

# The Preservation of the Mogao Caves in Dunhuang, China

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## Abstract

The Mogao Caves in Dunhuang, Gansu Province, are one of the most important World Cultural Heritage properties in China, in which scrolls, frescos, paintings and painted sculptures dated from the fourth to the fourteenth century are located in 492 caves, providing invaluable and irreplaceable data for disciplines of archaeology, art history, history, fine arts and religion studies, as well as for our understanding of cultural contact and exchange between South Asia, West Asia and East Asia in antiquity. However, owing to the abandonment of the Silk Route after the 13<sup>th</sup> century and subsequent cultural changes, the caves were deserted and the condition of the treasures inside the caves deteriorated significantly.

This article reviews the preservation history of the Dunhuang Caves from the 1940s to the present. It is clear that the state has been playing a significant role in the preservation and management of the grottoes, and the opening-up policies, the development of the economy and tourism, and the globalization process after 1979 in mainland China have significantly shaped the strategies, practices and techniques of the preservation since then. The preservation of the Mogao Caves in many aspects reflects or represents the history and development of cultural heritage preservation in mainland China since the 1940s.

## 1. The origins and significance of the Dunhuang Mogao Caves

Located at a small oasis at the western end of the Hexi Corridor in Gansu Province, People's Republic of China (PRC), Dunhuang used to be a very important city along the ancient Silk Route. According to archaeological data and historic documents, the town of Dunhuang was established more than two thousand years ago during the conflict-laden encounter of the Chinese ancient state and the nomads in northwest China owing to the strategic importance of its geographic location. Travelling from Dunhuang westwards, one can reach Central Asia, West Asia and eventually Egypt and Greece of the Mediterranean World and Rome in Europe. The ancient cities of Luoyang and Chang'an, both capitals of the Han (BC 206-AD 220) and Tang (618-907 AD) dynasties of Chinese civilization, can be reached from Dunhuang by travelling eastwards. The Steppe Silk Route north to Dunhuang can be reached by crossing the Mazong Mountain, while the Tang-Tibet Route leading to Nepal, India, Vietnam and Myanmar via the Tibetan Plateau can be reached by crossing the Altun Mountain south to Dunhuang. Consequently, Dunhuang was a crucial place in the

process of cultural exchange and ethnic dynamics between the East and the West in ancient China.

As a result of the expansion of Buddhism and Buddhist arts, many grottoes were carved in Dunhuang Prefecture between the fourth and the fourteenth century, namely the Mogao Caves and the Western Grottoes of a Thousand Buddhas in Dunhuang County, the Yulin Grottoes and the Eastern Grottoes of a Thousand Buddhas in Guazhou County, and the five temple-grottoes in Subei County. Together, these grottoes are generally referred to as the Dunhuang Grottoes, representing the culture and arts of ancient China and Central and Western Asia, as well as of the Han and many minority people. The Dunhuang Grottoes epitomize the combination of Buddhist arts with Chinese styles and characteristics, with the Mogao Caves serving as a typical example for this.

To date, Mogao is home to 735 caves dated from the fourth to the fourteenth century, housing more than two thousand polychrome sculptures and approximately 45,000 square meters of wall paintings. In addition, more than 50,000 pieces of scrolls and artefacts dated from between the fifth and the eleventh century were found in a sealed cave in 1900. The arts and artefacts in the Mogao Caves are very rich and diverse and of unique and universal cultural significance. The paintings, sculptures, scrolls and artefacts are a manifestation of the history of medieval Dunhuang, the Hexi Corridor and Western Asia. They reflect the activities and impacts of Buddhism, Daoism, Manichaeism, Nestorianism and Zoroastrianism, they preserve rich and lively images of Chinese and foreign arts, demonstrate the expansion and development of Buddhist arts spanning a period of more than one thousand years, and they illustrate the economic, social, scientific and technological changes in medieval Dunhuang and adjacent areas. The Mogao Caves and artefacts also serve as evidence of the cultural exchanges between China and the West over a period of more than one thousand years. They show cultural elements not only of Han China, but also Sogdiana, India, Persia, Islam, Greece, Mongolia, Roman, Khotan, Tibet, Uighur, and Hebrew. To summarize, the Mogao Caves have a very long history and contain impressive amounts of valuable data of great cultural significance; they are excellent examples of Chinese civilization and traditional arts, and have attracted great interest and attention worldwide. Consequently, the Mogao Caves were declared as a national monument by the State Council of the PRC in March 1960. In November 1987, the Mogao Caves were inscribed on the World Heritage List at the 11<sup>th</sup> session of the UNESCO World Cultural Heritage Committee (UNESCO 1987).

According to UNESCO, the Mogao Caves have satisfied all the six selection criteria for world cultural heritage, because the grottoes represent “a unique artistic achievement ... by production of more than 2,000 painted sculptures, and approximately 45,000 square meters of wall paintings, among which are many masterpieces of Chinese art”, “played a decisive role in artistic exchanges between China, Central Asia and India”, “bear exceptional witness to the civilizations of ancient China”, “constitute an outstanding example of a Buddhist rock art sanctuary”, and “preserve the example of a traditional monastic settlement” (ICOMOS 1986: 2-3). As decided by UNESCO, a site can be defined as world cultural heritage if it has outstanding and universal value and meets at least one out of six selection criteria for cultural heritage (UNESCO 2005). The fact that the Mogao Caves have satisfied all the six criteria illustrates the diverse and incomparable value of the grottoes. Consequently, the preservation of this cultural property has become very important. As pointed out by UNESCO at its eleventh session, the “committee drew the attention of the Chinese authorities to the need to take all necessary measures to safeguard the very vulnerable rock site of the Mogao Caves” (UNESCO 1987: 3); furthermore, a detailed plan for the conservation, restoration and management of the Mogao Caves was required (ICOMOS 1986). Today, the responsibility of preserving the Mogao Caves lies with the Dunhuang Academy. It is crucial to follow international concepts on heritage conservation, do our best to address the risks threatening

the Mogao Caves, and sustainably maintain the authenticity, integrity and outstanding values of the Mogao Caves in the interest of China and humankind.

## 2. Problems related to the Conservation of the Mogao Caves

The Mogao Caves are located in a desert area where the climate is very dry and the precipitation is low. This has facilitated a relatively stable microenvironment inside the caves. The pigments and colorants used in the polychrome sculptures and wall paintings are made from minerals or organic plants, and are relatively resilient. In addition, the reasonably stable natural and cultural context in Dunhuang has also helped the preservation of the grottoes for more than one thousand years, as there have not been any severe natural disasters or mass destructive wars in the region.

However, both natural and cultural factors have led to the deterioration of the caves and the treasures found inside them since the fourth century, and particularly since the mid-sixteenth century, when the Ming government decided to close the Jiayu Pass and migrate the Dunhuang residents into the Yellow River Valley. Consequently, Dunhuang became a marginal area, the carving of caves was suspended, and this once prosperous and sacred place of Buddhism was gradually deserted. No conservation work was carried out at the caves in the following four hundred years from the mid-sixteenth to the early twentieth century until the establishment of the National Dunhuang Art Institute in 1944 (Figure 1). As a result, the footpaths and some caves collapsed or were buried by sand (Figure 2) and flooded by river water, or occupied by people, using caves as residential space and installing beds and cooking facilities. Sand deposited in front of some caves and eroded the surfaces of some paintings (Figure 3). Moulds were found on other paintings, and some painted layers had been detached from the conglomerate wall of the caves (Figure 4). In summary, by the early twentieth century, the Mogao Caves were in extremely poor conditions.



Figure 1 The Mogao Caves in 1907. Photo taken by Marc Aurel Stein



Figure 2 The sand accumulated in front of cave No. 195 of the Mogao Caves. Photo taken by Samuil Martynovich Dudin in 1914



Figure 3 Moulds on the surface of paintings

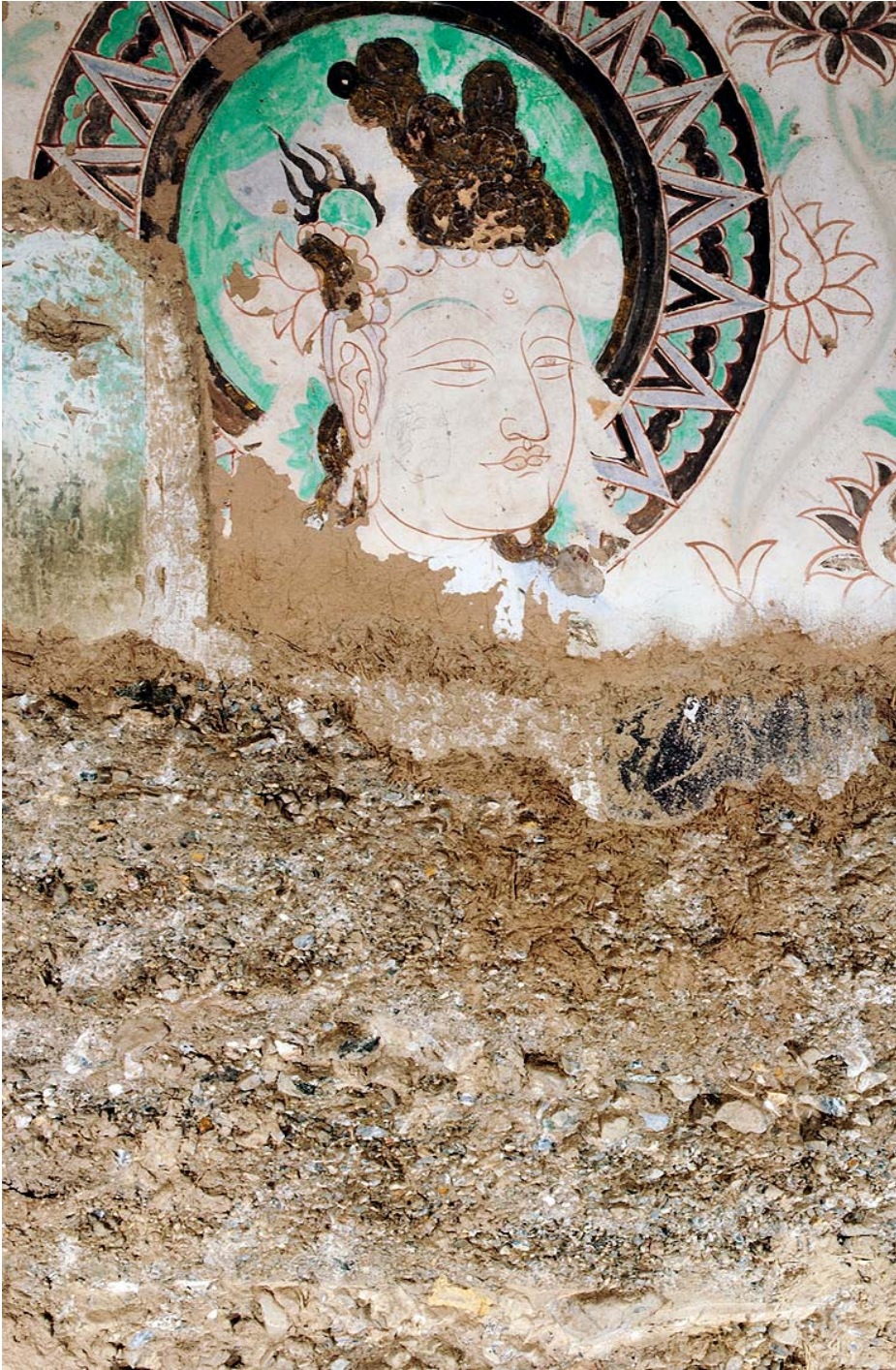


Figure 4 Part of the painting has been detached.

After the 1940s, the Dunhuang Academy conducted surveys, research and monitoring work on the caves, sculptures and paintings, as well as on the macro-environment of the site and the microenvironment inside the caves. The results revealed the various kinds of problems that have been threatening the Mogao Caves and their artefacts for decades. The deterioration of the Mogao paintings and sculptures is a result of the following combination of factors:

2.1 Windblown sand

Caved into a cliff face located at the edge of the Gobi desert, the Mogao Caves have been threatened by windblown sand for thousands of years. During heavy storms, sand falls from the top of the cliff and accumulates in front of the caves. The windblown sand weathers outdoor paintings and erodes the soft conglomerate rock supporting the caves; it even causes the collapse of parts of the rock. Further, the absence of doors and windows in many caves owing to the lack of proper management from the sixteenth century to the 1940s also led to sand being blown in and deposited inside the caves, causing further erosion of sculptures and paintings (Figure 5). Before the 1980s, a total of 3000-4000 tons of sand had to be removed from the grotto areas, which was a very costing exercise (Figures 6 and 7). To date, though the impact of windblown sand has been reduced as a result of conservation work, tiny sandy dust still deposits on the surface of the paintings and sculptures, leading to the further deterioration of the artefacts.



Figure 5: Sand deposited on the surface of wall paintings inside cave no. 431.



Figure 6: In the 1950s, the Dunhuang Institute for Cultural Relics clears the sand accumulated in the cave area.





Figure 7: In the 1950s, the Dunhuang Institute for Cultural Relics clears the sand accumulated in the cave area.

## 2.2. Water infiltration and soluble salt

The wall paintings are painted on a paint layer (the pigment layer), beneath which there is a layer of earthen plaster over the wall, consisting of clay, sand and plant fiber. During summer months, seasonal rain causes water to enter the caves through crevices in the rock surface that eventually permeates throughout the plaster layer of the paintings. This results in the deliquescence of salt distributed throughout the rock, which has caused the loosening of the rock and the flaking, exfoliation and detachment of wall paintings (Figure 8). Furthermore, summer rain also increases the exterior and interior humidity of the caves, hereby also causing the deliquescence of the salt in the plaster layer of the paintings. The ongoing cycle of salt deliquescence and re-crystallization represents a serious threat, as it leads to severe deterioration of the paintings, which is very difficult to control.



Figure 8: Harm caused by salt in Mogao Cave no. 80.

### 2. 3 Geological disasters

The Mogao Caves were built in a soft conglomerate rock and over time, the weathering process has resulted in the fracturing and disintegration of the rock body. In addition, Dunhuang is located at the edge of an earthquake region in Hexi, Gansu Province, in which earthquakes up to between 6 and 7 on the Richter scale have been recurring. Earthquakes can cause the collapse of the Mogao rock and lead to devastating damage inside the caves (Figure 9).



Figure 9: The weathered bedrock of the caves

#### 2.4 The impact of visitors

The numbers of visitors have been significantly increasing from 26,271 in 1979 when the Mogao Caves were officially opened to the public, to a recorded high of 808,182 visitors in 2012 (Table 1). In addition, because the Dunhuang area is very cold in winter and early spring, the majority of tourists come to the Mogao Caves between May and October (Table 2). As the size of the majority of the caves is quite small, and the sculptures and the paintings are aged and fragile, the influx of visitors has caused significant changes in the microenvironment of the caves, such as higher humidity, increased temperature and density of carbon dioxide, all of which can escalate the deterioration of the artefacts and threaten the long-term conservation of the caves, the sculptures and the paintings.

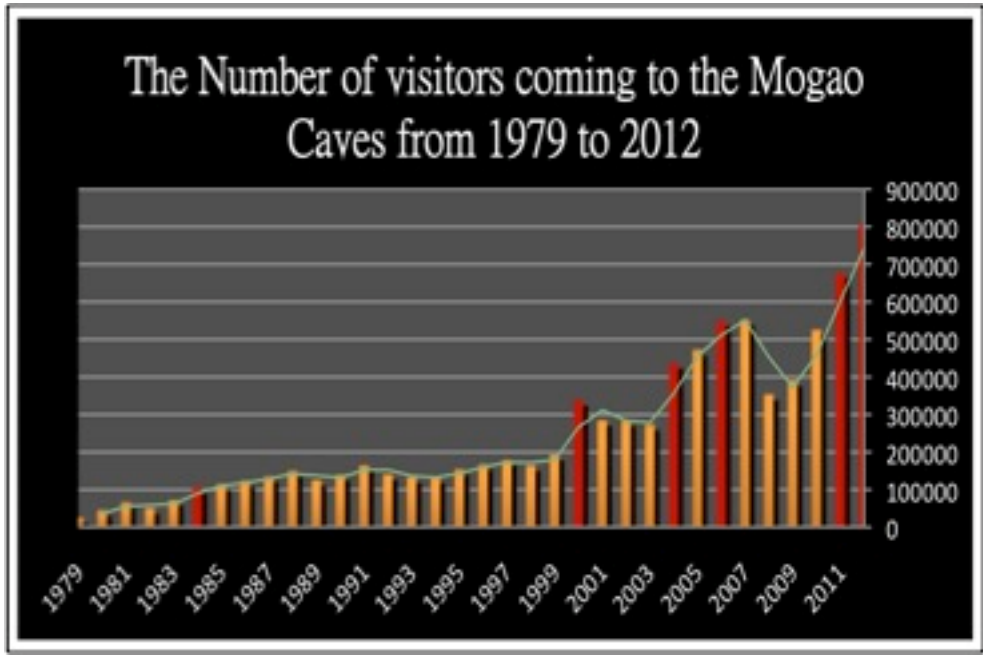


Table 1: The Number of visitors coming to the Mogao Caves from 1979 to 2012

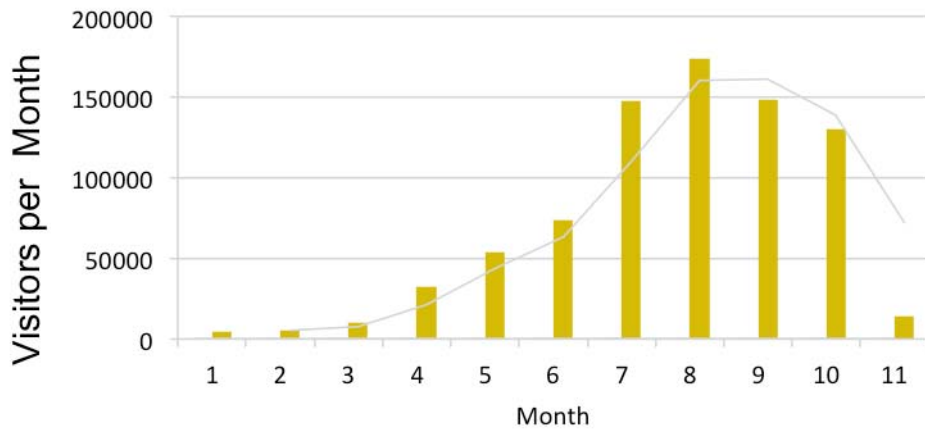


Table 2 Seasonal fluctuations of visitors in 2012

### 3. The Preservation of the Mogao Caves

The conservation of immovable and large-scale cultural heritage properties differs from that of movable ones. The latter is relatively small in size, usually made of one or only a few materials without succeeding modifications, and its environment is relatively controllable; the former in contrast is larger in size and usually made of various materials with succeeding modifications and thus the deterioration process is more complicated and the environment is not easily controllable. Therefore, it is much more difficult to preserve large-scale, immovable artefacts.

The Mogao Caves are a typical example for a large-scale and immovable cultural heritage property. The caves have been built and rebuilt over a period of one thousand years,

and then endured another four hundred years of transformations after the suspension of construction. The structure and the sculptures and paintings inside the caves have been constructed during different time periods, many of which have been repaired, re-sculptured and/or repainted using different materials and craftsmanship. Therefore, the causes of their current deterioration also vary. In addition, a large number of temples and pagodas as well as oases and the Gobi desert form the cultural-historical and the natural context of the Mogao Caves and are inseparable from them.

The *Principles for the Conservation of Heritage sites in China* (referred to as *China Principles* hereafter) point out that “(c)onservation refers to all measures carried out to preserve the physical remains of sites and their historic settings” (ICOMOS 2002 Article 2: 60). Complete conservation of the Mogao Caves should therefore not only entail the conservation of the actual caves themselves, but also of their architectural structures, wall paintings, and sculptures from different time periods and also the conservation of their cultural and natural surroundings. Furthermore, as a cultural heritage site of outstanding value, the Mogao Caves, as many other World Heritage Sites, have to fulfil an educational function. “Used in a rational manner” (ICOMOS 2002 Article 4: 60), the caves should be open and accessible for tourists and the general public. The presence of visitors may, on the other hand, pose a threat to the caves. Decreasing such risks must be an important element of the conservation work. Appropriate management should guarantee the rational usage of the caves without compromising their integrity.

The Mogao Caves are a unique World Heritage Site of outstanding value. They represent an irreplaceable and irreproducible human resource. Any damage will be irreparable. In the document inscribing the Mogao Caves on the World Heritage List it is stated: “...The Committee drew the attention of the Chinese authorities to the need to take all necessary measures to safeguard the very vulnerable rock site of Mogao Caves.” (UNESCO 1987: 5)

Article 53 of the “Operational Guidelines for the Implementation of the World Heritage Convention” states: “Nominations presented to the Committee shall demonstrate the full commitment of the State Party to preserve the heritage concerned, within its means. Such commitment shall take the form of appropriate policy, legal, scientific, technical, administrative and financial measures adopted and proposed to protect the property and its outstanding universal value” (UNESCO 2005: 14-15).

The conservation of the Mogao Caves began in 1944 with the establishment of the National Dunhuang Art Institute; in 1950, it became the Dunhuang Institute for Cultural Relics (敦煌文物研究所); and in 1984, its scope was broadened under the name of Dunhuang Academy, Institute for the Research and Management of the Mogao Caves (敦煌研究院莫高窟保护研究管理机构). For over 70 years, the spirit, the endurance, and the willingness to work towards the conservation of the Mogao Caves has been passed on from generation to generation. It has been a difficult and challenging process of surveying, exploring, researching, and implementation that has helped the conservation of the caves move forward, constantly striving to meet the highest scientific standards. Thanks to this, today’s Mogao caves have regained some of their original magnificence.

The following three sections will introduce the history of the Mogao Caves conservation work.

1) From 1944 to 1949, the well-known artist Chang Shuhong (常书鸿) served as the head of the National Dunhuang Art Institute. Together with other senior colleagues, such as Duan Wenjie (段文杰), Huo Xiliang (霍熙亮), Sun Rujian (孙儒间), Ouyang Lin (欧阳琳), Shi Weixiang (史苇湘) and others, he left the comfort of the big city to go and live at Dunhuang in the remote, desolate and sandy north-western border region. They managed to overcome

various challenges of no adequate housing, no electricity, no running water, insufficient funds, a lack of manpower, especially qualified personnel, and very little technological means. They defied these tough conditions and initiated a project to promote, investigate and preserve the Mogao Caves. They removed sand from over 300 caves, dismantled all of the brick beds and stoves built by the Russians, carried out various restoration works, and even raised funds to install doors in a few major caves. They also erected an enclosing wall around the caves to prevent sand and people from causing further damage (Figure 10). In addition, they made copies of the wall paintings, investigated their contents and categorized the different caves (Figures 11 and 13). They organised exhibitions, formulated regulations for visiting and working in the caves, produced introductory leaflets and appointed an official tour guide to take visitors around. Their hard work and determination represented the beginning of the recovery of these precious caves.



Figure 10: A protective wall built around the Mogao Caves in the 1940s by the National Dunhuang Art Institute.



Figure 11: Mr. Chang Shuhong copying a wall painting in 1945.



Figure 12: Group photo of members of the National Dunhuang Art Institute taken in 1946.



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Figure 13 The record card used by the National Dunhuang Art Institute in the late 1940s to document the contents and age of each grotto.



Figure 14: The Mogao Caves in 1948 after initial repair works by the National Dunhuang Art Institute.

2) From 1950 to 1966, under the guidance of the Dunhuang Institute for Cultural Relics, various government departments of the newly established PRC increased the efforts to preserve the Mogao Caves. Chang Shuhong remained head of the institute and with more staff available, he carried out the first comprehensive survey on how different natural factors affected the deterioration of the caves. During this time-period, the following large-scale remedial conservation works were undertaken: treatment of disintegrated wooden cave ledges; re-erection and stabilisation of fallen-over statues; fixing and consolidation of exfoliated wall paintings either by means of repairing the plaster edges using an earth-based plaster or by anchor rods and the technique of micro-grouting using adhesive materials to reattach the come off layers (Figure 16); in areas where high soluble salt contents led to plaster disruption and flaking, repair work was carried out using new materials and techniques following experiments with international experts. In the early 1960s, thanks to premier Zhou Enlai, the government allocated a significant sum of money towards the comprehensive and large-scale stabilization work of the vertically and horizontally fractured southern cave and rock area.

The caves were now able to withstand magnitude-7 earthquakes, which represented an important step forward in the overall conservation work. In order to prevent sand from causing erosion on wall paintings and statues, straw “checkerboard” barriers were put in place as sand shelters at the top of the caves. Additionally, the daily management of the site was improved. Overall, during this time-period, the highly endangered Mogao Caves, including their wall paintings and statues, were rescued and preserved to a degree that they were no longer in a critical condition.



Figure 15: Different projects undertaken by the Dunhuang Institute for Cultural Relics in the 1950s.

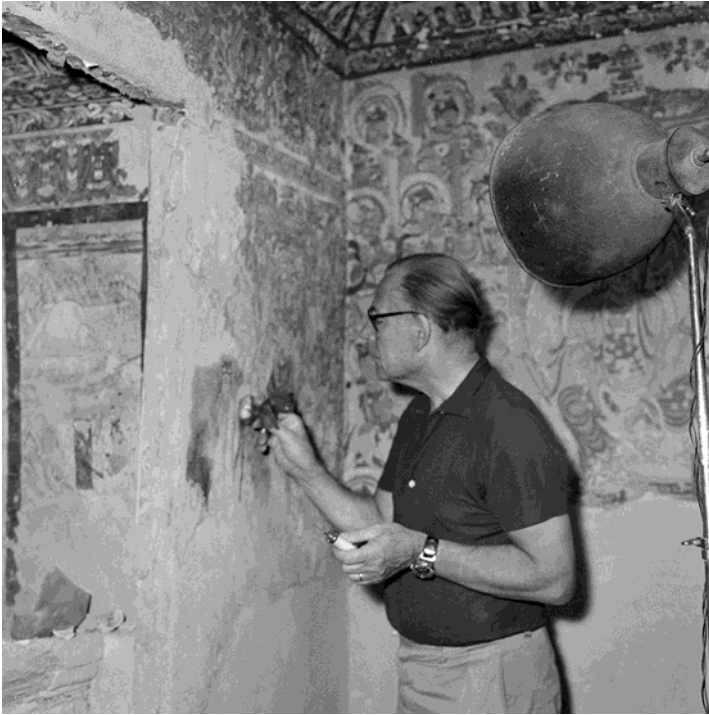


Figure 16: In the 1950s a Czech expert coming to Dunhuang proposed the usage of grouting to repair wall paintings.

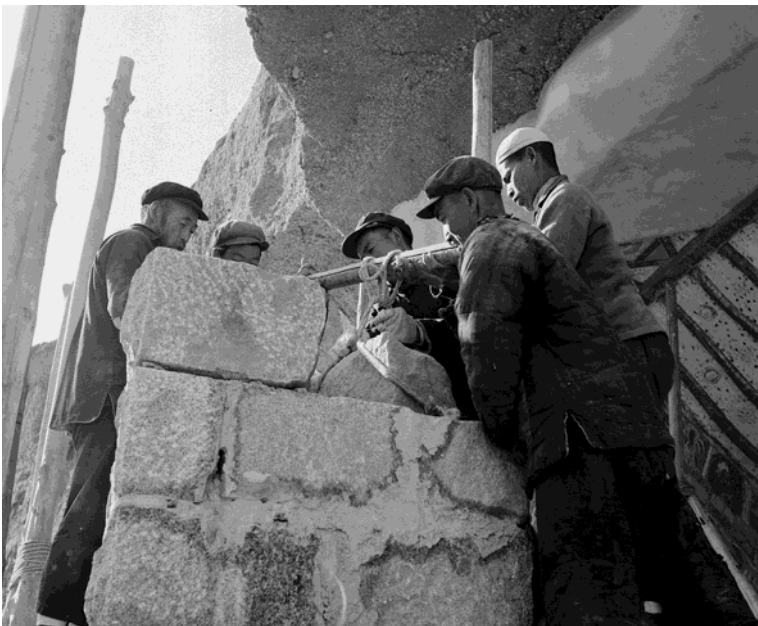


Figure 17: In October 1957, staff of the Dunhuang Institute for Cultural Relics carry out experimental stabilization work at cave no. 249.



Figure 18: Stabilization of rock body and clearing of pumice stones at the top of the cave in July 1965.



Figure 19: The Mogao Caves in 1966 after stabilization work.

3) After the Gansu provincial government decided to establish the Dunhuang Academy in 1980, its outreach and scope increased significantly, with new departments being created and personnel recruited. The “opening-up reforms” represented an opportunity for the Dunhuang Academy to also open up to further cooperation with domestic and international organisations in the conservation of the Mogao Caves, to train more staff, and to explore and apply new scientific research and management methods. The way was paved for a new period of scientific conservation. The “China Principles” point out: “Conservation in practice involves treatment of damage caused by natural processes and human actions and prevention of further deterioration, using both technical and management measures” (ICOMOS 2002 Article 2: 60).

During this time-period, the conservation and management of the Mogao Caves was comprehensively improved and professionalized. The following five points introduce the specific conservation work carried out in this period:

### 3.1. Special legislations and plans.

### 3.1.1 Legislation

Cultural heritage possesses an inherent and irreplaceable value. Its conservation, usage, and management always involve a number of complex technological, theoretical, social and cultural factors. In order to guarantee the unconditional safety of any piece of cultural heritage, international organisations and national governments have formulated respective laws and legislations, in some cases even special laws, stipulating strict regulations on the conservation, usage, and management of cultural heritage.

The conservation and management of the Mogao Caves strictly follows international regulations passed by UNESCO, including the “Convention Concerning the Protection of the World Cultural and Natural Heritage” (1972), and the “International Charter for the Conservation and Restoration of Monuments and Sites” (known as the “The Venice Charter 1964”). It also follows the Chinese constitution, including China’s “Law on the Protection of Cultural Relics”, the “Regulation for the Implementation of the Law” and the “Principles for the Conservation of Heritage Sites in China”. With the help and support from the Gansu provincial government, the Dunhuang Academy has drafted the “Gansu Province Rules and Regulations for the Conservation of the Dunhuang Mogao Caves”, which were approved by the People’s Congress of Gansu Province in March 2003. These rules and regulations clearly defined the objectives and scope of the Mogao Caves conservation work as well as the duties and responsibilities of the managing body. They also stipulated the policies and guidelines for the conservation work and respective rights and obligations as well as a code of conduct for government institutions, community organizations and citizens. This served as a crucial and strong legal foundation for the continuing conservation and management of the Mogao Caves.

### 3.1.2 Conservation plans:

The conservation of the Mogao Caves is an arduous and complex multi-layered process whose appropriate implementation requires clear-cut directions, goals, principles and methods. Between 1998 and 2004, three institutes from four countries joint forces to devise the “Master Plan for the Conservation of the Mogao Caves at Dunhuang (2006-2025)” (referred to as *the Master Plan* hereafter), including the Dunhuang Academy, the Getty Conservation Institute, the Australian Heritage Council and the Research Institute of Architecture History of the China Architecture Design and Research Group.

*The Master Plan* is based on both the “Convention Concerning the Protection of the World Cultural and Natural Heritage” and the Chinese “Law on the Protection of Cultural Relics” and adheres to the idea of carrying out conservation in a holistic, authentic and sustainable manner. The goals, principles and implementation regulations as stipulated in *the Master Plan* have been based on detailed and systematic assessments carried out in accordance with the “Principles for the Conservation of Heritage Sites in China” of firstly, the value of the Mogao Caves and their surroundings and secondly, of the caves’ current state of conservation, usage, management and research. On the basis of these four criteria, *the Master Plan* has devised specific subsidiary goals and measures as well as a detailed implementation timeline.

*The Master Plan* emphasizes that all conservation work must be oriented towards preserving the specific value of the Mogao Caves. *The Master Plan* stipulates the need to integrate the conservation of caves with that of the surrounding environment, to integrate conservation practices with scientific research, to integrate remedial restoration with daily maintenance work and to follow the principles of the integration of conservation and usage. *The Master Plan* is binding and obligatory and provides the foundation and standards for any conservation and management work carried out. With the formulation of this *Master Plan* and

its official enactment by the Gansu provincial government, all projects will be designed and implemented in accordance to it.

### 3.2 The conservation of the caves and their surrounding environment

#### 3.2.1 Implementation of cave and cliff stabilization

The cliff serves as a carrier of the caves and is thus of essential importance for the conservation of the caves. The northern area of the Mogao Caves with its 243 caves fulfilling different functions, most of them serving as religious and residential spaces for Buddhist monks, forms an important constituent part of this cultural heritage site. Centuries of harsh natural conditions have severely damaged this area. The cliff body is unstoppably weathering away and even collapsing, developing crevices, suffering from wind, rain and flood erosion. Inside the caves large amounts of sand have accumulated, which adversely affects their safety. Between October 2004 and October 2005, a stabilization project was implemented targeting the endangered cliffs of the northern cave area (Figure 20). On the basis of the stabilization work previously carried out in the southern cave area, the method of anchor rod reinforcement was used. Parts of the rock ceilings were supported, crevices were treated by means of injection grouting and the rock surface was made weather-proof. At the top of the cliff, water-retaining dams were built to obstruct water from seeping into the caves. This project guaranteed the safety of the northern cave area and helped to maintain the original form and appearance, adhering to the principle of “repairing the old like the old and not changing the historical condition”.



Figure 20: Stabilization work at the northern cave area in 2004.

The cliff surface of the southern caves had been suffering from years of wind erosion, mainly causing the problem of rock fall and quicksand. This represented a significant threat to



the safety of visitors and hindered the process of opening the caves to tourists. Another problem was the seepage of water into upper level caves that are situated close to the cliff roof and only possess a very thin ceiling. This caused the flaking and further erosion of wall paintings inside. Furthermore, crevices in the caves had not been properly sealed for years, developing to the extent that they formed dangerous stone blocks in the rock cliff that had adverse effects upon the conservation work. Between 2009 and 2010, these various problems were addressed adopting techniques developed by the Dunhuang Academy. Crevices were filled with potassium silicate (PS) for anti-weathering and a PS-F solution as grouting materials. Further, the thin cave ceilings were stabilized using the technique of anchor rod reinforcement, hereby stabilizing the entire southern cave area. These repair works have contained the problem of weathering and gravel fall during heavy rainfall and storms, and prevented large quantities of rainwater from permeating throughout the upper caves and causing damage to the wall paintings. During the heavy rainfall on June 6, 2011, for example, no harm was inflicted upon the caves thanks to this stabilization work (Figure 21).



Figure 21: On June 6, 2011, a torrential rainstorm hit the Mogao Caves

Before the foundation of the Dunhuang Research Institute, the gallery road at the southern cave area existed in a state of serious disrepair. During stabilization work carried out in the 1960s, a new gallery road leading directly to the caves was installed, but being over 50 years old, it now faces several problems. Its banister and walkways have been damaged to different degrees; the banister's height is inadequate, posing a serious threat to the safety of visitors; in some parts, the gallery road is too narrow, which may easily lead to congestion

when large numbers of visitors are present. To address these problems, the Mogao gallery road remodelling project was initiated in 2011. It entailed the fitting of a simple but firm banister that does not alter the exterior appearance of the caves. Building materials that suit local weather conditions were chosen and the installation process strictly adhered to local circumstances, following along the uneven cave structures. This simple but practical new banister exists in close communion with the caves and guarantees the safety of all visitors.

### 3.2.2 Development of scientific research on and restoration of wall paintings

Since the 1980s, the Dunhuang Academy has been collaborating with domestic and international research institutes to identify materials and techniques used in the creation of the paintings, to understand the micro environment in the caves, the causes and mechanisms of deterioration and to gain a more comprehensive understanding of the degree of deterioration. With regards to the research on painting materials and techniques, analyses have revealed the pigments and granularity used as well as the special painting characteristics of different time periods. This led to a basic understanding of the structure of wall paintings' ground plaster layer and their physical chemistry and helped identifying the types and characteristics of the original binding materials used in the pigments of the wall paintings. Careful analysis of the micro-structures of deterioration, the paint layers and the degree to which salt has penetrated the wall paintings and research into the connection between environmental problems and the erosion of wall paintings have helped us understand the mechanism behind exfoliation, disruption, flaking, and fading of wall paintings.

On the basis of the above-described results, materials and techniques for treatment were determined and used to treat exfoliating wall paintings, restoring about 3000 square meter of different kinds of wall paintings. In 1997, the Dunhuang Academy and the Getty Institute decided to carry out systematic and comprehensive scientific research to assess the significance of wall paintings, to understand their current conditions and the causes for deterioration. Moreover, research was carried out into potential materials for grouting; grouting was used for the first time to re-attach and consolidate wall paintings and to discharge salt contents (Figure 22). This represented a breakthrough in the search for a solution to the problem of soluble salt penetrating the caves. Subsequently, his method was used to restore and preserve almost 1000 square meters of delicate wall paintings in different caves.



Figure 22: Grouting of the wall paintings

### 3.2.3 Restoration of cave surroundings and environment

The “China Principles” point out that “(n)atural and cultural landscapes that form part of a site’s setting contribute to its significance and should be integrated with its conservation.

Elements in the setting that are potentially hazardous or that may adversely affect the landscape must be addressed” (Article 24: 64).

In order to preserve the Mogao caves and their affiliated historical architecture, all modern buildings that adversely affected the cave area have been eliminated according to the plan; all residential and commercial housing has been relocated; the historical landscape, including the mountain ridge, desert, river, and forest belt as well as the cultural landscape, including the group of pagodas and temples have been preserved. The newly built museum has been carefully designed to fit the cave environment. Many years of restoration work have successfully recovered today’s simple but graceful and quiet Mogao cave environment.

In the 1980s, the Dunhuang Academy in cooperation with domestic research organisations carried out research and tests to find suitable ways to comprehensively prevent windblown sand from causing damage to the caves and established protection principles, combining various methods of control.

Based on information gained from meteorological monitoring and specific research into the movement of sand, firstly, a 6000 metre high wind fence was installed to divert the sand masses. Secondly, on the sandy surface at the cliff top, in south-western direction, straw “checkerboard” barriers were put in place, covering an area of over 1000 square km (Figure 23). In front of the “checkerboard” barriers a vegetation belt consisting of shrubs and sand plants covering an area of around 100 square km was planted to stabilize the shifting sand. Between the vegetation belt and the cliff top, a gravel layer (gravel “mulch”), over 1600 square km in size, was placed on the sand. The combination of these different methods successfully blocks and diverts sand and thus protects the caves. According to monitoring results, the sand inside the caves has been reduced by about 75%, significantly slowing down the erosion of wall paintings and sculptures inside.



Figure 23: The “checkerboard” barriers to obstruct sand.

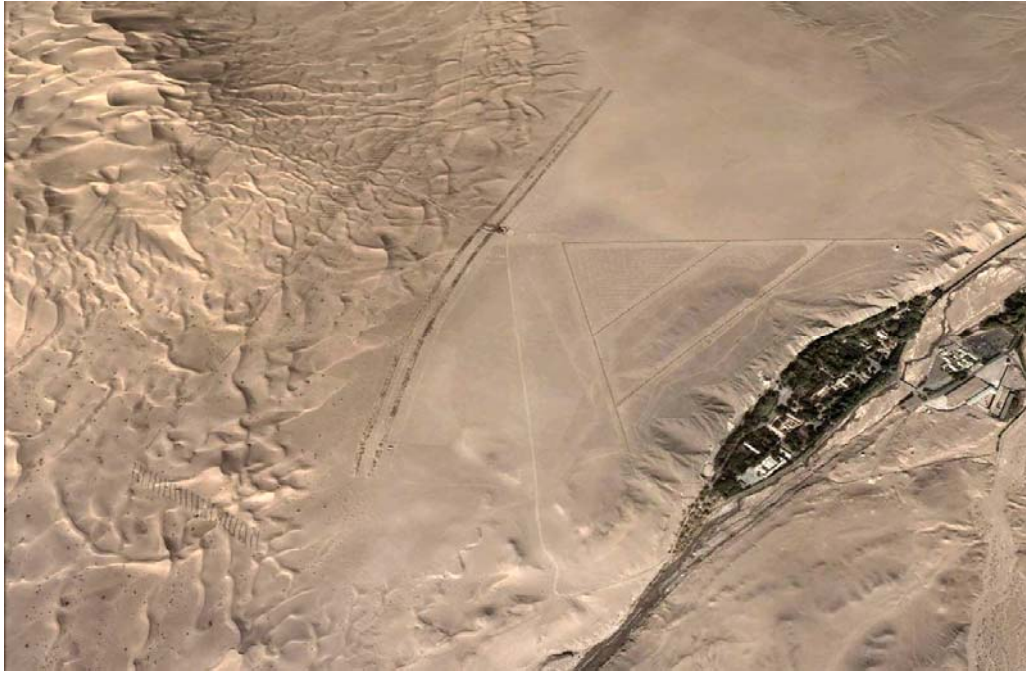


Figure 24: Google earth satellite image showing the comprehensive project to address the problem of windblown sand at the Mogao Caves.

### 3. 3. Establishing an early warning risk monitoring system

#### 3.3.1 Establishing a physical network-based risk warning and control system

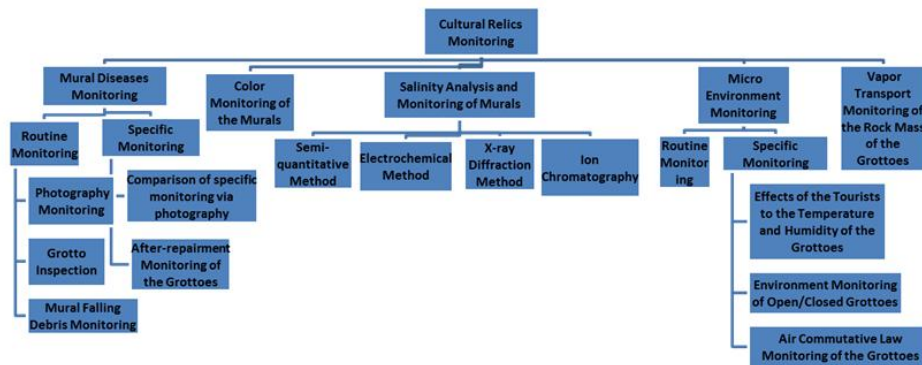
Influenced by human and natural factors, the Mogao caves are constantly exposed to change. Through science we can control this change and any involved risk factors, actively working against the degeneration of the historic site. To foresee any kinds of hazards is thus the most important managerial responsibility. All parts of the heritage site, including its environment and surroundings need to be monitored for potential risks and all factors leading to change and degeneration need to be well-known and analysed. This is the precondition for successful preventative conservation work. Effective monitoring is also the foundation, based on which any conservational or managerial decisions are made, providing us with the necessary figures and information to draw up conservation plans, carry out repair work and manage the entire site. As such, monitoring is the most important element in successful conservation work.

Over the past 20 years, monitoring activities have been expanded to cover wall painting conditions, rock body, windblown sand at the cliff top, visitors, the cave environment, and how environmental factors influence the conservation work of wall paintings and sculptures. Since 2005, the Dunhuang Academy has in cooperation with domestic universities and research units been developing a microenvironmental monitoring system, replacing previous outdated monitoring methods that generated imprecise numbers and results, hereby leading to various unforeseen problems. More recently, the physical network-based monitoring technique started to be widely used in the Mogao caves.

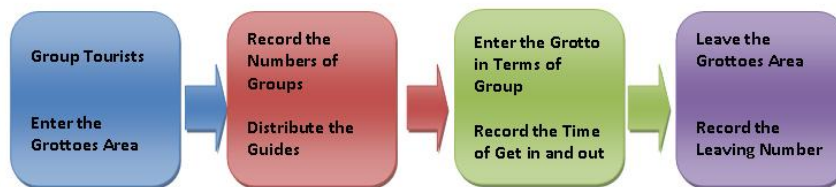
For the first time in China, modern sensors in combination with network-based monitoring and risk warning system were used to manage and conserve the Mogao caves. A wireless network covering the entire site was installed through which information on temperature, humidity, and carbon dioxide in the 60 opened caves can be transmitted in real time, hereby monitoring the microenvironmental changes inside the caves. This in combination with the number of visitors present at a time determines the microenvironmental

norms and limits for each cave. If any indicator exceeds these norms, the system will automatically give out a warning, enabling the Reception Department to adjust the number or redirect visitors. The system also monitors the external environment of the caves and automatically analyses how micro- and external environmental changes are interrelated. This helps us better understand the mechanisms of change. In addition to that, the system also disseminates useful information to tourists, allowing for an even more enlightening experience. The newly established condition-monitoring centre has become a powerful and essential tool in the effective management and conservation of the Mogao caves.

**The Diagrammatic Sketch of the Cultural Relics Monitoring System of the Mogao Grottoes**



**Tourist flow monitoring**



**3.3.2 Installation of effective security system**

To guarantee the security of the heritage site means to prevent man-made damage and theft. The original security system was obsolete and unable to meet the needs of present times. In 2009, the installation of a new first class security system was approved and completed in late November 2011. It offers all functions necessary to guarantee the safety of the entire site, including an intrusion detection alarm, a video and sound surveillance system, an online electronic inspection system, a perimeter alarm, security lighting, and communication security devices. The system covers all key areas of the Mogao caves, including the archives, and issues visual and audible warnings, thus guaranteeing the safety of the entire site.

**3.3.3 Using digital technology for the long-term conservation of the Mogao caves**

Cultural heritage is irreplaceable and also ephemeral. Natural and manmade factors lead to its slow degeneration. The above-described preservation measures can only prolong the life of the Mogao caves, but they cannot fundamentally stop their degeneration. In the past, painted replica, photographs and video recordings were used to record and store the contents of wall paintings. But the data gained from these methods cannot be stored long-term. Data loss is inevitable. This is why since the 1980s, the Dunhuang Academy has been testing

digital technology to store the artistic contents of cave wall paintings for future uses. To capture the most refined details on the artistic artefacts, advanced high definition photography equipment has been utilised. Cameras can be individually adjusted and their slightest movements controlled to guarantee the highest level of clarity. With the help of domestic and international research institutes, we have been able to overcome the problems of distortions or colour deviations when merging photographs together. We were able to produce and store a series of digital photographs, displaying the correct colour nuances of wall paintings. The ability to merge parts of wall paintings together has allowed us to also record paintings that are partially blocked by centre and rear pillars inside the caves (Figure 25).

Over the past few years, we have completed producing and merging digital photographs of over 70 caves and established an extensive digital database, which can be accessed and used by future generations and guarantees the long-term conservation of Dunhuang's artistic treasures (Figure 26).



Figure 25: The digitalization of wall paintings going on at the Dunhuang Mogao Caves.



Figure 26: Digital database of Dunhuang's artefacts.

### 3. 4. Fostering the opening and usage of the caves and offering a unique cultural experience to visitors

#### 3.4.1 Developing visitor surveys and research

In ancient times, the Mogao caves were a place of Buddhism and not a museum for tourists. The cave area is generally small in size, there are 18 large caves of over 100 square meters, 21 caves of 50-100 square meters, 41 caves of 25-50 square meters, 123 of 10-25 square meters, and 289 caves of about 10 square meters, the latter making up 58.7% of the entire cave area. The wall paintings inside the caves were produced using pigments, clay, wheat straw or wood. Their conditions are frail. Over the years, the majority of wall paintings have been damaged to different degrees. Every year, during peak season, vast numbers of tourists come, often exceeding the carrying capacity, which has had adverse effects upon the surroundings and constantly changes the microenvironment inside the caves. This has accelerated the process of erosion and adversely affected the efforts to preserve the precious cultural relics. Over the past decade, the local government has increasingly used the Mogao caves to develop tourism and hereby boost the local economy.

Since 1979, the number of visitors coming to the Mogao caves has continually increased, with 10 or 20 thousand earlier on, to about 800 thousand in 2012. This represents a big challenge for the site management. The Dunhuang Academy has followed the principle of “reasonable public usage on the premise of conservation and conservation-oriented opening-up” to reconcile the contradiction of tourism and heritage preservation.

In order to reduce the risk of visitors adversely affecting the caves and to be able to take preventative measures, in 2001, the Dunhuang Academy together with the Getty Institute began to carry out the “Mogao caves carrying capacity study”. This study involved taking into account various complex parameters, such as cave size, degree of damage, attractiveness of site, environmental condition, number of tourists, visitor flow, amount of time tourists remain in one site etc. After long-term and extensive surveying, the study is now complete. On its basis, taking into account all of the important factors, it was decided that daily visitors are to be limited to a number of 3000.



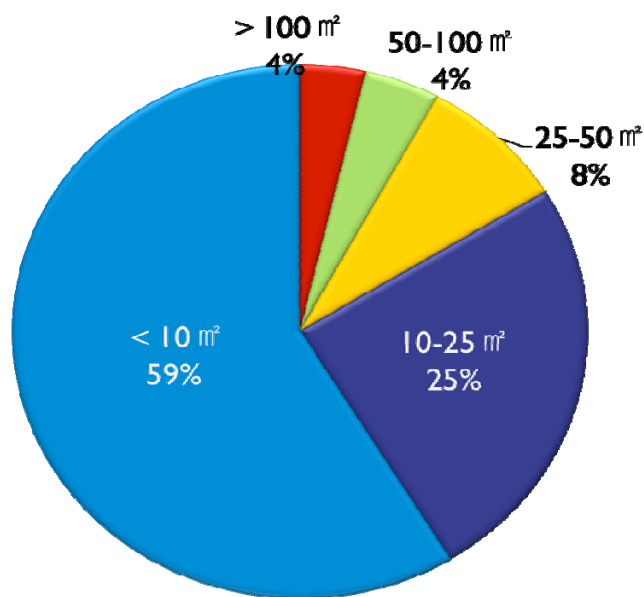


Diagram showing the percentage of differently sized caves

Based on the results of the carrying capacity study, the following steps for the visitor management have been put forward:

- 1) To establish norms for the opening of caves: caves must be larger than 13 square meters to give visitors sufficient space; wall paintings and clay sculptures should not show any major signs of damage, visitors' presence must not endanger the cultural relics; but caves holding representative cultural relics of outstanding value should be opened to the public.
- 2) Implementing a system for the opening of caves: a rotation system for the opening times of specific caves should be implemented, giving caves time to recover. Additionally, in order to maximise visitor's experience and enjoyment, no more than 25 people should enter a cave at one time.
- 3) A reservation system during peak seasons must be implemented, according to which tourist admissions are planned and regulated. Considering the increasing amount of individual travellers, there should be multiple ways to make a reservation, in person, by phone, online or by sms; further, a special booking centre will be established.
- 4) During peak seasons, several different visitor routes should be opened so that large groups can be simultaneously directed through different paths. This will improve the quality of tours and also reduce the pressure for individual caves.
- 5) Developing visitor surveys to gain information on different tourists, to comprehensively understand their needs and experiences and to then adjust the specific visitor management accordingly.

### 3.4.2 Training of high-quality tour guides and improvement of the overall level of service

The contents of wall paintings inside the caves are wide-ranging and profound but also difficult to understand. It is thus necessary to provide well-trained guides who can explain the artistic motives of different time periods, and give background information on the various precious artistic artefacts found in different caves to visitors. It is an essential part of visitor management to train a team of well-educated, multi-lingual professional tour guides. During off-season, every year, special training sessions are organised, during which tour guides are informed of the most recent research developments. It is important that guided tours disseminate the most updated information to visitors. Tour guides are sent to universities to

learn foreign languages or foreign teachers are invited to instruct tour guides at the site. Presently, most guides are proficient in at least one foreign language and tours in English, Japanese, French, German, and Korean are offered. It is important to constantly improve the language level of all tour guides.

### 3.4.3 Setting up a Mogao caves visitor centre

Following the approval by the National Development and Reform Commission (NDRC), in 2010 the building of a visitor centre was launched outside the conservation area of the Mogao caves that went into operation in 2014. The domed film auditorium that is part of the centre will screen digital movies introducing the cultural relics inside the caves. For the first time worldwide will visitors be able to enjoy high-definition coverage of a cultural heritage site inside a dome cinema. In this way, information on the artistic details can be portrayed in a distinct, and accurate way, enriching the experience of visitors. This will also reduce the pressure of tourists inside the caves. The visitor centre can hold up to 6000 people at one time.

### 3.5 Cooperation and training of qualified personnel

At the beginning of the 1980s, living and working conditions at Dunhuang were harsh and there existed a lack of qualified staff and professional equipment. This has changed over the past 30 years. The rapid developments in heritage conservation work have paved the way for cooperation and the training of qualified personnel.



Figure 27: Research students studying wall paintings receive a lecture in one of the Mogao caves.

### 3.5.1 Opening up for cooperation

Following the “opening-up reforms”, the Dunhuang Academy engaged in cooperation with the Tokyo National Research Institute for Cultural Properties, the Getty Research Institute and Foundation, the Andrew W. Mellon Foundation, the Australian Heritage Council, the British Courtauld Institute of Art as well as with various domestic organisations, including Zhejiang University, Lanzhou University, Wuhan University, Tsinghua University, and several institutes of the Chinese Academy of Science, among others, the Shanghai Institute of Ceramics, the Institute of Geology and Geophysics, and the Cold and Arid Regions Environmental and Engineering Research Institute. Through the extensive collaborative research with these international and domestic organisations, the Dunhuang Academy has managed to generate a whole series of methods and technologies to comprehensively preserve the cultural and natural heritage of the Mogao caves. Furthermore, a team of outstanding professionals has been trained whose theoretical and practical knowledge meets global standards. The cooperation has greatly and rapidly strengthened the capacity and standard of the conservation work carried out by the Dunhuang Academy.

### 3.5.2 The training of qualified personnel

Qualified staff is the most crucial asset in the successful implementation of the project. Even though Dunhuang is home to this outstanding and unique heritage site, life in this remote part of the country is not comparable to life in the big city in terms of transportation, working and living conditions. This is why attracting qualified personnel is a challenge. The above-described success in the conservation of the Mogao caves is a result of the tireless efforts of local staff to attract and train professional personnel in preservation, research, promotion and management. The conservation work involves expertise from various natural sciences. The Dunhuang Academy tries to train and form a team that covers all areas of expertise. At present, specialised teams for the analysis of cave materials, for the analysis of degeneration mechanisms, for the investigation of conservation materials and restoration technology are already in place.

Dunhuang also needs the expertise of the humanities. The Academy has gathered teams of experts in art, archaeography, history, archaeology, literature, ethnology, and management studies.

Every year a certain budget is allocated towards the training of personnel. The training is geared towards the individual abilities of staff and is enabled through the generous financial support from foreign individuals, universities and research institutes. Staff trained abroad represent a crucial resource, ensuring the sustainable and long-term accumulation of knowledge and expertise at Dunhuang.

## 4. Conclusion

Many years of relentless work and research have improved and lifted the conservation and management of the Dunhuang Mogao caves to a new level. As long as the caves remain, their conservation, research, usage and management will never end. Future conservation work will confront many new problems and situations. It is thus important to constantly strengthen preventative protection work and to constantly deepen our understanding of the degeneration mechanisms in order to be able to generate suitable and effective countermeasures and postpone the overall decay of the caves. Furthermore, it is important to carry out more research into how to reconcile the contradiction of opening the caves to tourists and the endeavour to conserve them. At the same time, any pressure and possible changes or damage inflicted upon any part of the heritage site must be prevented. The cooperation with domestic

and international organisation must be continued and new concepts, practices, experiences and technologies in conservation, presentation and management should be incorporated. Qualified staff is the foundation for this; the training of personnel must thus be expedited and improved. Finally, if problems are detected through monitoring and the daily management of the caves, conservation measures must be constantly adjusted to address them and improve the situation. The aim is to create a heritage conservation system that meets the highest scientific standards in all aspects and allows the Mogao caves to be preserved, used and managed in the best possible way.

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