either side,

earned much lower scores than the more intricate protruding edifices, though this could be due to other factors such as differences in environmental/insolation exposure or visibility limitations during analysis.

### *Repeat Photography*

Providing a more aesthetical assessment of the Deir's contextual setting and physical condition, the repeat photography analysis identified a few major landscape changes over the past century that could influence the monuments stability moving into the future (Figure 6.7). The most obvious change has been vegetative. The shrub growing on the upper façade has been removed and the thick vegetation growing around the base of monument has been reduced to scattered grasses. The ground change in ground cover could be due to a number of factors including grazing, increased foot traffic, climate change, or intentional removal to enhance visual appeal or access to the site. Another explanation for the vegetation loss may be minimal excavation of the hewn niche in the left hand side of the image, as evident by a lower ground levels in the area and newly exposed soil lines and horizontal fissure in the recent repeat. In addition, the trees growing to the right of both pictures, subsequently obscuring part of the façade, are different species, indicating the previous tree either died or was removed and the current tree has grown in its absence.

In terms of the monument itself, the repeat pair illustrates the deceptively intact appearance of the monument by revealing relatively little discernable difference over the past century. Major decay concerns identified in the CSSI analyses appear to have been influencing the monument long before modern tourism was established in the valley. The large textural band influencing CSSI scores on the lower levels of the monument is clearly visible in the historic image, along with the advanced decay in the areas below it. The most significant structural difference between the photographs is the large hole in the center upper window. Closer inspection revealed what appear to be several bullet holes around the intentionally removed material, indicating vandalism as the cause for the discrepancy (Figure 6.8).

Unfortunately, vandalism and unsafe behavior is an on-going problem in Petra and at the Deir, forcing authorities to erect fences, signs, and walls denying access to fragile and potentially dangerous areas. The newly established guardrail preventing people from entering the inner chamber of the Deir is clearly visible along the base of the entrance, as well as the various signs informing visitors that going

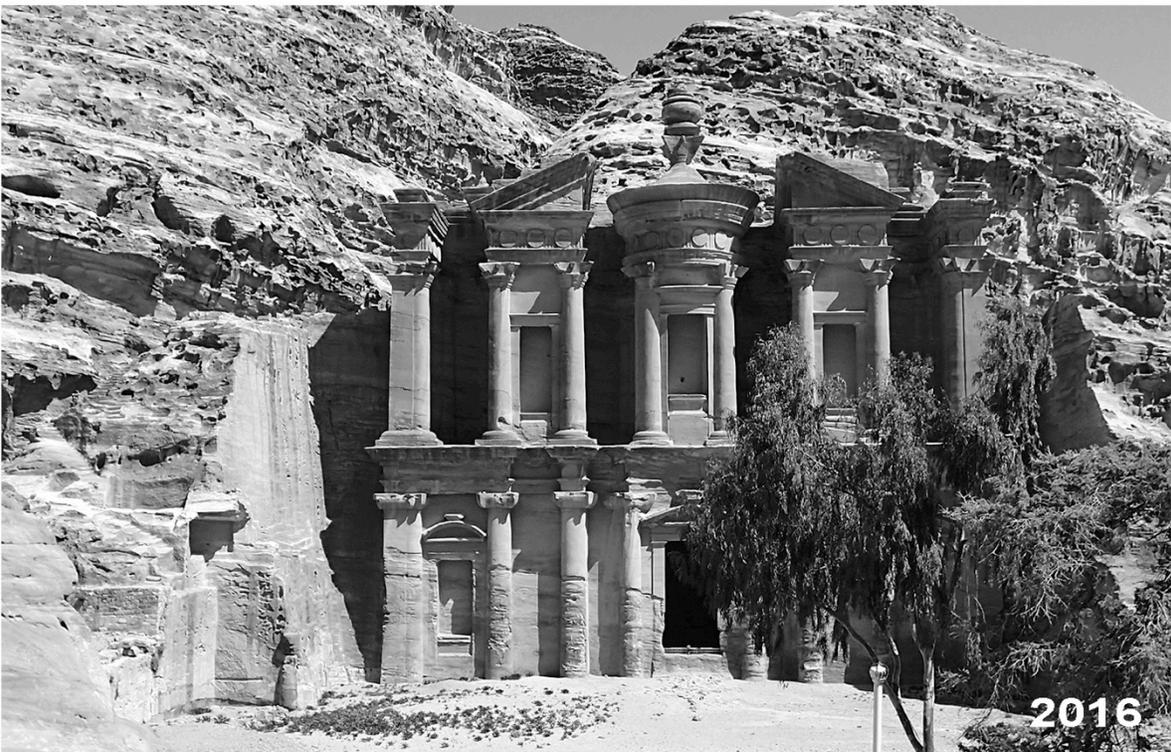
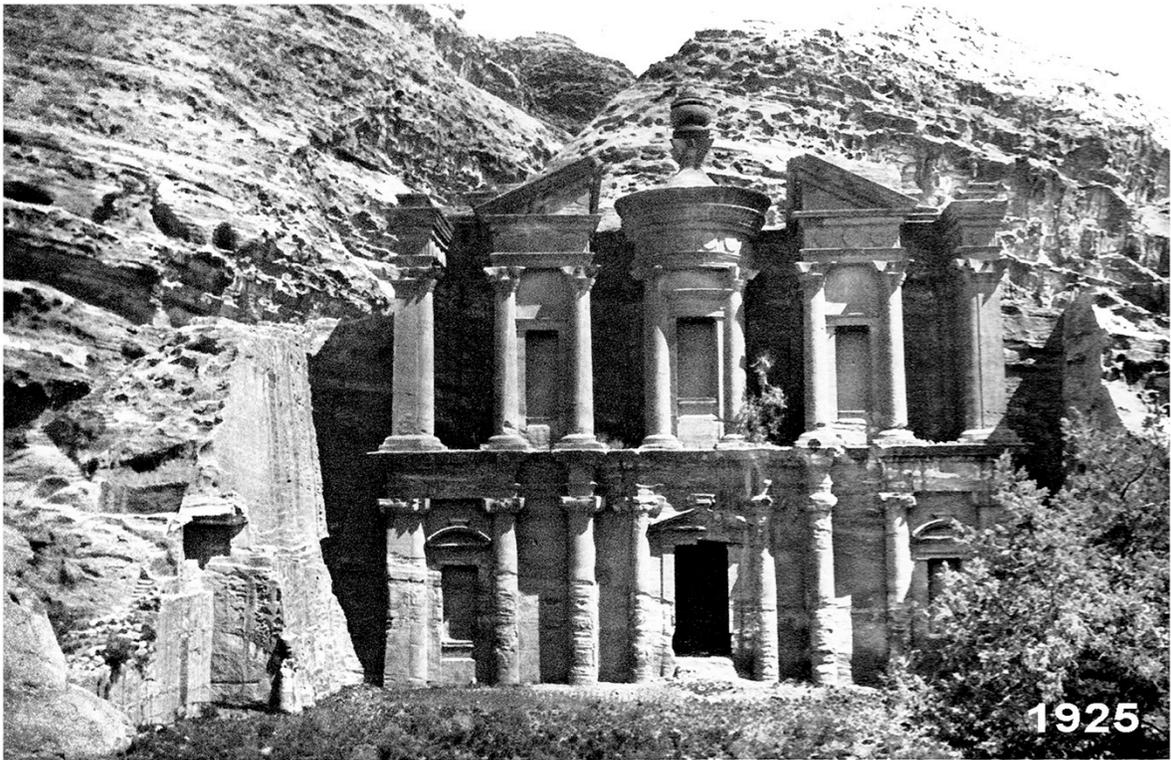


Figure 6.7: Repeat photographs of the Deir (The Monastery). 1925 photograph from A. B. W. Kennedy (1925). 2016 photograph by author.

beyond the rail is forbidden. In addition, visible in the lower left corner of the images is a small, reconstructed rock wall blocking a questionable footpath leading up the monument's colossal ornamental urn. The path, as well as another trail leading behind the monument, was sealed after a tourist reportedly fell to his death from the top, though no reliable references could be found to confirm this. Despite these heightened restrictions, the Deir is still one of Petra's most famous attractions and local business owners have established a small café and seated viewing area just beyond the scope of the repeated photographs, though the exhaust pipe from the café is visible in the lower right side of the modern repeat.



*Figure 6.8: Closer view of the bullet holes and damage within the highest false window, or niche, of the Deir. This inset is in the center panel of the second floor, directly beneath the monument's iconic cone spire and urn decoration. Photograph by Casey Allen, 2016.*

### **6.3.2 – The Turkmanyia Tomb**

Located just off the small paved road leading to the Bedouin Village of Umm Seyhoun and technically beyond the boundaries of the archaeological park, the Turkmanyia Tomb is unlike most other monuments in Petra and presents unique management challenges. Dating to the mid-first century AD, the Turkmanyia tomb exemplifies the simple and eclectic Nabataean architectural style sporting a separated crow step cornice paired with relatively basic mantels and column decorations (Taylor, 2001). The key feature of this tomb is a long intricate Nabataean inscription above what was once the door. While there are a few other small and personal inscriptions around the region, the formality and décor of the Turkmanyia script is unmatched in Petra. Scholars have interpreted the inscription as declaring the tomb and everything in it under the protection of Dushara (the supreme Nabataean deity), as well as dictating the legal and religious requirements for anyone wishing to be interred within (Browning, 1973). The stylized calligraphy of the Turkmanyia inscription actually reminded early scholars of writings found throughout the Sinai, as seen by Murray (1858) describing it as “Tomb with Sinaitic Inscription”. It wasn’t until the later-eighteen hundreds when the script was properly identified as Nabataean (Doughty, 1888).

Situated lower in the valley, the Turkmanyia in part of the iconic red Umm Ishrin sandstone so the delicateness of its inscription is rivaled only by the intensive decay processes that surround it. Adjacent cliff walls are perforated with tafoni, sandstone drapery, and fissures while leisegang banding and iron concretions constrict water, dissolvable solids, and salt movement to particular areas and strata, resulting in the spectacular display of color and texture for which Petra is famous. Unfortunately, these processes have already had detrimental impacts on the monument itself, as the majority of what was once assumed to be the main entrance and lower portion of the monument has complete disintegrated and several fissures now intersect the entire façade, including the inscription. Some of these fissures coincide with iron banding and run all the way into the interior rooms of the tomb. With so many threats, it was imperative to assess not only the general monument features, but also its key element and context. Therefore, the Turkmanyia tomb was divided into six panels, including contextual panels on either side of the monument, and then the panel containing the inscription was further subdivided into two more telescoping panels: one with the inscription and the immediately surrounding area and another containing only the inscription itself.

## CSSI

The most damaged of the three assessed monuments, the Turkmanyia Tomb had an average CSSI score of 67.8, well within the highest descriptive category: *Severe Danger of Erosion* (Figure 6.9). Nearly every panel scored between mid sixties to mid eighties—dangerously high for RASI/CSSI scores. The only two exceptions, panels 7 and 8 scoring 55.3 and 38.0, respectively, were supplemental panels designated to assess specific elements within broader panels/features. That said, the general panel on which they are located, panel 5, scored 64.0, which is considered *Severe Danger of Erosion*.

Experiencing most of the rock decay processes typical for sandstone, the CSSI scores for this monument identified major concerns in nearly every section of RASI/CSSI, but the most immediate issues appear to be structural. There are several fissures transecting the façade and the surrounding cliffs, some even spouting springs or vegetation. One large fissure runs vertically through the entire monument and well into the hollowed out interior as well. The disjointedness of the cliff-face makes the tomb vulnerable to undercutting and detachment of large boulders (Wolters & Müller, 2008). In fact, the majority of the monument's lower façade is completely missing, presumably due to rock fall and undercutting. These concerns are reflected in the CSSI scores, as both fissures (independent *and* dependent of lithification) and undercutting (both preparing and detached) consistently scoring high at this site. In addition, some of the smaller fissures have begun to infill with dust and sand, making fissure development, where physical and chemical interactions between accumulated soils exacerbate fissure expansion (Villa et al., 1995), a possible threat to the façade in the near future—though they do not appear to be an immediate problem (only scoring 1s and 2s in CSSI).

While broader structural concerns were the most intense, smaller topical decay is also greatly impacting the visual integrity of the Turkmanyia. Aesthetical elements, such as rounding of the carved features and loss of design details, regularly warranted higher scores. Disaggregation decay processes, such as granular disintegration, crumbly disintegration, and abrasion (all scoring high in CSSI), are prominent across the façade and have effectively reduced large portions of the monument to indistinguishable ledges or pediments with the appearance of having melted. Across the entire monument, there is only one small section on panel 5 that still displays intact original stone dressing

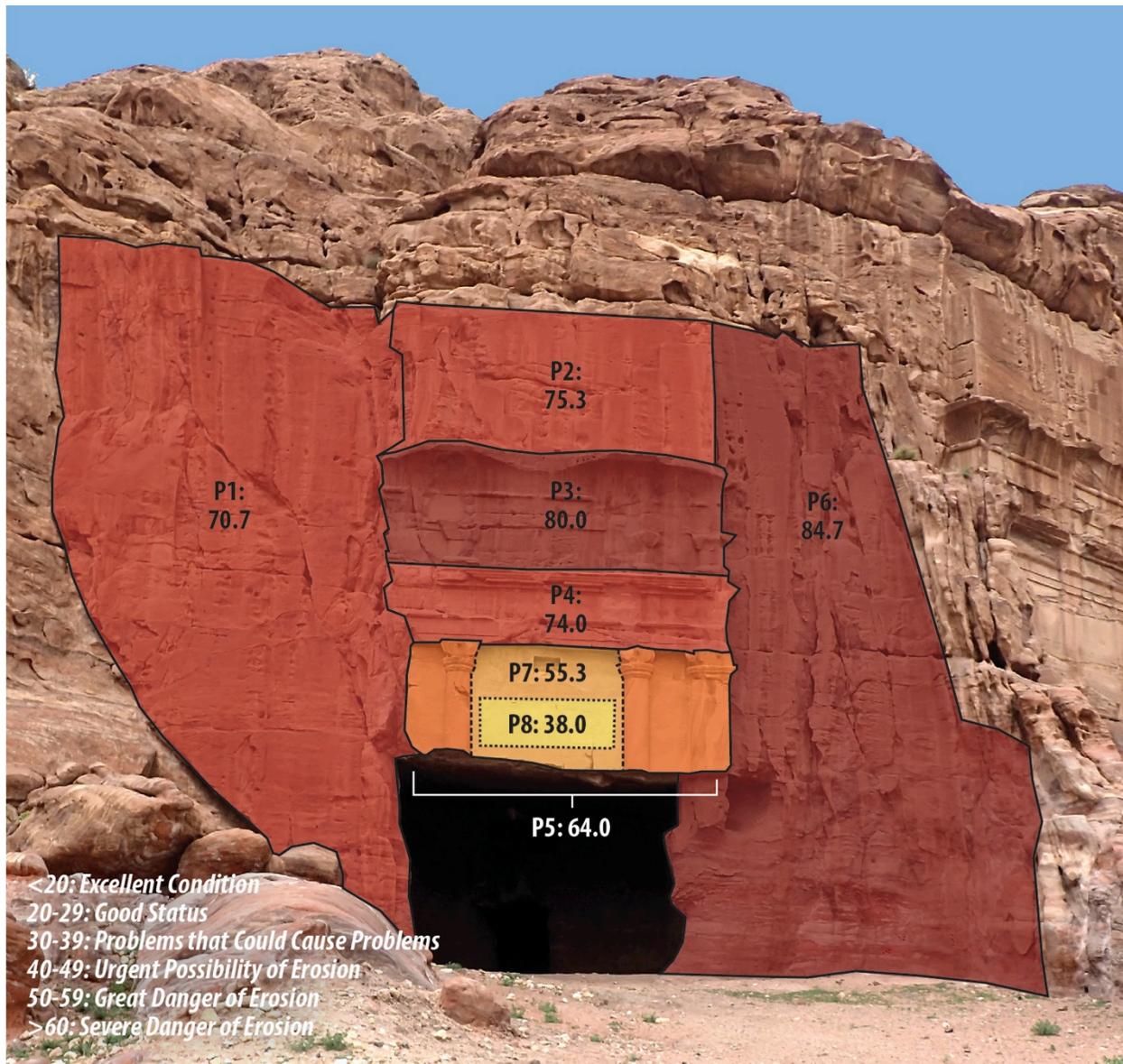


Figure 6.9: The different CSSI panels and scores for the Turkmanyia Tomb. In pretty rough condition, the colors for this tomb begin at yellow (instead of green), to orange, to light red, to dark red signifying the highest CSSI scores and most significant areas of decay. Graphic and photograph by author, 2016.

applied after construction. Other superficial decay processes such as scaling and flaking are also concerns for this site, reflected in their high CSSI scores.

That said, the one element that makes the Turkmanyia unique—the Nabataean inscription—is relatively stable (Figure 6.10). Illustrating the flexibility of CSSI panel designations, the Turkmanyia assessment utilized three separate panels, at different scales, to analyze the stability of inscription. The



Figure 6.10: Section of the Nabataean inscription at the Turkmanyia Tomb. Translations of the inscription reveal a list of social and legal conditions for interment within the tomb. The engraving also represents one of the longest and most in tact Nabataean writings in the region. Photograph by Casey Allen, 2016.

widest assessment, panel 5, encompassed the entire architectural feature on which the inscription is located, including adjacent pillars and design elements. With an average CSSI score of 64.0, this panel is within the *Severe Danger of Erosion* category and rated particularly high in independent fissures, undercutting (both impending and present), and invasive bird activity (e.g. nesting, bird droppings, etc). The next inscription assessment scale, panel 7, incorporated the dressed rectangle housing the inscription and its immediate surroundings—no other pillars or decorative elements beyond the inscription. Scoring lower (CSSI average of 55.3: *Great Danger of Erosion*), this panel excluded the severe decay occurring along the outer edges of the broader feature assessed as part of panel 5. Within this more focused area, CSSI identified the largest risks as independent fissures, inherent rock weakness, undercutting, and abrasion. The final inscription assessment, panel 8, concentrated solely on the small area actually containing writing. Working in a much smaller area than the other feature areas, this panel only scored 38.0 (*Problems that Could Cause Erosion*), with the biggest problems identified as

fissures and stone weakness. The differences in these three scores exemplify the importance of context: the inscription itself may be moderately stable but the ledge on which it is located could cause problems in the future.

### *Repeat Photography*

According to the repeat photographic analysis, the Turkmanyia tomb has been in rough shape for some time (Figure 6.11). The tomb's recognizable missing lower half is gone in both images, though it seems some of the rock fall debris has been cleared since the 1925 photograph was taken. Abrasion and streaking from water flow and rain runoff is present in both photos, though it seems to have intensified near the top of the monument between the historic image to the modern repeat. Decay also appears to



*Figure 6.11: Repeat photographs of the Turkmanyia Tomb. 1925 photograph from A. B. W. Kennedy (1925). 2016 photograph by author.*

have advanced on the lower right side of the monument's entrance, where undercutting and flaking has created a small ledge in the modern repeat not present in the historic photograph. Extended beyond the doorframe, other areas of the lower context wall exhibit a greater degree of decay and loss of material

This decay, as well as the clearing of debris, could be explained by other visible changes in the contextual landscape. The sediment and materials ramped against the boulder in the foreground and along the cliff wall at the base of the monument appear to be alluvial deposition, possibly evidence of flood activity. Nested at a nexus of multiple canyons and wadis, Petra is no stranger to flooding (Paradise, 2012). The Turkmanyia Tomb as situated within a wadi of the same name, Wadi Turkmanyia, with a steady enough water supply to sustain a relatively large lemon orchard and other forms of intermittent agriculture. It would be reasonable to assume this wadi has flooded at least once over the past century, possibly causing the observed difference in decay along the base of the cliff and depositional patterns. Alternatively, the rock fall debris could have been salvaged for building material and the boulders in the foreground were extremely friable when touched, making it just as reasonable to assume the differences in visible decay was the result of natural incremental deterioration. Further exploration of the site would be necessary to determine which hypothesis has the most evidence.

### **6.3.3 – *The Lion Triclinium***

Found part way up the trail to the Deir, the Lion Triclinium is located at the end of a small winding canyon. Tucked out of the sight from the main trail, the only indication of its existence is a single sign posted on the side of the monastery trail stairs. This monument is smaller than the other two selected for this case study, but is more decorative. The detailed mantels sport buttoned discs similar to those found on the Deir but are bookended with two pilasters adorned with carved masks and floral scroll-work. In addition, there are two carved lions, one on each side of the door, for which the monument was named. Somewhat uncharacteristic of late-Nabataean architecture, the masks—speculated to be Medusa—and overly stylized design of this triclinium have lead some scholars to believe the monument was actually created during the Early Roman period in Petra and not Nabataean at all (Browning, 1973). However, the striking similarities of the cornice and mantel designs with the Deir could just as easily suggest a Nabataean origin with a more liberal artistic license and heavy Roman inspiration.

Geologically trapped between the Umm Ishrin and Disi sandstones, the Lion Triclinium exhibits some very pronounced decay features and structural concerns. The most obvious of these is the warped shape of the main entrance. Conceptualized as once being a rectangular door and either square or circular window (e.g. Browning, 1973), a design common in Petra, the entrance is now a narrow keyhole shape with decay processes advancing in all directions, especially along a horizontal fissure/iron band that transects the entire cliff face. Much like the Turkmanyia Tomb, the key features of the Lion Triclinium required a staged CSSI analysis, where general panels were assessed first, and then additional more-focused examinations were made of each lion and mask. The Dushara shrine immediately to the left of the monument was also assessed, as well as two contextual panels on either side of the main façade.

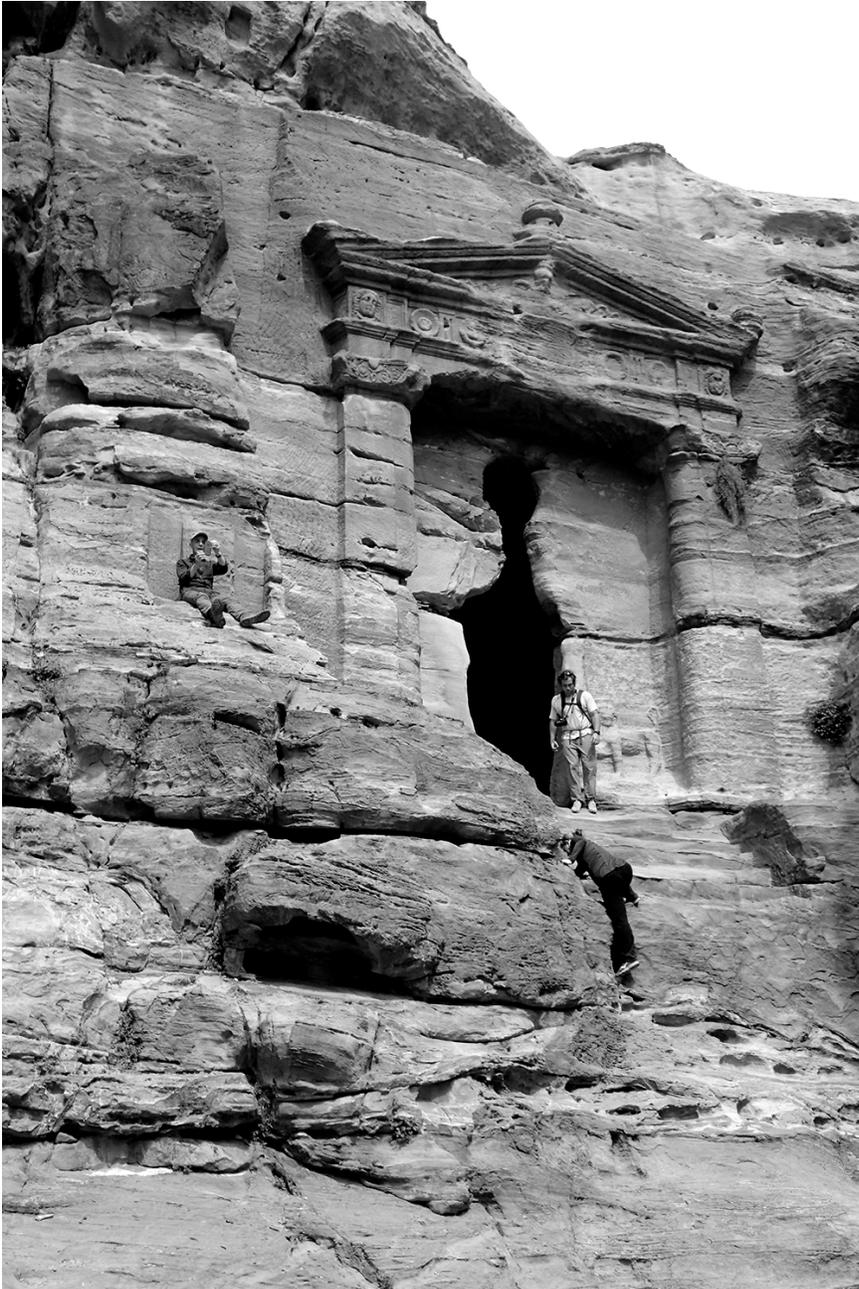
### CSSI

With an average CSSI score of 56.7, the Lion Triclinium was the most stable of the three selected monuments, though it still ranked within the second highest descriptive category, *Great Danger of Erosion* (Figure 6.12). This could be due to a number of factors, possibly including its isolated setting or elevated position within the canyon. Similar to the Turkmanyia, the supplemental panels focusing on specific design elements appeared more stable than the broader panels on which they are located. For example, both carved lions had significantly lower scores (panels 11: 62.0 and 12: 55.3) than their contextual panel (Panel 6: 70.0). With the unique location of the monument and protected surroundings, the majority of concerns identified by CSSI were superficial decay processes mostly centered on loss of detail. Decay processes such as flaking, granular disintegration, and rounding of design features scored particularly high. Large sections of the upper mantels and cornices have been completely smoothed and degraded, making them appear to have melted or dissolved. Advanced flaking, scaling, and crumbly disintegration around the edges of the monument opening serve to support the speculation that the monument once sported a separate door and window. Future loss of detail at this monument is also highlighted in its CSSI scores. Both impending scaling and flaking as well as splintering development are of particular concern. These processes could be exacerbated by tourist activity, as climbing and entering the monument is unimpeded (Figure 6.13).



Figure 6.12: The different CSSI panels and scores for the Lion Triclinium. Colors coordinate with degree of degradation, ranging from green indicating stable conditions to yellow, to orange, to light red, to dark red signifying the highest CSSI scores and most significant decay. Graphic and photograph by author, 2016.

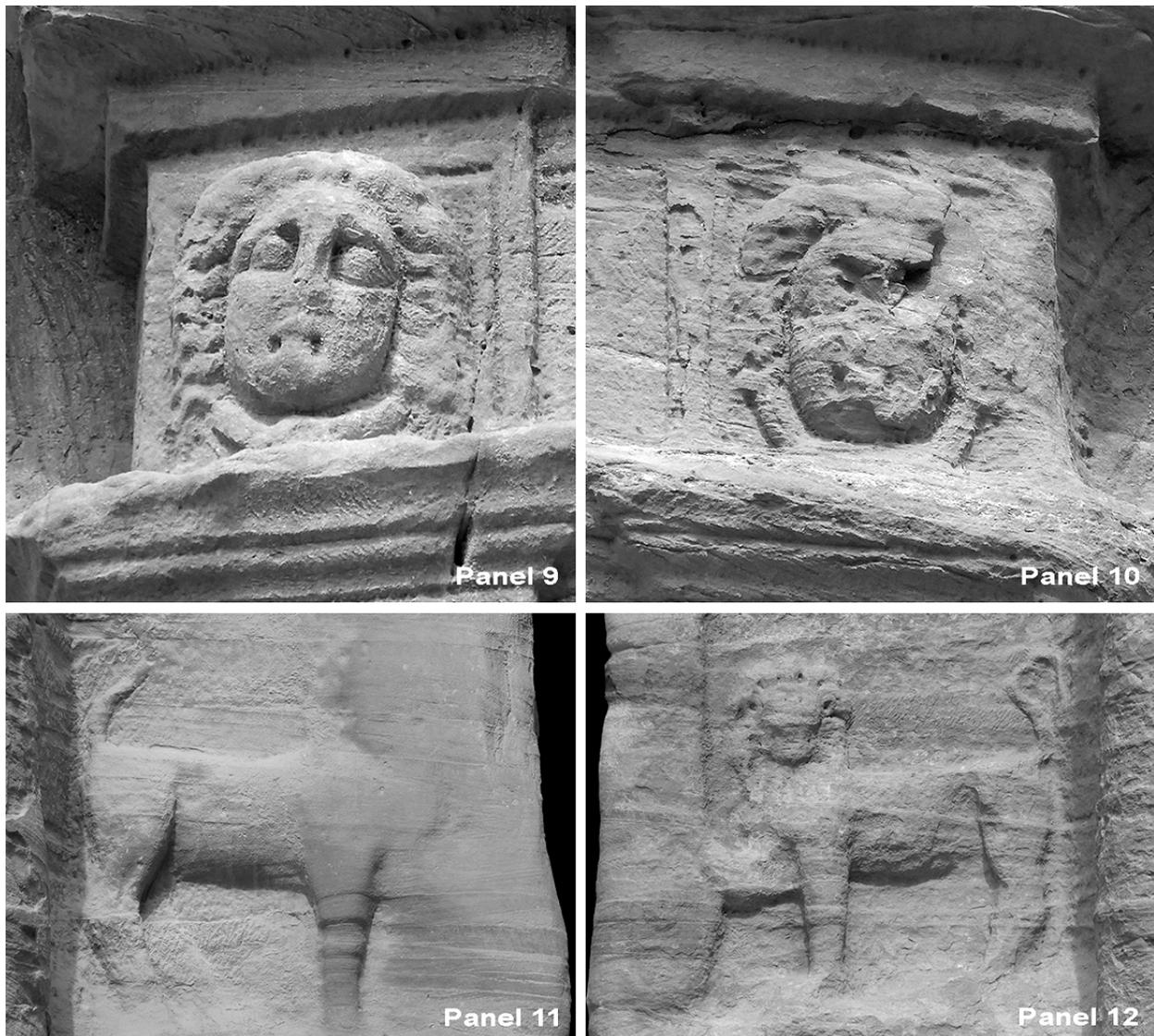
The monument was also not without at least a few structural issues. Most notably were fissures along the bedding plain and textural anomalies. Similar to the Deir, iron rich bands in the substrate have created natural barriers stopping the migration of salts and minerals through the sandstone. With standing water just below the monument and evidence of run off near the façade, along with plant growth on the and near the monument, water seems to play a major role the triclinium's decay—making the



*Figure 6.13: Tourists climbing and sitting on the Lion Triclinium and neighboring shrine indent. The lack of stairs for easy access or signs encouraging or forbidding such activities exacerbates the issue, as tourists only have other tourists' behavior to determine what is appropriate and what is not—which not always correct and can lead to problems (du Cros & McKercher, 2015). Photograph by author, 2016.*

impermeable iron banding all the more impactful. Areas directly adjacent to the banding, for example, exhibit significantly higher rates of splintering, crumbly disintegration, and flaking.

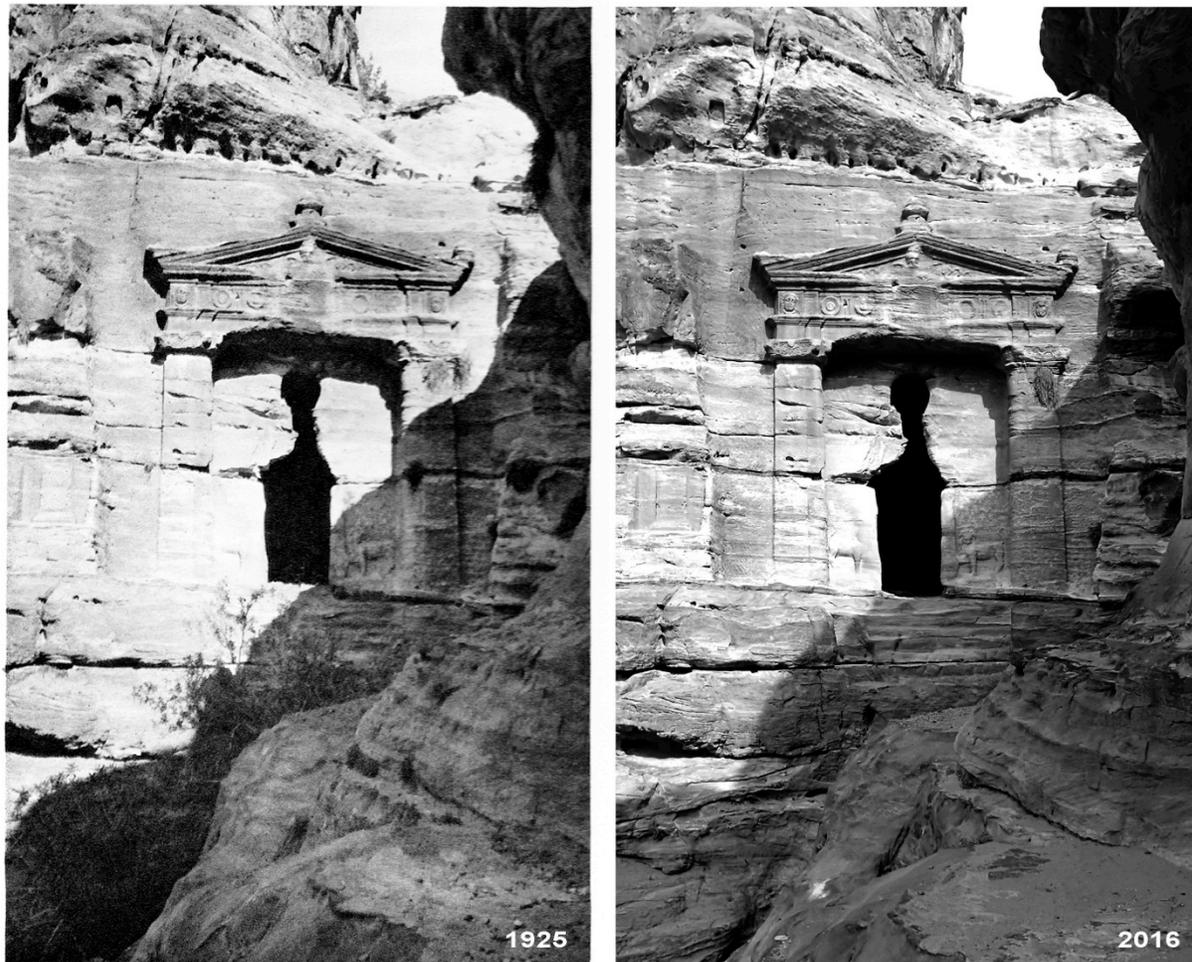
In addition to broader feature assessments, the Lion Triclinium analysis also included four supplemental panels specifically focused on the monument's unique carved elements (Figure 6.14). A few of these features are among the most stable panels on the entire monuments. The lowest scoring



*Figure 6.14: Close up photographs of the carved features on the Lion Triclinium. Demonstrating the flexibility of CSSI panel designation system, these four features on the triclinium were assessed individually as well as part of the surrounding panels. Each panel/feature displayed different decay concerns and stability conditions. Photographs by Casey Allen, 2016.*

panel, panel 9: 28.7 (*Good Status*), is a delicate carved face on the upper left mantel, with the most significant threats being inherent stone weakness and textural anomalies decaying differently. The face on the other side, panel 10: 52.7 (*Great Danger of Erosion*), was not as stable, mainly due to a large missing section of material from scaling and textural issues. Both faces also rated high for granular disintegration, which basically accounts for indistinguishable loss of material/detail and deteriorating stone matrices. When paired with relatively low rock hardness (as is the case for much of Petra), granular

decay can be quite devastating to delicate or detailed stone decoration—making them appear to have been erased or non-existent. For example, large portions of the iconic lions, including the left lion’s face and feet, have blurred almost completely from granular disaggregation. Fortunately, the right lion, panel 12, is in slightly better condition (55.3: *Great Danger of Erosion*), though flaking and salt activities still threaten the feature’s future stability.



*Figure 6.15: Repeat photographs of the Lion Triclinium. Since the shadow of the adjacent cliff face is so prominent in the historic image, it took three separate visits to the site to correctly replicate the photograph. 1925 photograph is from A. B. W. Kennedy (1925). 2016 photograph is by author.*

### *Repeat Photography*

Tucked away in its isolated canyon, the Lion Triclinium doesn’t appear to have changed much over the last century (Figure 6.15). The most noticeable difference between the photographs deal with

vegetation: The tree in the crevice below the façade is gone, the shrub growing in the fissure near the center of the right pillar is not longer there, and the tree along the Monastery trail in the upper background is not longer visible above the canyon opening. The hanging plant in the upper right column has grown, though the second plant behind it have since fallen or been removed. There also appear to be a few small ledges or loose material that have eroded since 1925, especially on the left side of the entrance along the prominent iron banding. The surrounding area also seems to have changed relatively little between the two photographs. The ledge in the foreground exhibits the most significant difference, though this could also be the result of slightly different camera angles or technological distortion.

#### **6.4 – DISCUSSIONS AND CONCLUSIONS**

Selected for their uniqueness, as well as their representativeness of Petra's awe-inspiring landscape, each of the three assessed monuments face different natural threats and management challenges. According to CSSI scores, the Deir, one of Petra's most famous monuments, is highly impacted by salts, intrinsic lithological weaknesses, and visitor impacts. Thankfully, park management has already taken steps to reduce negative anthropological influence by closing the monument entrance and prohibiting climbing on or around the façade. The Turkmanyia Tomb, with its delicate Nabataean inscription, poses a unique challenge as it is technically beyond official park boundaries. Regular traffic to and from Umm Seyhoun, along with frequent school fieldtrips to this site, may be exacerbating the decay of this already disintegrating edifice. The significance of the inscription paired with the most prominent decay processes being structural makes the every-looming risk of rock fall at this site all the more concerning. The third monument, the Lion Triclinium, while the most stable, is still at risk of losing key design elements and carved detail due to several natural sandstone decay processes. However, these processes may be accelerated by unrestrained tourist activity, suggesting some form of access restriction/control may be beneficial.

In terms of supplemental methodology, the repeat photography served the same purpose for monuments/CSSI as it did for the Arkansan rock art/RASI (See Chapter 4): providing temporal context for decay processes and risks identified in the geologic stability scores. An excellent example of this is regarding the missing bottom portion of the Turkmanyia Tomb. The CSSI analysis ranked undercutting,

both impending and active, as major threats to the monument's stability—especially the lower panels directly above the chasm. However, both the historic photograph and concept drawing display the façade basically as it is today, indicating a relative stability and tempers the immediacy suggested by the higher CSSI scores (See Figure 6.11). By no means, does this negate the concern of undercutting causing further damage in the near future; it just provides a timeline and temporal context for that concern. The same can be said for both the Deir and Lion Triclinium as well, where vegetation and land-use changes were among the most significant visual differences.

With an expanding tourism industry and international travel becoming more accessible to the average consumer, there is an ever-increasing need to develop time and resource sensitive means of assessing the structural and geologic stability of the world's irreplaceable stone heritage. This case study has shown how pre-existing rock art decay research techniques can be suitably adapted to analyze other forms of cultural stone, such as monument facades in Petra, Jordan. The intention of RASI/CSSI is to provide a rapid field assessment to quickly catalog site stability, establish a rudimentary rock decay baseline, and to help direct future research in the most appropriate direction (Dorn et al., 2008). This makes it an excellent method for pilot studies or to address particularly large sites with an often-overwhelming number of individual stone elements. This has been a problem for establishing long-term stability management in Petra, Jordan. Attempts have been made, such as the UNESCO-led risk assessment pilot study by Paolini et al. (2012), but the employment of CSSI and other rapid field assessment techniques could help park management and the Jordanian government to develop effective conservation policies to both protect their stone heritage while also prolonging their viability as economic and tourism resources.

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Excerpt from:

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