An assessment of the condition of nine engraved sites in the Hong Kong Special Administrative Region

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Nine engravings in the hinterland around Hong Kong Island have been studied independently by the authors, as part of an overall assessment of current management practices, the state of the engravings, conservation impacts and future survival. Four independent studies were commissioned in 2009 by the Hong Kong Heritage Museum in conjunction with the Antiquities and Monuments Office who have legislative responsibility for all archaeological sites within the Hong Kong Special Administrative Region. The sites have received varying levels of protection in the form of roofs, fences, and screens, and in more recent times, a range of conservation treatments aimed at prolonging their life and improving legibility. This paper reviews the state of the engravings from the point of view of protection and presentation and considers the effectiveness of the infrastructure in mitigating what are often conflicting needs. Modern conservation treatments must be considered in several dimensions: their effectiveness and durability in an aggressive climate, given that the engravings have survived for 3000 years, and the feasibility and cost of maintaining such treatments over the next 3000 years and longer. This paper describes field observations rather than measured data, due to the nature of the commission, highlighting the value of intelligent observation as an investigative tool. The main focus of the paper is on the impact of protective shelters and applied treatments as observed during two of the independent surveys, concluding that protection must address all environmental and visitor impacts to be fully protective.

Keywords: Rock engravings, Condition assessment, Protective shelter

Introduction

The Hong Kong Special Administrative Region (SAR) contains nine known rock engravings, predating the establishment of Hong Kong as a city, from a time when the coast and islands contained a series of small villages and fishing havens. The engravings vary in motivation but seem to be offerings or appeasements to sea spirits.

All sites are located within 1 km of the coast, with most being on or within sight of the ocean (Fig. 1). The sites are all volcanic or plutonic rocks. These are granite, basalt or porous yet reasonably well consolidated and indurated tuffs, as indicated in Fig. 2. All sites have public access requiring the construction of pathways, shelters and in some instances substantial sea-walls, to protect both site and visitor. The age of the sites is not precisely known, however it is believed they date from around 3000 years ago, up to a datable and reasonably decipherable inscription at Joss House Bay of 1274 CE. Paint is found within two motifs but is invariably a more recent enhancement.

The AMO commissioned a study of the sites five years after the first intervention, to assess site conditions, to ensure that visitor amenities provide positive experiences, and to ensure management and interventive programs are up-to-date and effective. Four reports were commissioned independently from each other and with express instructions not to collaborate with the other researchers. This removed the influence of collaboration, which on the one hand avoids ‘collusive’ judgement but on the other reduces
Figure 1  Distribution of the nine engraving sites around Hong Kong SAR. The 2014 IIC Congress was held at the yellow cross.

Figure 2  Geological map of Hong Kong SAR with the sites plotted. It can be seen that with the exception of the Po Toi Island site (PT), all others lie in the violet shaded volcanics zone. The Po Toi site in Fig. 2 is actually located on a tuff band adjacent to substantial basalt and other intrusive seams.
the benefits of collective knowledge. This paper presents the views of two of the researchers, brought together after the project was completed and with the sanction of the client. All four reports were made public after the project and the majority opinion on the assessment of the sites, that infrastructure can be improved in some cases and that treatments, while appropriate, can be fine-tuned is contained within the paper.

Summary of geology and climate relevant to site stability

Hong Kong lies 22° north of the equator in a sub-tropical climate. With mild dry winters from December to February when temperatures remain largely below 22°C, the remaining months offer varying levels of high temperatures, with June, July, and August having average highs just above 32°C and with the highest recorded temperature not much higher, at 36.3°C. The average monthly diurnal range is no greater than 7°C, however this may be higher for specific days.

It is worth stating that average climatic data offer little insight into hygrothermal stress mechanisms causing rock erosion, however, the study did not permit detailed data collection within this review project. Recommendations for such would be made if a hygrothermal problem were identified, but this was not particularly the case. No freezing conditions have been recorded.

The study sites receive 1800–2400 mm of rain annually with the five hottest months, May to September, bringing 80% of the annual rainfall.

Hong Kong can experience up to 20 typhoons annually with a long-term annual average of 6.5 per annum. These typhoons are indicative of a highly turbulent atmosphere in the region, bringing destructive winds and high seas to the sites, most of which are in very close proximity to the sea. Since the survey one of the sites for which modifications were proposed had all of its infrastructure completely removed in a particularly powerful typhoon. (pers comm; Karen Wai-Yin Fong, Hong Kong 2014). Proximity to very turbulent seas excludes rainfall as a destructive mechanism as the coastal sites are just as frequently inundated by high seas as belting rains.

Even in calm seas aerosols become more significant and rain serves more to rinse exposed surfaces and thus prevent build-up of damaging salts. In the more protected sites a balance between aerosols and rainfall shapes the argument for whether roof structures provide a positive protection where aerosols are freely deposited but rain flushing is excluded. Most engraved panels are well above soil level, although those that are touching show little evidence of erosion from ground moisture or salts.

The engravings are found on granite, basalt, or rhyolitic tuffs from the Mesozoic period (Fig. 2). All three rock types result from cooling magma and thus have similar chemistry. Granite cools more slowly, generally as a result of being formed under land masses, whereas basalt is the same magma that has cooled more rapidly, generally as a result of forming under the sea. Tuffs are formed from lava exposed in the atmosphere. All rock types are subjected to direct weathering, with the most significant difference between the three types being porosity. The granite and basalt sites are denser more rounded forms, less prone to absorption of water and aerosols, while the rhyolitic tuffs are more angular, porous, fissured and subject to surface modification through dissolution and precipitation processes that create a differentially denser outer surface. All three rock types are generally stable geologically when compared with marble, limestone, and sandstone. More precise geological data on each site was not available at the time of the surveys but featured as a recommendation in reports.

While the climate and geology were relatively uniform across the nine sites, with the presence of tuff being the only substantial variable, the accumulated infrastructure applied to protect the sites provided far greater variability both in its intended function and its ability to protect or threaten the engraved surfaces.

Main threats to the engraved surfaces

The main threatening mechanisms prevailing at the sites are climatic, as already described, visitor impact and its management, and according to one of the four invited rapporteurs, recent interventions and management practices. It is this latter criticism of treatments and current management practices, expressed at various times prior to the study by a local independent archaeologist, which led the government to commission the status review summarized by this paper.

Natural climatic and geological interactions

While the interactions between the rocks and their climate have been discussed in general terms the following specific mechanisms have been identified. It is important to stress that these observations are precisely that and do not derive from thoroughly researched data.

- Frost action is not a factor in sub-tropical climate zones at sea level.
- Aerosol deposition has a high incidence, offset to a large extent by regular rain washing. Salts have only been suspected as a mechanism in the fully enclosed site of Cheung Chau.
• Diurnal temperature ranges are quite low due to the moderate climate. There is a low likelihood of thermal stress.
• Hygrothermal stress has a high potential due to the tropical regime during the hottest and wettest season, May to September. Hygrothermal stresses are a product of rapid change between wetting and drying. The magnitude of wetting is not as important as the subsequent rapid drying through intense solar radiation or wetting following intense heating (Thorn, 2008).
• Wind and sea abrasion may well contribute to loss of surface detail, although there is no measurable evidence of this. Many of the sites have had protective screens placed directly in front of the vertically inclined engraved surfaces in recent years. These protect the surface from abrasion but there is no evident difference between the protected surface and immediately adjacent surfaces.

Protective infrastructure
As visitors have begun to seek out the engravings, it has become necessary to provide safe access to what can be unpredictably dangerous sea-swept locations. This has required the development of pathways, boardwalks and fences. In addition to visitor facilities, the engravings themselves have been offered varying forms of protection from the elements since 1978. Protective structures serve a two-fold purpose of protecting the engravings from the elements and the impact of inappropriate visitor behavior.

In general roofs have been provided at some sites since the early twentieth century and more recently these have been augmented with protective barriers, diversion drainage, and in some cases, protective screens providing physical protection and passive climate modification (Fig. 3). The more exposed sites have been afforded better access through the earlier construction of substantial concrete walkways-cum-sea walls that offer a view of the site, though at some cost to the overall natural harmony that prevailed at the time of their creation.

The recent assessment of this infrastructure provides a central discussion for the current state of the engravings, both from visual and visitor perspectives and for environmental impact mitigation (Thorn, 2009; Magar, 2010). Proximity to the sea provides high salt deposition, mitigated largely by constant rain flushing. The introduction of various levels of protection can disrupt this relationship to a significant extent. A roof, if well designed and maintained, will intercept all rainfall. This might be considered a positive modification in relation to calcitic stones and their rapid dissolution in acidic rain environments. The environmental impact of roofs is more complex than simply catching rain and that being a benefit.

Aerosols are transported in all directions and while high levels of maritime aerosols eventually fall out of the atmosphere they remain at high levels close to the coast (Hutton, 1976). Not only are the coastal sites subjected to high loadings of saline aerosols but one or two receive direct sea water wash in rough seas. The sites with roof-only are well out of reach of wave-borne salts but all are within a distance where sea salts will be highly concentrated in the air. A roof does not prevent deposition, however it does remove the all-important rain flushing ensuring that exposed surfaces never accumulate high levels of crystallizing salt for long periods.

China is the largest producer of anthropogenic aerosols damaging to outdoor cultural heritage (Air Science Group, 2012), having seven of the 10 most polluted cities in the world, several of which lie along distribution paths carrying pollutants to Hong Kong, which has the world’s fourth most polluted urban air. Roof structures will do little to reduce aerosol impact while preventing flushing.

Roof structures have a positive benefit in limiting hygrothermal stress by both reducing water supply and the intensity of solar radiation. Given that hygrothermal stress has been identified as a significant deteriorant in sandstone (Thorn, 2008) it is sensible to hold similar expectations for volcanic tuff unless specific studies indicate otherwise.

Protective screens
Protective screens provide the inverse protection to that of roofs. They intercept aerosols, reduce wind, and minimize direct impact from raging seas. They also permit rain flushing but do not reduce solar radiation. It is often contended that screens placed close to rock surfaces will trap humidity and thus increase condensation and biological growth. These factors may prevail where the screen encapsulates the rock in a pocket of air that cannot readily exchange with the ambient atmosphere. Data loggers inserted into close-fitted screens on partially outdoor mural paintings at the Commandant’s House, Port Arthur, Australia showed that with an open-edged screen scenarios have been observed and are considered for their benefits to the engraved surfaces.

Protection provided to the sites is in the configurations indicated in Table 1, together with a list of recent treatments.
placed at approximately 2 cm from the painting there may be a slight modulation, but no significant increase or decrease in moisture within the screen or on the surface of the exposed plaster and paint layer (Thorn, 2005a). The Hong Kong screens will not necessarily conform to these observations, however it is believed that the screens intercept more moisture than they trap. In a humid climate it is quite feasible that a screen will retard evaporation and thus provide a more conducive bio-environment. The control of biota has been dealt with by HKHM staff through both application of biocides and associated hydrophobic treatments.

Screens are largely installed to protect the surfaces from visitor impact and for this they have been more or less successful. The best form of visitor protection is public education, as it is in museums, however at an unsupervised location short-term protection is best achieved through a physical barrier. The fact that barriers reduce direct aerosol deposition whilst maintaining rain flushing has been considered a satisfactory modification. Given the visual impact and ambience on the site it is difficult to state that screens provide better protection than a fully exposed surface.

Cage enclosure
A cage has been built around all sides of the Kau Sai Chau site on an island to the east. This site is at the base of a cliff just above the water line and surrounded on the landward sides by a golf course above with no direct access. The motifs are very faint and the cage provides no protection other than from visitors. Access to this site is not easy due to the steep cliff and its only identifier from the sea is the cage. Given that the cage is only there for visitors and visitors are most likely only there due to the cage, it has been proposed that the cage serves no useful function and could be removed. The site provides a baseline for impact in a fully unprotected situation but with visitors excluded.

Full screen enclosure
The Cheung Chau site is located on a busily populated island from which it takes its name. The site sits below a relatively modern hotel with landscaped gardens that sit immediately above the site. Any excess watering of the gardens appears to drain into the site as evidenced by a dark stained rock surface in one area.

The complete glass enclosure appears not to affect the engraved surfaces too much and on the whole they are clean and free of biota. This is partly due to recent biocidal treatments but reducing water supply
at the surface suppresses biological growth, provided the enclosure does not raise humidity. This is achieved at the site by ventilation ports which configure the enclosure as a combination of a front screen and clear roof above.

The Cheung Chau site is the most visually compromised due not only to the extensive screen but also because it is situated immediately below a tall modern hotel building and within a busy tourist and residential precinct. The main impact perceived at the site appears to come from percolation of irrigation water from the hotel garden that manifests in the site as a saline seepage area. The screen provides no protection from this intrusion.

Unaltered surface
The Wong Chuk Hang site is the only one of the nine that has not had its surface exposure modified in some way. The site has been cleaned of biota, together with some soil stabilization works above. There is no indication that this site is more eroded or otherwise altered. Wong Chuk Hang is the most protected of all nine sites, being farthest from the sea and surrounded by tall shade trees. Viewing is achieved by a platform placed across the stream and this provides a natural barrier and ideal viewing place.

Anthropogenic pollutants
Pollution impact has not been observed on the engraved surfaces for several reasons. First volcanic rocks are not high in acid-soluble minerals. Published data for nine ignimbrites in New Zealand, reviewed as part of an assessment of rock engravings in that part of the Pacific (Thorn, 2011 a, b), showed that CaO is below 3% and as low as 0.2% of rock composition in the nine samples. While calcium carbonate will be vulnerable to acid dissolution it is no more abundant in tuff than in granite and many sandstones.

The second reason that no impact is observable is simply that the industrialization of China has been quite recent. Hong Kong is the world’s fourth most polluted city and lies in range of pollutant fall-out from several of China’s major industrial regions. The Guangdong-Guangxi-Guizhou-Sichuan basin south of the Yangtze is the largest most concentrated generator of acid rain pollution in the world.

To control regional pollution Hong Kong has signed co-operative agreements with neighboring Guangdong Province. Hong Kong is also the world’s third busiest seaport, a heavily polluting activity on a local level. Given that this is a modern industrial escalation of pollutant levels it is most likely that any dissolution, salt formation or microbial reduction will not yet have had a measurable impact on the rocks.

Any short-term impact is most likely to be in the form of biological retreat from the surfaces. A short-term study cannot accurately gauge this. The HKHM have also been actively reducing biota through chemical means and hence evidence for pollutant impact is not observable.

Visitor behavior
The sites vary in accessibility from those located along busy thoroughfares (Cheung Chau, Big Wave Bay) to several being in quite remote locations on outer islands (Po Toi) or isolated from regular thoroughfares (Kau Sai Chau). All of the sites have been offered some form of visitor protection through protective screens or grilles. In the exceptional case of Wong Chuk Hang the site is separated from access by a small stream. This is a minor deterrent but very little damage in the form of graffiti or scratching has been noted. The worst impact has been through the removal of infrastructure from time to time.

The most enduring impact from visitors has been through enhancing the engraved channels themselves (Fig. 4). This has been a tradition, even for rock engraving conservation, in many parts of the world (Andersson, 1986) but is generally considered in the archaeological community to be a potentially damaging distortion of the original appearance.

Recent interventions
With care of the engravings being mandated to the AMO, the sites have seen a more interventive approach in recent years, brought about to a large extent through partnering with HKHM, which has brought a more technological assessment and interventive strategy to the sites. Given that much of the local criticism has been leveled at these interventions it was essential to assess and comment on each approach. The assessment has been objective and impartial and where alternative approaches or modifications have been identified these were first discussed on site so that no surprises would be encountered upon the submission of reports.

Various methods have been implemented since 2004, either in a controlled evaluation or by follow-up broad-scale treatments, where trials have indicated benefits. The works have proceeded with appropriate caution and should continue, with one or two refinements, into the future.

Surface appearance issues have been treated with a combination of dry brushing and surfactant-aided cleaning, together with biocide reduction of biota and associated stains.

Four of the nine sites have received a water-repellent treatment using hydrogen functional siloxane (Wacker Chemie), with one of these also being consolidated with ethyl silicate (Wacker Chemie). In general these latter treatments have been applied to the rhyolitic tuffs and follow the same technology determined as...
the most effective means of stabilizing similar rock surfaces elsewhere. Most notably the Moai of Rapa Nui have been considered best protected by this combination of treatments (Bahamondez Prieto, 1994; De Witte et al., 1994). The critical issue here is to ensure that no moisture comes from within the rock, since it has the potential to cause spalling if its exit through the treated surface is impeded by hydrophobic treatment (Thorn, 2011a). This concern had been raised by local observers of the sites, and it was a particular requirement of the commission to assess the performance of these treatments.

The critical issue to evaluate here is not whether the treatments are working effectively in isolation but that the decision making process has a sound logical basis. Hydrophobic treatments had been applied to four sites over a number of years with one attempted in the first year of HKHM conservation procedures in 2006, and three more following closely after. It is difficult to argue, from observations alone, that water repellency has improved the durability of the rock, but the literature indicates a benefit, provided that the moisture regime is fully analyzed. In studies by one author of a far more porous lava-flow ignimbrite (Thorn, 2011b) water repellency was assessed to be a dangerous proposition, so much so that even the application of ethyl silicate was considered a risk to stability due to its initial hydrophobic phases that can last up to eight
weeks (Thorn, 2011a). The reports have emphasized the need to study the moisture movement in greater detail prior to any further hydrophobic treatments and that the dilution ratio of the hydrogen functional siloxane should be carefully considered with reference to published data (Thorn, 2005b).

There is no major issue with the use of ethyl silicate at one site as this serves as a useful field trial with little likelihood of adverse impact on the surface should it fail to achieve its objective of a more stable granular cohesion.

Several sites have had water diversion walls installed above, and while these are currently formed of Portland cement containing potentially destructive soluble salts, alternatives using silicate cements have been proposed (Thorn, 2010). No evidence of impact was seen except at the Cheung Chau site where evidence of leaching was more likely due to the fertilizing of garden beds above the engraved rocks. In that case the mineralized surface also showed signs of delamination. It is noteworthy that Cheung Chau is the most enclosed site and thus rain washing has been removed. Similar conditions prevail at Big Wave Bay where the dam walls all lie under the roof. In this case substantial rain is collected off the rock slope above and channeled in under the roof. This means that the Portland cement walls become saturated but do not have salt formations washed away.

Biocidal treatments include the addition of surfactants and metallic bio-toxins. Surfactant cleaning has been carried out at five sites, with two of these being protected by roofs, two by screens, and at the fully exposed Wong Chuk Hang site. The issue here is whether this approach is beneficial beyond its primary motivation to improve legibility of the engravings. It can be said that where a surface is regularly washed by rain the surfactant issue will not be a problem. With roofed structures it is essential to ensure that the surfactant has not become absorbed into the porous surface, where it can become an attractant for further dust and soiling and also set up chemical reactions that may lead to alteration and staining.

Access infrastructure
Prior to the AMO taking responsibility for the care of the sites they were afforded varying levels of access infrastructure. This was in the form of Portland cement concrete pathways and painted mild steel railings. Two issues were apparent here: the presence of Portland cement and its damaging implications, and the visual compromise to the natural ambience. Both aspects are encapsulated in the Tung Lung Island site in Fig. 6.

The Tung Lung site has a massive concrete access and viewing platform that places the viewer immediately adjacent to and within reach of the engraved surface. While the concrete is well below and not in contact with the engraved panel and thus not a threat through mineral erosion, it does impose itself on the site. It has been placed for ready inspection of the engraved surface but this in itself reduces the visitors’ ability to take in the whole rock surface. Given that Holocene sea levels, those considered relevant to the making of these engravings, have always been lower than current, it is appropriate to view the site from a lower position. By revising the viewing platform through lowering or preferably removing the concrete, the site can be viewed from a position that prevents direct contact. It would also clear the site of infrastructure when viewed from the sea as one approaches by the normal mode of transport.

Similar observations have been made for other massive concrete structures such as those surrounding the Po Toi site and across the stream from Wong Chuk Hang.

Counter to these proposals, particularly where a light-weight viewing structure has been proposed at Tung Lung, a recent typhoon completely stripped all screens and railings from the Po Toi site (pers. comm. Karen Wai-Yin Fong, Hong Kong 2014). This extreme but not unexpected event underlines the danger of both installing infrastructure, and more pertinently here, giving advice on its improvement.

![Figure 6](image-url)

The Tung Lung Island site is heavily congested with a concrete viewing platform and more recently a protective screen. The elevation sketch on the left indicates the extent of concrete and its proximity to the engraved panel. A proposed modification on the right removes all of the concrete and lowers the viewing platform.
Conclusion

The four surveys, conducted by four independent consultants and available through the AMO website, drew more or less consistent conclusions about the present condition of the nine engraved sites. Three of the reports were unanimous in stating that while some previous management practices have left several sites in a compromised visual condition due to a preponderance of concrete infrastructure, the current management and interventive actions are all ensuring good protection of the sites.

What is most apparent in assessing current methods is that they have all been implemented in a cautious and sequential manner. Surfactant cleaning was applied to one site and assessment after one year determined whether such treatment should be continued. Consolidation using ethyl silicate has been applied to one site only whereas hydrophobic treatment has been applied to four sites in a short time frame. What has been articulated through the collaborative site inspections is a series of refinements and hold points to ensure that no treatment has an adverse impact. While surfactants can be extracted and biocidal regimes abandoned, this is not the case with silane-based treatments that are not readily removed from the surface. The reporting team, represented in this paper by two of their number, has aimed to give confidence to those treatments that are considered, at arms-length, to have a positive benefit. Identification of negative aspects, such as the placement of concrete in the form of pathways and dam walls, has been responded to on site and through adoption of recommendations contained in the reports, in a positive manner.

Screens and roof structures are of limited benefit in preventing erosion but do provide protection from visitor impact. Visually they alter the site context dramatically but this is less of an issue in Hong Kong than it might be in a less urban environment.

The study has provided a critical review of current practice for the HKHM conservators and this process indicates an essential maturity for all outdoor conservation practice, whereby recent treatments have been open to examination and review (Villasenor & Meurs, 2012) It is very easy to criticize any intervention if one focuses on the shortcomings, as it is possible to find a select body of literature challenging the use of ethyl silicate, for example, in a larger corpus of literature endorsing this as an appropriate treatment for siliceous rocks. What the review process has enabled is an objective yet collegial assessment of a difficult management issue.

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