# باستان‌شناسی ایران
## (۳)

موسسه‌ی بین‌المللی مطالعات گردشگری وهشت مینا

در این نوشتار ضمن مروری بر یافته‌های باستان‌شناسی مرتبط با تولید و استحصال نقره (شامل اشیاء نقره‌ای و آثار باقی‌مانده از به کارگیری فن غال‌گذاری) به ویژه در هزاره‌های چهارم و سوم پیش از میلاد، روش غال‌گذاری مورد استفاده در دوران باستان به طور مختصر توضیح داده شده است. سپس نگاهی اجمالی بر کانسارها و معادن باستانی سرب نقره‌دار ایران انجام گرفته که از آن میان معدن سرب نخلک واقع در مرکز ایران توصیف شده است. در این مورد نتایج آنالیز ایزوتوپی سرب کانسنگ نخلک با آنالیز یافته‌های محوطه‌های سیلک و اریسمان مقایسه شده است. بر این اساس به نظر می‌رسد که با توجه به شواهد آزمایشگاهی، قدمت معدن نخلک و تاریخچه‌ی استحصال سرب نقره‌دار از آن بسیار پیشتر از دوره‌ی ساسانی بوده، احتمالاً به هزاره‌های سوم و چهارم پیش‌ازمیلاد برسد. نگارندگان با توجه به تمامی شواهد گردآوری شده شامل قدیمی‌ترین اشیاء نقره‌ای یافت شده از محوطه‌ی سیلک، قدیمی‌ترین آثار به کارگیری فن غال‌گذاری در سه محوطه‌ی سیلک، اریسمان و حصار و نیز همخوانی قابل توجه علامت ایزوتوپی (سرب) کانسنگ معدن باستانی نخلک با یافته‌های سیلک و اریسمان، سرزمین ایران را به عنوان خاستگاه و زادگاه فناوری استحصال و تولید نقره پیشنهاد می‌نمایند.

## بازنگری مجموعه منتسب به دوره فراپارینه سنگی از مکان قلعه عسگر، البرز مرکزی

**فریدون بیگلری**

محوطه باز قلعه عسگر در سال ۱۳٦۸ توسط هیات بررسی منطقه دماوند به سرپرستی زنده یاد عنایت اله امیرلو شناسایی و در سال ۱۳٦۹ کاوش شد. در کاوش محوطه مجموعه‌ای از دست ساخته‌های سنگی متکی بر تولید تیغه-ریز تیغه، بقایای یک اجاق، بخشی از لبه یک ظرف سنگی با تزیین کنده و تکه‌ای از یک پیکرک گلی (شاخ بز) یافت شد. بقایای جانوری که عمدتا شکسته بودند، توسط دکتر مرجان مشکور بررسی شدند. در همان سال گزارش کوتاهی از این کاوش منتشر شد که در آن محوطه و یافته‌های آن به دوره فراپارینه سنگی (۱۸ تا ١٤ هزار سال پیش) منسوب شد. متاسفانه با مرگ نابهنگام ایشان نتایج این کاوش هیچگاه منتشر نشد. از آن زمان تاکنون، در بسیاری از انتشارات، قلعه عسگر به عنوان یک مکان فراپارینه سنگی معرفی شده است. مجموعه‌ی قلعه عسگر در سال ۱۳۸۷ به بخش پارینه سنگی موزه ملی ایران منتقل و بررسی اولیه آن انجام شد. در این بررسی روشن شد که مجموعه از لحاظ فناوری و گونه‌شناسی دارای ویژگی‌های مشخص صنایع نوسنگی منطقه است. پس از مدتی بررسی کامل مجموعه شامل طبقه‌بندی جنس سنگ‌ها، اندازه‌گیری نمونه‌ها و ثبت و ضبط مشخصه‌های فناوری انجام شد. نتایج این مطالعه همراه با نتایج بررسی بقایای جانوری، سالیابی نمونه‌های استخوان و منشایابی ابسیدین در آینده نزدیک منتشر خواهد شد. مجموعه شامل سنگ مادرهای تیغه- ریز تیغه و تراشه، قطعات شکل‌دهی و اصلاح سنگ مادر، یک کوبه‌ی سنگی و شمار زیادی تیغه- ریز تیغه است. تولید تیغه- ریز تیغه هدف اصلی فناوری به کار رفته است و در تولید آنها هم از شیوه‌ی ضربه غیرمستقیم (قلم و کوبه) و هم روش فشاری استفاده شده است. بسیاری از سنگ مادرهای تیغه- ریز تیغه یک سکویی بوده که در کناره‌ها و سطح پشتی آنها آثار آماده‌سازی دیده می‌شود. شمار اندکی از نمونه‌ها دارای روتوش و جلای داس هستند. در مجموع ویژگی‌های فنی-گونه‌شناختی صنعت قلعه عسگر نشان‌دهنده‌ی وجود یک استقرار یا استقرارهایی از دوره‌ی نوسنگی در این مکان است. با توجه به نتایج این بررسی جدید، قلعه عسگر بایستی از سیاهه مکان‌های فراپارینه سنگی ایران خارج و به مکان‌های شناخته شده‌ی نوسنگی در منطقه افزوده شود.

## گزارش حفاظتی یادمان‌های ساسانی طاق‌بستان کرمانشاه در غرب ایران

**جاناتان کمپ**

در شهریور ماه ۱۳۸٦ نگارنده بررسی حفاظتی‌ای بر روی تعدادی از یادمان‌های ساسانی در طاق بستان کرمانشاه در غرب ایران انجام داد که نوشتار حاضر خلاصه‌ای از گزارش

آن بررسی است. محوطه‌ی باستانی طاق بستان شامل دو ایوان بزرگ و کوچک و نقش برجسته‌هایی از اواخر دوران ساسانی در پای کوه طاق بستان (رشته کوه‌های زاگرس) است که از شاهکارهای هنر نقش برجسته‌ی اواخر این دوره محسوب می‌شود. به طور کلی آسیب‌های متعددی در گذشته به صورت عمدی یا غیرعمدی یا بر اثر تغییرات محیطی به این مجموعه ارزشمند وارد شده است که غیرقابل جبران است. اما امروزه این محوطه دچار عوامل دیگری از جمله نفوذ سالانه‌ی آب برف و باران به داخل آثار و جاری شدن آب بر سطح و دیواره‌ی صخره، وجود رطوبت زیاد در محیط محوطه، آلودگی‌های ناشی از کارخانجات مختلف، وجود گازهای گلخانه‌ای نگران‌کننده در محیط، لمس سطح این آثار توسط گردشگران، تردد وسایل نقلیه در نزدیکی محوطه، وجود آبراهه و کانال‌های جلو محوطه، مرمت‌های انجام شده در گذشته با استفاده از مصالح نادرست مرمتی همگی از عواملی هستند که باعث تخریب و فرسایش تدریجی این مجموعه ارزشمند می‌شود و بایستی در برنامه‌های حفاظتی کلیه آن‌ها مورد توجه قرار گیرند.

نگارنده در این مقاله پیش از پرداختن به گزارش‌های حفاظتی در ابتدا و به طور خلاصه به توصیف باستان‌شناسی و اهمیت این یادمان‌های تاریخی و محیط اطرافشان اشاره داشته و سپس به نتایج بررسی سال ۱۳۸٦ و عوامل پوسیدگی و زوال این آثار پرداخته است.

با توجه به نتایج بررسی و شناخت عوامل حفاظتی، نگارنده روش‌های درمانی و درمان حفاظتی را برای کاهش و متوقف کردن اثرات پوسیدگی و تخریب بیشتر در این یادمان‌ها پیشنهاد داده است که به ترتیب اولویت، پس از اقدامات اولیه‌ی حفاظتی، با همکاری مسئولین میراث فرهنگی انجام می‌شود.

## گزارش مقدماتی شناسایی مرکز شهر غندجان / دشت بارین در جلگه‌ی سرمشهد در شمال خلیج فارس

**پارسا قاسمی**

غندجان یا دشت‌بارین(باری) نام‌جای شهری باستانی است که در اغلب متون تاریخی و کتب جغرافیایی اوایل اسلام به آن اشاره شده است. با توجه به شواهد تاریخی این شهر یکی از شهرهای مهم فارس باستان بوده که مرکز تولید پارچه‌های سلطنتی، گلیم‌بافی، جاجیم بافی و بالشت بوده، و ادبا و فضلای مشهوری داشته که همه‌ی آن‌ها در سده‌های ٤ و ٥ هجری می‌زیسته‌اند. طبق متون تاریخی، جنگ مهمی بین گروهی از خوارج به نام ازرقیان با مهلب در اینجا رخ داده است.

ابن بلخی در ذکر راه‌های غربی فارس از غندجان به عنوان یکی از منزلگاه‌های بین راهی مرکز فارس به ساحل دریا نام برده است. با توجه به گزارش‌های او و وجود محوطه‌های بزرگ استقراری شناسایی شده از دوره‌ی ساسانی و آغاز اسلامی توسط نگارنده، موقعیت این شهر با دشت سرمشهد تطبیق پیدا می‌کند. در نوشتار حاضر نگارنده بر اساس اطلاعات نام‌جای‌های ذکر شده در متون و همچنین شواهد مستند بررسی‌های میدانی باستان‌شناسی نام‌جای جغرافیایی غندجان و دشت بارین را با محوطه‌های دشت سرمشهد تطبیق داده و روشن کرده که مرکز این شهر محوطه کلی‌کوهه سرمشهد در نزدیکی روستای تل سامان امروزی بوده است.

# Sassanid Monuments of Taq-e Bostan, Kermanshah, Western Iran, Summary of a Conservation Report

**Jonathan Kemp**[1]

**Abstract:**
This article summarises a conservation report written to describe the material condition of a group of Sassanid monuments in Western Iran following a survey executed by the author in August 2007. The article briefly describes the monuments and their surrounding environment before summarising the conservation reports findings on the physical condition and conservation treatments proposed by the author to mitigate the effects of further decay. Reference is made to analysis of samples along with the relevant ethical guidelines under which the conservation treatment proposals have been made. An online glossary of conservation terms is referred to and a brief summary of the results from sample analyses is appended.

**Keywords:** carving, contour scaling, delamination, disaggregation, iwan, karst, laser, lime, scialbatura, sulphation.

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**Introduction: Taq-e Bostan**

The Taq-e Bostan complex is a group of reliefs carved directly into the semi-metamorphic limestone at the foot of Taq-e Bostan mountain in the Zagros mountains, at the northern outskirts of Kermanshah, western Iran. The complex comprises of two three-sided, barrel-vaulted hall, open at one end, called *iwan,* and one bas-relief panel and demonstrate an intense engineering effort. The author surmises that for the two *iwan* each arched shape was defined and cut back into the rock contiguous with all other elevations being finished as smooth surfaces before the lengthy execution of the elaborate reliefs could take place. The third monument, an earlier relief panel, would have also been prepared first as a flat surface before any detailed relief work was begun.

In the larger *iwan* the junctures between the two hunting panels and the massive equestrian panel indicate a possible chronology of carving because as a matter of practical technique the equestrian panel would have been laid out with its forward most levels being roughed out before the framing of the two side panels, the hunting panels, could be determined (Fig. 1).

Carving directly into the karst formation also meant to carve across or through the naturally occurring fault/vent system typical of karst formations. In the large *iwan* these vents are particularly obvious especially at the apex of the arch – if the carvers had set the arch some 500-1000mm lower it might have mitigated some of the current water ingress problems for the panels below as the water flow would have been projected much further forward away from the face of those panels.

**Figure 1. Early 20th Cent. photograph from a 1969 Report by the Institute of Oriental Culture, The University of Tokyo**

**Depictions on the Monuments:**

**I) Early Relief Panel:**

The 4th Century relief panel bears a carving depicting of three figures standing over one fallen figure. The scene has been variously described as being the Investiture of Shapur II or Ardashir II by Ohrmazd and Mithra, standing in attendance on lotus flowers and wearing a crown of sun-rays, and commemorating one of Ardashir II's victories (Azarpay 1982, Hermann & Curtis 2003) (Fig.2). Others consider that the panel depicts the victory of Shapur II over Julian the Apostate with Mithra, carved as a pothumous commemoration (Hermann & Curtis 2003, Nicholson 1983).

**Figure 2. Sassanid 4rd Cent. Relief panel**

**II) Small Iwan:**

The smaller 4th Century *iwan* bears two Pahlavi inscriptions and carvings of Shapur II and his son Shapur III. The figures are facing each other, and are believed to have been carved during the reign of Shapur III, with completion around 385 AD. Each figure stands approximately 3.0 metres high, and adorned with necklaces and pointed beards that seem to end in rings (Fig. 3).

**Figure 3. Small 4th Cent. Iwan**

**III) Large Iwan:**

The largest *iwan* bears both shallow and deeply carved bas-reliefs on its inner and outer elevations, including a scene in which the Sassanid King Khosrow II (reign 590–628) is being crowned by Ahura Mazda and Anahita. Below is the equestrian figure of Khosrow II mounted on a horse, both in full battle armour (Fig. 4).

**Figure 4. Large 6th Cent. Iwan**

To the left and right of these deep bas-reliefs are shallower carved panels depicting royal hunting scenes - to the *iwan's* proper left (ie. the viewers right hand side as facing into the *iwan)*, a deer hunt, and to the *iwan's* proper right, a boar hunt.

On the upper proper right elevation of the *iwan* there is a polychromed bas-relief carved at the order of Dowlat Shah, Qajar Governor of Kermanshah (1797-1834).

On the outer elevations to the *iwan* an arch with decorative foilage moulding springs from two pilasters that each bear a delicately carved tree of life. Above this arch and located on the two opposite sides are figures of two winged angels complete with diadems and a motif of ribbons, framing a centrally placed crescent or torus carving.

Near the angel on the *iwan's* proper left elevation, and on the side of the rock formation in which the smaller *iwan* is carved, there is a small inscriptional carving, from the Qajar dynasty, with extant gilding and black pigment observable.

**Geological and Environmental Description:**
The reliefs have been carved into a mass of semi-metamorphic limestone, contorted and overthrust as a part of the karstic system that forms the Zagros mountains. Taq-e Bostan lies in what is described as the highland zone of the karst formation (Fig. 5). This zone is identified as having been folded, crushed, faulted and overthrust with a common morphology of numerous escarpements existing at the head of the thrust sheets (Braud, J., 1987; Heydari, S., 2010).

Detailed geomorphic descriptions lie outwith the scope of this article, however, and generally speaking, karst formations will have long faulting systems, both horizontally and vertically, amplified and extended over time by water percolation and drainage: at Taq-e Bostan inclined parallel faultlines subsect the complex which is at the head of an out-thrust of moderately hard semi-metamorphised limestone. A high annual precipitation together with the presence of many karst springs in the area leads to a significant discharge of water.

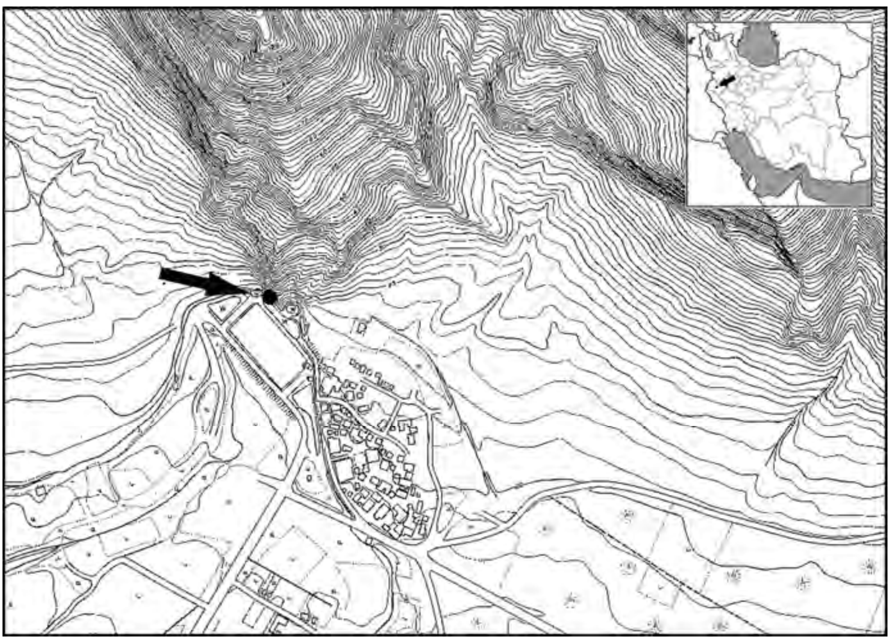

**Figure 5. Map of region (Fukai etal. 1969-1984)**

Notably, the complex has two adjacent springs, one of which empties into a large pool at the base of the escarpment.

The wet season in Kermanshah province is from December to the end of April with an average of between 200 and 350 mm a month, and over the year rainfall varies between 6 to 350 mm / month.

The complex faces South West and is slightly protected by trees in the adjoining public area from the prevailing winds coming from the West. Temperatures range from -8.0 to 35°C, and the severity of the winter is exhibited in, for example, archival photographic evidence with the formation of icicles depicted on, for example, the equestrian figure of the large Iwan.

The complex is on the outskirts of the city of Kermanshah, in western Iran. The city is a both trade centre for the regions agriculture and a growing industrial base of oil and sugar refineries, and cement, textile and flour factories.

In 2007 air pollution was noticeable to the author when looking from the site towards the city and its related deposition products (both as soluble and particulate wet and dry depositions) are to be expected around the complex - vehicle emissions are especially a concern.

Traffic is kept some 500metres away from the site and the complex itself can be reached only on foot – Taq-e Bostan is a significant tourist destination and footfall traffic is gradually increasing as provisions to promote tourism take effect. Generally speaking, people have had access to the carvings and they have been extensively touched, with those in the larger *iwan* that receive most attention as evidenced by the polished areas of the lower parts of the reliefs. Only since 2010 visitors been prohibited from touching the sculptures.

**Conservation Preamble:**

The conservation report was prepared for what should be described as a second phase of preservation works designed for the Taq-e Bostan Complex. It should be understood that the reports proposals for the conservation of the sculptural reliefs can only be implemented after the execution of appropriate geohydrological engineering works, (as “Phase One”), designed to redirect and minimise the current levels of water ingress through the karst system, which is the principle factor in the deterioration of the carvings.

It should be noted that the conservation proposals were made in accordance with both the 1964 Venice Charter - The International Charter[1] for the Conservation and Restoration of Monuments and Sites, and in the spirit of London's Victoria & Albert Museum Ethical Checklist[2], which is both a tool for decision-making and a filter reflecting prevailing philosophies of conservation.

**Conservation Report Scope:**

The conservation report aimed to detail the extent and nature of decay processes active within each of the three monuments in the Taq-e Bostan complex; the specification of conservation treatments that reduce the impact of these processes; and the cost in terms of man-hours to execute the works.

The conservation report did not include discussion about the conservation treatments in detail except in arguing for the use of moderately hydraulic lime mortars and the use of the laser cleaning technique, and two appendices that outlined their use were appended.

The net gain accrued by the execution of the proposed works within the conservation report are defined by the author as:

the mitigation of the negative effects of previous interventions; the stabilisation of some of the more advanced and pronounced decay processes (in conjunction with the successful completion of the Phase One Engineering works to the Complex); and the enhanced appearance of the monuments by the lessening of discontinuous staining etc. that currently disrupt the reading of the monuments.

Following the execution of the proposed works the author states that the consequences for the authorities responsible for the complex include:

the implementation of maintenance schedules designed by the conservation team detailing, for example, the clearing of debris from all gullies to allow the outflow of water; the clearing of snow from around the monument to prevent freeze-thaw traps; the provision of winter covers to the monuments (which will have an affect on tourism) to reduce the severity of freeze-thaw cycling; and the undertaking of a commitment to the training of staff in the continued monitoring of the monument and in carrying out any remedial lime works.

1.http://www.international.icomos.org/charters/venice_e.pdf (accessed November 12th, 2012).
2. http://www.vam.ac.uk/files/file_upload/27932_file.pdf (accessed November 12th, 2012).

With regard to the latter, it should always be understood that the proposed hydraulic lime works are inevitably sacrificial – in other words they are designed to fail before the surrounding original material of the monuments is affected by, for example, the egress of water. Thus there should be a commitment by the custodians to periodically carry out small repairs in the correct manner.

**Conservation Report Terms:**

**Terminology:** Descriptive terms will be used throughout the conservation report that accord to previously used conventions from both architectural and conservation disciplines. The amplitude of the extent and activity of decay processes in 2007 is noted in the conservation report and for definitions of the terms in bold type contained hereafter in this article please refer to the online glossary[3].

**Photography:** A photographic record of the complex was executed (August 2007) and forms a separate digitised record along with selected imported images for the purpose of illustrating the conservation report and this article. It is hoped that these images will be incorporated and form a continuing record for the relative measurement of the condition status of complex.

Digital images were taken of all elevations, the surrounding environment; stone morphologies, surface details, human interventions, typical decay forms, and details of extant polychromy, were all also documented.

**Measurement:** Very general measurements were executed with both a tape and laser measure. Approximated sizes were incorporated in graphical images produced for the conservation report, along with areas of specific decay mechanisms.

**Examination:** Visual examination was carried out from the ground, and from a ladder. Over one day all uppermost elevations were examined with use of a mechanical lift from the back of a lorry.

As a result various decay mechanisms, reaction products, and previous human interventions have been identified according to denoted conventions and/or normative geological definitions. Features documented in the conservation report included examples of stone inclusions, fractures and the disruption of internal morphologies through delamination and disaggregation; previous repair regimes where, for example, reaction products have been generated or mechanical stresses imparted; and the detailing of isolated processes with an evaluation of their effect on the condition of the complex. Sample sites, collected during the survey, were also identified.

**Sampling:** Both patinated and unpatinated samples of loose stone were collected from the site for their mineralogical identification. Samples were returned to the United Kingdom for analyses at the Department of Conservation, Documentation and Science at the British Museum, and subjected to analysis by X-ray diffraction (XRD), an X-ray scattering technique, to reveal information about the crystallographic structure, chemical composition, and physical properties of a material. X-Ray Fluorescence (XRF), was also used to determine the elemental composition of samples both qualitatively (determining what elements are present), and quantitatively (determining how much of each are present). A summary of the unpublished report is appended to this article as Appendix 1.

What follows in the rest of this article is a summary made from the conservation report of the condition and proposed treatments for the three monuments.

**I) Sassanid Relief Panel**

The relief panel is carved into the terminus of a rock outcrop and is immediately adjacent to a pool (replenished by at least one spring). The panel's vertical plane is carved on a slight ellipse rather than on a perfectly flat plane. The three standing figures are deeply carved in three-quarter profile, with fine detailing to all their costumes, features and accessories. They are set against a flattened and recessed panel, and are depicted as standing on a step on which are carved shallower reliefs of a lotus flower and a vanquished opponent. All of the figures appear to have suffered from some deliberate **vandalism** to their heads, with that of Izad Mithra being the worst affected.

**Structural Condition:**

There is a plane of disruption to the upper proper centre right area of the panel and to the lower proper centre left, and although the figure between these two areas is not fractured, there is a **faultline** discernible between the two kings.

3. A glossary of stone and polychromy decay terms used in this article is available at http://jkconservation.com/index.php/teaching/glossary/ (last modified November 14th, 2012).

The placement of the stone blocks, to define what might loosely be called the architrave, was photographed during execution in the latter part of the twentieth century. An earlier photograph shows that originally the architrave never projected forward of the relief, which consequently left the panel exposed to inundation from above (Fig. 6).

**Figure 6. Panel before restoration. Attributed to The Institute of Oriental Culture, The University of Tokyo, ca. 1965**

These comparatively recent works may be described as: firstly, a small indent of moulded stone was added to the proper right of the panel as a continuation of its framing; secondly, three large tooled blocks were then added to provide a heavy architrave to nominally aid in shedding water away from the carving on the panel. The line of this feature was roughly projected as far as the furthermost point of the extant rock, upper proper centre right (Fig. 7).

Thirdly, the pedestrian area seems to have been paved in its current configuration around this time.

Unfortunately the author found that any protection that this architrave might have offered is mitigated by the extant rock in the central area with its series of cleavages that allow, in principle, water to run down onto the face of the panel.

**Figure 7. detail showing paved area/footing to panel, with hard cement pointing between paving and footing; hard cement pointing to rock fault line; and evidence of the progressive deterioration of fissures through water being prevented from egress by hard cement.**

The placement of the blocks has also led to a large area behind to be inappropriately capped in cement. An ill defined gully has failed to take water away from the upper reverse of the Panel, and this, along with the impermeable nature of the cement, has led to the entrapment of water and promoting **freeze-thaw** cycling.

Because of the paving being brought both higher and very close to the footings of the panel, there are signs of **spalling** to the bottom edging of the rock side where water percolation has been prevented, intensifying, for example, the effects of **freeze-thaw cycling** on the stone fabric.

The problems of the restoration have been compounded by the use of an impermeable cement freely applied both as a bedding and jointing medium for all the paving and restoration works.

**Surface Condition:**

Calcium oxalate coatings (known as **scialbatura**) are commonly found on the complex and can be the result of bioagent activity and/or the decay of an organic coating. The orange colouration of the Complex has been determined through sample analysis to be mainly due to the ferrous content of the rock.

Generally speaking, the surface of the Panel is stable. There are some localised disruptions especially around areas pointed with cementitious material, which has generated a loss of profile through **dissolution** and **disaggregation** around the pointing zones. Where areas have suffered from the effects of water ingress, they exhibit **granular_disintegration** and **spalling** especially evident at the panel's footing, along with evidence of a concomitant **bioinfestation**. Further areas exhibit the effects of **freeze- thaw cycling** especially in the **fractures** and **delaminations** evident around the natural fault/cleavage planes of the rock.

An area on the central figure's proper left leg has been replaced with a piece of new stone set in polyester resin/cement. It is both out of alignment and aesthetically unsympathetic.

**Conservation Recommendations:**

Before any structural work is carried out the panel should be protected with protective padding and waterproof sheeting as care should especially be taken to ensure no spillage or contamination occurs from any of the wet-works (cleaning, lime works) recommended.

Adequate scaffolding and lifting equipment is required for the removal and subsequent re-setting of the 1970's stone blocks (each approx. 150kg. in weight). Supplies of water, power and lighting, are also required along with a secure area for equipment storage. Furthermore, if works take place during the high season, canopies or similar should be available to cool both the workers and any lime-based works. Documentation should be kept of all stage of the work along with appropriate images and systematically archived for future reference.

**Structural:**

**1)** Engineering works are recommended to the pedestrian area[4]:

*either*

a) execute general site pavement removal and lowering of ground level to divert sources of water ingress (including rising damp) away from Panel footing; or

b) create trench at footing to panel approximately 1500mm deep x 400mm filled with appropriate gravel to allow for the drainage of water away from Panel footing.

**2)** Check that all restoration stonework is geologically compatible to original karst stone and consider its replacement if not. Careful releasing and lowering of all restoration stonework and the removal of all cementitious material.

**3)** Removal of all previous regimes of cement capping from behind upper reverse to Panel.

**4)** Removal of all cement material from the restoration stonework in preparation its for re-use.

**5)** Re-setting of all stonework on moderately hydraulic lime mortar bed**.**

a) all pointing to stonework to be carried out in moderately hydraulic lime mortars coloured/toned as appropriate with natural earth pigments.

b) capping sympathetically replaced with moderately hydraulic lime mortars as appropriate to help shed / percolate water away from Panel.

**Surface:**

**6)** The careful dry-brushing and vacuum cleaning of all surfaces.

**7)** The careful removal with handtools of all cement pointing on and around the panel.

**8)** Removal of all areas subject to bioinfestations. Consider use of borate based biocide.

**9)** The lessening of **sulphation** through the application of:

a) ammonium carbonate poultices/wet cleaning techniques and / or

b) laser cleaning*

(*a specialist technique that has several practical and safety implications for its effective utilisation)

**10)** Removal of new stone to leg, removal of all resin / cement excess; either repair area with a moderately hydraulic lime mortar coloured/toned with natural earth pigments, or re-work stone indent and re-attach and point with a suitable hydraulic lime mortar.

**11)** Careful re-pointing of all fractures etc with moderately hydraulic lime mortars coloured / toned as appropriate with natural earth pigments.

**12)** The provision of permeable winter covers should be considered to mitigates effects of subzero temperatures.

**II) Small Sassanid *Iwan***

The small *iwan* is carved some 3.5 metres into the karst formation, and its vestibule terminates in a plain back wall adorned with two high relief, or *alto-relievo* deeply carved figures. There are two Pahlavi inscriptions either side of the figures detailing their subjects divine lineage.

4. the complete removal of the pavment and lowering of the ground level from around the three monuments was completed in 2011-2012.

The two standing figures are deeply carved in three-quarter profile, with fine detailing to all their costumes, features and accessories, and set against a flattened and recessed panel, the upper parts which bear the inscriptions. They stand on a ledge below which is a plain flat panel.

**Structural:**
The *iwan* is carved directly into the foot of the karst formation and thus crosses several **fault/vent lines**, resulting in **fractures** through which, according to the season, water can seep or flow.

The lower plain panelling to the back of the *iwan,* an area to its lower proper right, and areas to the lower proper left front have all been restored in the 1960 - 70's, with damaged rock cut out and replaced with new stone fixed in cement. Where this restoration work was carried out there is now significant **calcite leaching** with large calcite deposits observable between the new and original stone (Fig. 8).

The vestibule of the *iwan* exhibits several **fault/vent lines** that have been extensively filled with a hard cementitious material inhibiting the egress of water, diverting the water around the fills which has caused some **dissolution** to the edges of the stone.

**Figure 8. Calcite leaching between upper original rock and restoration**

With the paving being brought both a) higher and b) very close to the exterior footings of *iwan* there are signs of **granular disintegration** and **spalling** to the bottom edging of the rock side where water percolation has been prevented, intensifying, for example, the effects of **freeze-thaw cycling** on the stone fabric, and also encouraging **biodeterioration** (Fig. 9).

**Surface:**
Generally the various surfaces of the iwan are stable although all bear significant amounts of **bioinfestation**, particulate deposition and **staining**, along with evidence of **calcite leaching** in the form of its surface re-deposition. Oxalate and / or iron patinas are extant to many surfaces.

**Figure 9. spalling due to water entrapment and subsequent freeze-thaw cycling**

There are also significantly large areas on the vestibule elevations affected by the build up of **sulphation** deposits. The most significant **sulphation** is on the two Pahlavi inscriptions with a black crust forming. There is also hydrated calcium oxalate present in the form of weddelite (see **Appendix 1**). **Blistering** and **delaminating** areas are extant to both lower proper left and right lower elevations to the *iwan.* These are **contour scalar** in nature and show cleavage along the worked profile rather than the bedding plane of the *iwan*.

**Conservation Recommendations:**
As in the case of the panel, protective padding and waterproof sheeting should be used once adequate scaffolding and lifting equipment is in place and before any work commences. Documentation should be kept of all stages of the work.

**Structural:**

**1)** Engineering works to pedestrian area: either

a) execute general site pavement removal and lowering of ground level to divert sources of water ingress (including rising damp) away from *iwan* footing; or

b) create trench at footing to external elevation *of iwan* approximately 1500mm deep x 400mm filled with appropriate gravel to allow for the drainage of water.

**2)** Check that all restoration stonework is geologically compatible to original karst stone and consider its replacement if not. Careful removal of all cementitious pointing to all restoration stonework as far back as possible – if in removing the pointing it becomes apparent that the stones are easily removed then it is recommended that they be reset in hydraulic lime mortar, otherwise the removal of cement pointing as far back as possible will help mitigate the effects of leaching.

**3)** Re-pointing of all restoration stonework on moderately hydraulic lime mortar.

a) All pointing to stonework to be carried out in moderately hydraulic lime mortars coloured / toned as appropriate with natural earth pigments.

**Surface:**

**4)** The careful dry-brushing and vacuuming of all surfaces.

**5)** The careful removal with handtools of all cement pointing from all cracks/fissures in and close to the *iwan*

**6)** Careful removal, where possible, of all loose accretions and deposits including gypsum and calcite crusts with non-metallic handtools

**7)** Removal of all areas subject to **bioinfestations**. Consider use of borate based biocide.

**8)** The lessening of sulphation through the application of:

a) ammonium carbonate poultices/wet cleaning techniques and / or

b) laser cleaning

**9)** Careful re-pointing of all fractures etc with moderately hydraulic lime mortars coloured/toned as appropriate with natural earth pigments.

**10)** The provision of permeable winter covers should be considered.

**III) Large Sassanid *Iwan:***

**Condition:**

The large *iwan* is carved some 6.5 metres into the Zard-i Kuh (Yellow Mountain) mountain, and is approximately 7.75 metres at its widest point (the springing line of the arch) with a maximum vestibule height of approximately 8.5 metres high.

The largest *iwan* bears both shallow and deeply carved bas-reliefs on its inner and outer elevations. The front elevation consists of a castellated facade replete with two flying figures with diadems framing a central crescent/torus; The arch itself has a decorative foilage moulding, and lower down are two tree of life panels flanking the vestibule entrance. Near the angel on the *iwan's* proper left elevation, and on the side of the rock formation in which the smaller *iwan* is carved, there is a small inscriptional panel, from the Qajar dynasty.

Within the vestibule both proper left and right elevations bear elaborate bas-relief panels depicting scenes from, on the proper right, a boar hunt, and on the proper left, a deer hunt.

On the back elevation the upper high relief carving depicts the Investiture of Khosrow II, separated by an architectural device that frames the large equestrian figure of Khosrow II.

The Qajar polychromed bas-relief is on the upper proper right elevation of the *iwan*.

**Structural**

The *iwan* is carved directly into the foot of the karst formation and thus crosses several **fault/vent lines**, resulting in **fractures** through which, according to the season, water can seep or flow.

The vestibule of the *iwan* exhibits several of these **fault/vent lines** that have been extensively filled with a hard cementitious material which has largely failed. The consequent diversion and egress of water has caused significant **dissolution** to the the stone as seen, for example, at the uppermost juncture of the *Investiture* carving and the ceiling, and the extensive build up of staining combined with calcitic deposits through water run-off and **calcite leaching** (Fig. 10 & 11).

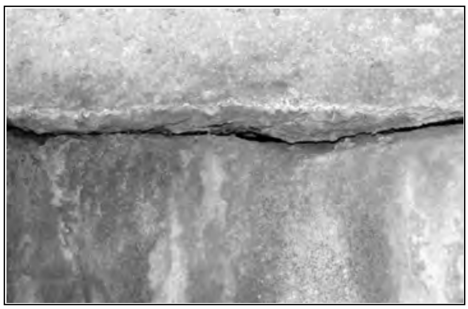

**Figure 10. Dissolution through water run-off**

**Figure 11. Water run staining with calcite deposits**

With the paving being brought both a) higher and b) very close to the exterior footings of iwan there are signs of **granular disintegration** and **contour scaling** to the lower elevations of the two bas-relief hunting panels in part caused by the artificial raising of the water table to higher levels than before the paving was installed.

The effects of **freeze-thaw cycling** on the stone fabric are extensive with notable areas of fracturing to all elevations within the *iwan* – particularly but not exclusively where previous repairs have prevented water percolation or helped cause water entrapment.

The gully behind the castellations to the facade has been poorly capped in cementitious mortar with an uneven fall created. Furthermore it has not been maintained – cracks and debris are apparent preventing the successful outflow of water away from the *iwan* (Fig. 12).

**Figure 12. Debris preventing outflow of rainwater from gully behind renewed castellation.**

The castellations have been extensively restored or replaced. Along with the uppermost proper right side of the facade, repairs including the bedding and pointing of new stonework have been carried out in cement. Furthermore original features to the facade (extant castellations, the torus, the junctures between the new stonework and both the flying figures and the moulded arch etc) have been capped with the same hard cement leading to a general breakdown of coherence of the stone.

**Surface:**
Generally the surfaces of the *iwan* are stable although all bear significant amounts of **bioinfestation**, **sulphation**, **delamination**, **contour-scaling**, particulate deposition and **staining**, along with evidence of **calcite leaching** in the form of its surface re-deposition. Oxalate and/or iron patinas are extant to many surfaces.

**Front Elevation:**
The proper left tree of life panel exhibits extensive surface erosion (approximately 70%), although at the time of inspection it appeared to be stable ie. no significant **disaggregation** was apparent. There is minor **bioinfestation** present. **Dissolution** and etching occurs in the water washed areas and **sulphation** in the sheltered areas, especially where the new block has been inserted in the upper area (Fig. 13), and the lowermost branches of the tree there are significant areas of **delamination** with associated losses caused by the effects snow build up aggravating **freeze-thaw_cycling** (Fig. 14). Cement has been applied to various fracture lines.

**Figure 13. Dissolution and sulphation**

The proper right tree of life panel exhibits approximately 30% surface erosion. As with the proper left panel the lower area exhibits **delamination** with some areas in the process of detachment.

**Dissolution** and etching occurs in the water washed areas and leaves a pitted topology contrasted with the harder **scialbatura** (Fig. 15). Cement has been applied to various fracture lines inhibiting the egress of water.

**Figure 14. Delamination of lower panel. Sulphation on leaves**

**Flying angels, crescent, and foilage moulding:**
The proper right angel is in good condition with little disruption observed, except to the upper right where there is evidence of **scaling** and **staining** associated with rock **fracturing**. There are some surface discontinuities where **faultlines** have been pointed with a hard cementiticious material, but the castellations immediately above have not been heavily restored.

There has been more extensive restoration work to the stonework immediately above the figures diadem, with the castellation having been replaced once before its current incarnation as a singular piece of stone. There are significant amounts of cement spillage onto the original surface including part of the foilage moulding.

The proper left angel has been extensively disrupted following, at some point, a collapse in the mountain. After an early attempt at rebuilding, a later phase of restoration including new stone blockwork also included the extensive capping with cement along the fractured edges of the angel. In this later reconstruction of the facade, cement was used in the rebuilding, both for bedding and pointing the stonework - water transport has been mitigated by introducing an impermeable material and contributed to the water penetration and associated **leaching** and **staining** of the *iwan* ceiling.

The decorative foilage moulding has been capped along its disrupted edges and also a **faultline** has been filled in the same impervious cement. An area on the proper right is severely fractured and weakened and in danger of detachment.

**External Inscriptional Panel:**
The inscriptional panel near the proper left angel and on the side of the rock formation of the smaller *iwan* is probably a Quajar inscription. A **fracture** runs from the upper central moulding through to the proper left capital. In the upper inscriptional pediment there is a large amount of an unknown black pigment used to pick out the carved relief forms of the inscription. On the lower panel and the proper right capital there are very small surface disruptions that appear to be signs of **sulphation**. To the lower proper right through to the centre bottom moulding cement has been applied to a **fracture** line (Fig. 15).

**Figure 15. Dissolution contrasted to scialbatura**

**Qajar Polychromed Panel:**
The 19th Cent. Qajar Polychromed Panel is a lavishly painted recessed panel of four figures carved in bas-relief (Fig 16) with an inscriptional relief carved framework around in the shape of an ogee arch. A second inscriptional relief is carved above two of the figures, and a further inscriptional relief abuts the frame to the lower proper right.

The extant polychromy exhibits at least two kinds of blue, two kinds of green, a red, black, yellow and gilding. The pigment generally appeared stable, though **faded**, without significant **powdering** or **flaking**. There are some stone losses eg. to the carved chair, and a significant loss has occurred near the top of the panel along a **faultline**.

The most extensive damage is due to gypsum formation as a result of **sulphation** with a significant amount of iron present to give it a characteristic brown discolouration, and further compounded by a calcium oxalate interaction, possibly a product of **bioinfestation** or organic coating. The panel also sits across a significant **faultline** and smaller **vents** where water percolates through at various points leading to associated **dissolution**, and **scaling**.

**Figure 16. 19th Cent. Qajar Polychromed Panel**

**The large iwan ceiling:**
The ceiling graphically displays the trajectory of water ingress as a striated patterning of gypsum along with iron, calcium oxalate and calcitic deposits (Fig. 17). **Calcite leaching** is associated with precipitation through the egress of water in the karst formation. Oxalate skins, known as ***scialbatura*** are possibly related to the periods of bioagent infestation and activity within the rock in the *iwan*. **Sulphation**, in the form of gypsum crusts, are a result of pollution, where sulphur dioxide and nitrogen dioxide combustion products combine with water to form sulphuric and nitric acids that react with calcium carbonate to produce calcium sulphate (gypusm) - in sheltered areas this takes the typical form dendritic encrustations which here include iron and carbon giving a characteristic brown and black colour; and where water washed there is stone dissolution as the reaction products are removed by further water ingress.

These deposits are manifested through water ingress through the various **faultlines** in the rock canopy. These have been filled with a hard impermeable cementiticious material, much of which has failed with the consequent effects of **dissolution** particularly noticeable.

**Boar hunt bas-relief panel:**
The relief has an approximately 75% covering of orange **scialbatura** identified with calcium carbonate, calcium oxalate and iron interactions.

There is a **faultline** running from the ceiling and Quajar panel above that traverses through the panel from the upper central to its lowest point near the front of the *iwan*. This has been filled with a hard impermeable cementitious material that has generally failed. Either side of this faultline, and covering variously depicted boars and foilage, there is a brown accretion identified as **sulphation** (see **Appendix 1**).

There are various fracture planes where there is seasonal water egress, especially to the upper proper right of the panel; along the large diagonal faultline; and most prominent to the mid-lower proper left (Fig. 18) where significant dissolution and losses have occurred.

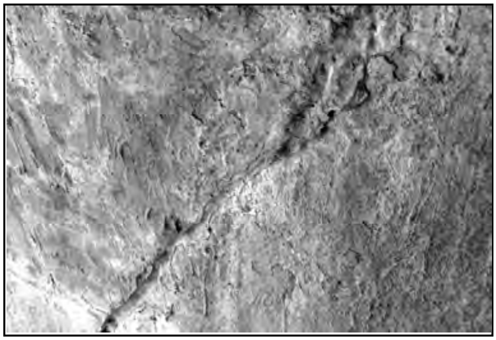

**Figure 17. Calcium oxalate and calcite deposits**

**Figure 18. Boar Panel detail**

Severe **contour scaling** and **granular disintegration** is taking place at the juncture between the lower area of the panel and the *iwan* floor (Fig. 19). This **contour scaling** is associated with water percolation and entrapment aggravated by both the artificial raising of the water table and, in part, through the diversion of water through the use of with impermeable cementitious material in previous restoration attempts. Scratched graffiti from various epochs is also present.

**Figure 19. Boar Panel: Detail of contour scaling at lower edge**

**Deer hunt bas-relief panel:**

This relief panel has an approximately 90% covering of orange **scialbatura** identified with calcium carbonate, calcium oxalate and iron interactions, with less than 10% dark grey stone surface visible, except in those areas that have been subjected to touch. Near the entrance to the *iwan*, a significant area exhibits surface weathering with associated **dissolution**, skin formation and **staining**.

There is one **faultline** running through the panel from the upper proper left central to its lowest point near the front of the *iwan*., another running vertically down in the first third of the panel towards the back of the *iwan,* and a third from near the upper proper right corner running diagonally to the bottom centre proper right area around a new stone insert. They all have been filled with a hard impermeable cementitious material that has generally failed, although less so on the inner fractures. There is noticeable **dissolution** of the stone surface around these fractures (Fig. 20).

**Figure 20. Deer Panel: detail of dissolution around impermeable cement**

As with the boar hunting panel, there are various fracture planes where there is seasonal water egress, especially along the faultlines and including through the fracturing around the unfinished deer to the centre proper left of the panel. There is a reported seasonal dampness to the group of unfinished musicians that surround the king figure in the upper central area of the panel.

Severe **contour scaling** and **granular disintegration** is taking place at the juncture between the lower area of the panel and the *iwan* floor. Like the boar hunting panel, this **contour scaling** is associated with water percolation and entrapment aggravated by both the artificial raising of the water table and, in part, through the diversion of water through the use of with impermeable cementitious material in previous restoration attempts. New stone has been added to the lower edge centre proper right of the panel with cement pointing and bedding, and scratched graffiti from various epochs is extant.

**Central Investiture panel:**

There are multiple exit points for water egress in the Investiture panel, including the major **faultline** in the apex of the arch (which does not appear to have been pointed). The egress of water has caused significant **dissolution** to the stone with significant loss zones especially between the central and proper left figures.

There is extensive staining combined with calcitic deposits through water run-off and **calcite leaching**, and approximately 85% orange **scialbatura** covering identified with calcium carbonate, calcium oxalate and iron interactions. There are also significant zones of bioinfestation.

The figures suffer from multiple losses, some through **vandalism**, but also there are fractured areas eg. around the ribbon decoration of the central figure; beneath the proper right arm of the proper right figure; through the proper right shoulder and in the proper right forearm of the central figure; the sword and feet to the central figure; severe fracturing through the proper left side of the proper left figure (Fig. 21). There is also a significant part of the central figure's headdress in danger of becoming completely detached. This headress also exhibits repairs in hard cement, as does the proper left side of the arch. There is also build ups of sulphation apparent in sheltered areas, for example, behind the various headdresses as well as to the back wall.

**Figure 21. Investiture Panel, proper left figure: Detail of fracture and loss to proper left shoulder**

There are significant hollow areas around the proper left shoulder and waistband of the central figure although no **blistering** (Fig. 22). It appeared as though there was **friable** material inside and around the affected areas along with possibly insect activity.

An area to the proper right of the arch seems to have been removed in order to carve the Qajar polychromed panel.

**Figure 22. Investiture Panel, central figure: Detail of hollow area and debris**

**Large equestrian figure:**

The figure suffers from multiple exit points for water egress and water has caused significant **dissolution** as well as encouraging **bioinfestation** and various gypsum and calcite based accretions.

There is a natural cleavage plane bisecting the horse which has been unsuccessfully pointed with a hard cementitious material which has generally failed. The figure appears structurally stable although water egresses from the vent (Fig. 23).

The panel surround to equestrian figure is heavily etched eg. the proper right side of proper right side column and the area between the horse head and this column. Etching may be associated with the percolation of rainfall, a weak carbonic acid, egressing through the karst formation and reacting with the calcium carbonate substrate (Fig. 24).

A large area on this side of the panel has been replaced with new stone, bedded and pointed with a hard impermeable cement. There is a large area of cement spillage associated with these works. A build up of sulphation apparent in sheltered areas eg. behind the columns and their capitals and to the proper right column base. There has also been extensive damage to the proper right column base with repairs carried out in a hard impermeable cement. All surfaces exhibit the same high degree of **scialbatura**.

**Conservation Recommendations:**

As in the case of the other monuments, protective padding and waterproof sheeting should be used once adequate scaffolding and lifting equipment is in place and before any work commences. Documentation should be kept of all stages of the work.

**Figure 23. Equestrian Figure: Natural cleavage plane through reverse elevation**

**Figure 24. Equestrian Figure, proper left column: Detail of etching to marble and calcium oxalate skin formation**

Engineering works to pedestrian area should be executed with pavement removal and lowering of ground level to divert sources of water ingress (including rising damp) away from *iwan* footing. All surfaces should be lightly clean with dry brushes, conservation grade vacuum cleaners and deionised water as appropriate.

**Front Elevation: Castellations and restoration stonework:**

All adjoining gullies should be cleared and all cement cappings removed before re-capping with moderately weak hydraulic lime mortars ensuring a clear fall away for rain. Ideally all restoration stonework (upper proper left side of the facade; new castellations; new stonework) should be checked for geological compatibility (and replaced if too dissimilar), de-constructed and all cementitious material removed. Assuming such deconstruction is unlikely, all cement pointing should be removed as far back as possible from all joints before re-pointing of all new stone work with moderately hydraulic lime mortars.

**Front elevation: including tree of life panels, Flying angels, crescent, foilage moulding, External Inscriptional Panel, and Qajar Polychromed Panel:**

- removal of bioinfestations
- removal of cemetitious material including spillage
-lessening of sulphation using dry/wet/laser techniques
- structural pinning of detaching area to arch moulding
- possible localised consolidation of details (eg. proper left tree of life panel)
- possible localised consolidation of pigments to inscriptional and Qajar panels
- repointing and capping of fractures with colour matched moderately hydraulic lime mortar
- consider use of borate based biocide as preventative treatment

**Large iwan ceiling, Deer and Boar hunt bas-relief panels:**

Before executing the treatments itemised above to the panels and ceiling, extant calcite deposits should be first removed with non-metallic handtools followed by wet techniques as appropriate.

Areas of the bas-relief panels affected by fracturing, contour scaling, and dissolution should be injected and capped with hydraulic lime grouts and colour matched moderately hydraulic lime mortars. The use of acrylic co-polymer or hydrated lime dispersions should also be considered on these panels for localised consolidation as appropriate. Furthermore, the removal and re-setting in moderately hydraulic lime mortar of the restoration stonework on the Deer hunt bas-relief panel is recommended.

**Investiture panel and Large equestrian figure:**
As with all other features, the removal of all accretions and surface deposits with non-metallic handtools, and the lessening of sulphation and staining using wet/laser techniques is recommended. The removal of all cemetitious material from these features is also necessary, including from around the restoration of central figure's headdress, which might also be remodelled after appropriate discussion. If possible the newer stone from previous restoration works should be checked for geological compatibility (and replacement if it is significantly incompatible), removed, reset and pointed in moderately hydraulic lime mortar. All hollows, fractures/faultlines to the figures and surrounding stonework should be injected and capped with hydraulic lime grouts and colour matched moderately hydraulic lime mortars. As above, localised consolidation of details may also be necessary.

**Acknowledgements:**
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## Appendix 1: Summary of Unpublished Examination Report on seven samples from the Taq-e Bostan Complex, Iran.

In November 2007 analyses of seven samples from the Taq-e Bostan complex were made using X-Ray Diffraction and X-Ray Fluorescence by the Dept. of Conservation, Documentation and Science, British Museum, London. The unpublished results indicate the presence of gypsum, calcite and weddellite. In addition, a rock fragment from the area was also examined under XRF. The XRF results indicate that the orange-red colouring on most of the samples is due to iron. One sample, labelled as 'orange dust' (sample 7) was found to contain significant amounts of copper, zinc, lead and bismuth in addition to iron.

A preliminary test of the samples with hydrochloric acid indicated the presence of calcium carbonate. The XRD patterns indicated that four samples were made from gypsum (calcium sulphate), one sample was calcitic, and two samples were composed of gypsum and weddellite (hydrated calcium oxalate).

The samples indicating gypsum are assumed to be sulphation products on the 'marble' semi-metamorphised limestone surface. The weddellite and gyspum found together on two samples may be the result of interaction between algae/lichens and the stone or the decay of an organic coating – such oxalate coatings (scialbatura) are commonly found on exposed marble surfaces. The calcitesample indicates calcites precipitation around fracture sites where water egresses in the grottos. The occurrence of copper, zinc, lead and bismuth along with traces of silicon, aluminium, potassium and titantium may be explained by airborne pollution.

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