

International  
Conference  
on the  
Conservation  
of Grotto Sites

Mogao Grottes  
at Dunhuang

October  
1993 Mogao  
Grottes  
at Dunhuang

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# Conservation of Ancient Sites on the Silk Road



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Proceedings of an International Conference on  
the Conservation of Grotto Sites

Conference organized by the Getty Conservation  
Institute, the Dunhuang Academy, and the Chinese  
National Institute of Cultural Property

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*Edited by Neville Agnew*

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LOS ANGELES

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# Foreword

THE GETTY CONSERVATION INSTITUTE is committed to the preservation of the world's cultural heritage and, as such, seeks to find ways to enhance the knowledge and information available to conservation professionals as well as to a broader audience. These proceedings are part of that commitment. They have been long in the making, but waiting for them has been worthwhile.

The International Conference on the Conservation of Ancient Sites on the Silk Road, sponsored by the Getty Conservation Institute together with China's Dunhuang Academy and State Bureau of Cultural Relics, took place in October 1993 at the Mogao grottoes, Dunhuang, the People's Republic of China. Since then, several other meetings have been held. They all shared in the objectives of the initial conference: to bring together an international panel of specialists from a wide range of disciplines to provide a critical mass of expertise that would or could be applied to solving the difficult and numerous problems that threaten some of the world's most imposing and important cultural heritage sites, the magnificent Buddhist grottoes on the Silk Road.

Grottoes pose particularly thorny problems for conservation. They require a fundamentally holistic view if the conservation approach is going to be valuable in the long term. At the same time—because of their magnitude, geographic location, richness and variety of materials, unique microclimates, continuing use as religious sites, and growing attraction for tourists—the Buddhist grottoes of the Silk Road require dedicated study with a variety of disciplines to understand their deterioration problems and appropriate methods of prevention.

The conference on which these proceedings are based marked the first time that scholars and scientists from the West and China had convened at a heritage site in China for the common purpose of providing information, exchanging ideas, and devising mechanisms to save grotto sites. The essays assembled here represent contributions from Australia, Canada, France, Germany, India, Japan, Singapore, Sri Lanka, Switzerland, and the United Kingdom, as well as China and the United States. They cover such topics as site management, microclimatological analysis and evaluation, and geotechnical and environmental concerns, and provide views on a range of conservation issues that convey some of the excitement of the conference itself.



Special thanks are due to Neville Agnew who has toiled long and hard over this publication. His organizational efforts for the conference were only the first steps down the road leading to these proceedings. His attention to detail and seriousness of purpose exemplify his profound interest in the conservation of these sites as well as others around the world. It is our hope that, through this publication, the reader will gain not only insight into the scientific and technical aspects of conservation but admiration as well for the wonderful history and art of the ancient sites on the Silk Road.

Miguel Angel Corzo

DIRECTOR, The Getty Conservation Institute

# Preface

**T**HE GENIUS OF ANCIENT CHINA is remarkable and unparalleled. For three thousand years it was the undisputed master of invention and discovery—achievements well documented by Joseph Needham, the West's foremost scholar of Chinese science, in his definitive work, *Science and Civilization in China*. Consider the chemical arts of ancient China, for example; they have had a profound influence on the world. In Chinese, the word for chemistry is *hua xue*, which literally means “the study of change.” This is particularly apropos in view of the work being done at sites like Mogao and others on the Silk Road. To study change is indeed necessary if we are to understand it. As custodians of the cultural heritage, our common purpose is to study the changes and deterioration affecting the physical fabric, paintings, and sculptures of Mogao and other sites throughout the world, and then to try to slow or even prevent these changes through harnessing modern chemistry and science in the service of conservation.

The West owes its knowledge of the metallurgical arts and the manufacturing processes for paper, salt, wine, porcelain, and, above all, silk, to ancient Chinese alchemy (or, as we would call it today, applied chemistry). Many of these empirical discoveries date from the last half of the second millennium B.C.E. in northern China.

Ancient Chinese technology was philosophical in nature rather than scientific, like the old Chinese theory of medicine. It is a remarkable achievement that the technological sophistication of ancient China—without the benefit of modern scientific theory—remains unsurpassed today. Who can fail to be awed by the artistic beauty and technical perfection of a bronze vessel of the Eastern Zhou (late sixth to late third century B.C.E.) or the serene splendor of the art of the Tang dynasty?

The technical inventions of ancient China were created through innate ability and industry to improve the human lot and beautify life. They are too numerous to elaborate completely; here is but a partial list:

- **Metal.** Smelting, purification, alloying, casting, and forging of all the important metals (copper, iron, zinc, lead, tin, silver, gold, mercury) date as far back as the time of the Warring States (481–255 B.C.E.).

- **Ceramics.** The making of pottery commenced very early in human history. China, however, was producing porcelain—that most precious of ceramics—by the time of the Han dynasty (206 B.C.E.–220 C.E.), a feat that baffled Europe for the next one and a half millennia. Interestingly, glass glaze for porcelain was introduced to the Han dynasty from Rome.
- **Gunpowder.** In its earliest forms, gunpowder seems to have been known in China for some two thousand years. By the Sui dynasty (581–618 C.E.), fireworks had been developed as well as instruments of war. Indeed, the world’s oldest pictures of a gun come from the Mogao grottoes of Dunhuang, in a detail from a painted silk banner of the mid-tenth century (now in the Musée Guimet, Paris).
- **Lacquerware.** This goes back into Chinese legend.
- **Colors and Dyes.** Ancient Chinese writing does not fade because the principal materials are carbon (lampblack) and glue. Western ink, being iron based, is not as permanent. The natural dyes, such as indigo and saffron, were known since antiquity in China.
- **Zero.** We take the concept of zero for granted, but its invention was of the utmost importance in history; it is essential for carrying out mathematical computation. Mathematicians in China may have used the zero before those in India.
- **Silk.** The Romans believed that silk grew on trees (Pliny and Virgil). The Chinese, who had discovered its secret a thousand years earlier, had no intention of dispelling the myth, as they maintained a monopoly on the trade. So great was the Roman lust for silk that, by 380 C.E., its high cost began to have a serious impact on the economy of the empire.

Although the Silk Road is one of the oldest of the world’s great trade routes, it acquired this name only in the last century, as Peter Hopkirk points out in his book, *Foreign Devils on the Silk Road*. The term, coined in the last century by Baron Ferdinand von Richthofen, is misleading because the Silk Road consists of a number of caravan routes across China, Central Asia, and the Middle East. It carried a great deal more than silk and was traveled in both directions. China-bound caravans, for example, carried gold and metals, wool and linen, ivory, coral, and glass. Many items were bartered or sold on the way. Parthian middlemen controlled the route beyond China, so Chinese merchants were never seen in Rome. Recent archaeological evidence suggests that trade along the Silk Road was conducted even earlier than believed. John Noble Wilford reported in the *New York Times* in 1993 that strands of silk had been found in the hair of an Egyptian mummy dating from about 1000 B.C.E. This is long before regular traffic began on the fabled trade route, and a thousand years before silk was thought to have been used in Egypt.

More than goods were traded via the Silk Road; more important in many ways was the cultural exchange of ideas, religious beliefs, language, and thought—evidence of which are to be found at Dunhuang, the eastern hub of the great route and a gateway to China. It is for this reason that the conference

was held at the Mogao grottoes: to exchange information and ideas—to trade, as in days of old, knowledge for the common good of humanity’s cultural heritage.

The Getty Conservation Institute has been working in China with the State Bureau of Cultural Relics at the two great sites of the Mogao and the Yungang grottoes. Why should the Getty Trust, a private foundation, be undertaking conservation in China, especially since none of the programs at the Getty collects Asian art or has a specialized interest in it? The answer is found in the philosophical ethic that guides the Getty Conservation Institute in its mandate and mission of preservation of the cultural heritage.

The world’s cultural heritage reflects the achievements of humanity since the dawn of civilization. Cultural heritage is essential to the understanding of history and of the forces that create contemporary societies. It is a living source of our identity and an expression of our spirit as it unfolds through time. Cultural heritage transcends temporal and geographic boundaries; it offers a sense of continuity in a rapidly changing world and connection with other societies, past and present.

Today, cultural heritage is threatened as never before. Technological innovations and the global population explosion have given rise to unchecked development, industrial pollution, increased tourism, rapid obsolescence, and increasingly destructive methods of warfare. As a result, the store of material evidence of our past is vanishing at an ever-accelerating rate.

We recognize the importance of development and acknowledge that preservation efforts must take place within a framework of the evolution of today’s societies. Yet the physical remains of the world’s cultural heritage are irreplaceable. They must be protected and managed effectively for present and future generations. To achieve a balance between these concerns, considered choices must be made to save the cultural heritage. The significance of the sites and objects we seek to preserve must be understood; we must ask for whom are they important and why. Responses appropriate to the historic cultural context of the materials must be developed.

Conservation is a science, an art, and a craft. Beyond that, it is a concept that needs to be encouraged and fostered as a part of our way of life. Conservation is the means whereby the survival of the cultural heritage—which defines the image of humanity—is ensured, now and in the future. Conservation, as the custodian and preserver of the earth’s artistic and historic legacy, must shape the ethic of humanity.

The Getty Conservation Institute has worked in China with the State Bureau of Cultural Relics and with the site authorities at Mogao and Yungang to promote the preservation of the grottoes through site-conservation measures and an intensive site-management training course, as well as through scientific analysis and training, the introduction of new conservation materials and techniques, pollution studies, environmental monitoring inside and outside the grottoes, discussions, and professional contacts. Throughout this work, we have collectively taken the broad picture by looking at the most severe threats to the sites and by considering their real needs.

In addition to being a conference record, these proceedings celebrate the fiftieth anniversary of the founding of the Dunhuang Academy. They also

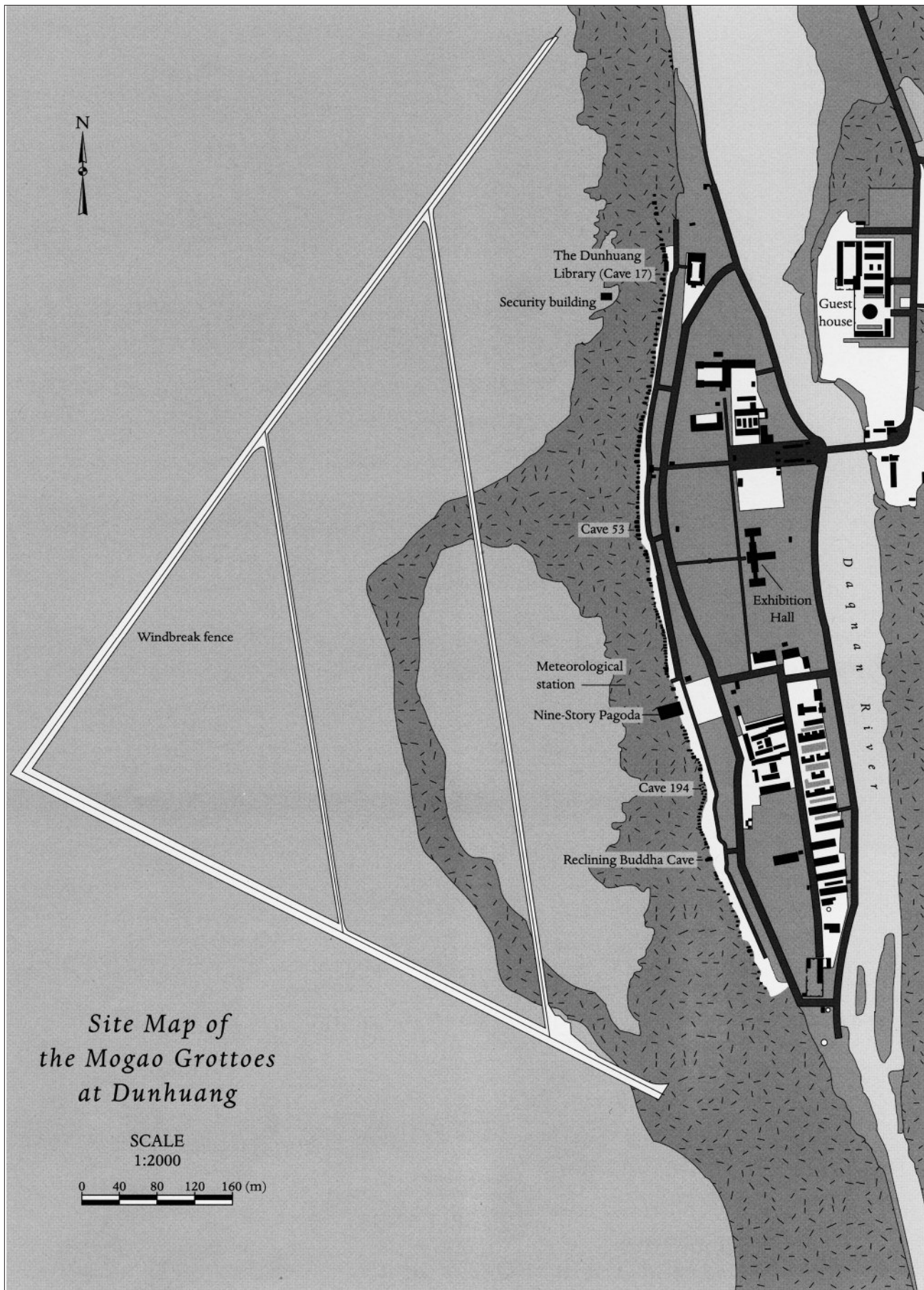
pay tribute to director Duan Wenjie and his life of dedication to the study and preservation of *Mogaoku*—the “great art gallery in the desert,” as the site has been called.

This conference was a success because of the outstanding contributions of many people. In particular, I extend sincere appreciation and thanks to our esteemed colleagues Director Zhang Deqin and Deputy Director Zhang Bai from the State Bureau of Cultural Relics. Along with their predecessor, Shen Zhu, they have been unfailingly supportive of our collaboration. Thanks also to Kwo-Ling Chyi, Joan W. Shi, Sara Tucker, and Jeffrey Riegel for assisting with interpretation; and Chen Shiliang, Lin Hongliang, Jeffrey Riegel, and Zhang Yuzhong for presenting lectures during the post-conference tour. In the organization of the conference, we have enjoyed full partnership and collaboration of the Dunhuang Academy guided by Deputy Director Fan Jinshi and her excellent staff.

In the preparation of these proceedings for publication, appreciation is extended to Dinah Berland of the Getty Conservation Institute for managing the editorial production of the publication and editing many of the texts, Jeffrey Cohen of Getty Trust Publications for designing the series, and Hesperheide Design for typesetting and layout of this volume. Thanks also to GCI staff Sara Tucker, Shin Maekawa, Michael Schilling, and Francesca Piqué, and to consultant Po-Ming Lin, for preliminary review of the proceedings; to Lin for coordinating the articles of the authors in China and, with Kwo-Ling Chyi and Charles Ridley, translating the Chinese texts; to Keith Eirinberg and Elizabeth Maggio for copy-editing the articles; to Joy Hartnett for editorial assistance and research; to Scott Patrick Wagner and Alison Dalgity for helping with desktop production; to Desne Border for proofreading; and to Anita Keys for coordinating the book’s production.

Lastly, I offer a tribute to Huang Kezhong, a fine colleague and friend, who enjoys a special place in the hearts of GCI staff members who traveled with him across China on innumerable occasions by plane, by train, and—on one trip indelibly engraved in our minds—by bus for twenty-four hours in snow and dust storms. The Getty Conservation Institute is proud to be associated with these projects in China and is privileged to have met fine people who are now called friends.

Neville Agnew  
ASSOCIATE DIRECTOR, PROGRAMS  
The Getty Conservation Institute









## China Dynasty Table

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Xia	ca. 21st century–16th century B.C.E.
Shang	ca. 16th century–11th century B.C.E.
Western Zhou	ca. 11th century–770 B.C.E.
Eastern Zhou	
Spring and Autumn Period	770–476 B.C.E.
Warring States Period	475–221 B.C.E.
Qin	221–207 B.C.E.
Western Han	206 B.C.E.–24 C.E.
Eastern Han	25–220
Three Kingdoms	220–280
Wei	220–265
Shu	221–263
Wu	222–280
Western Jin	265–316
Eastern Jin	317–420
Southern and Northern Dynasties	420–589
Sui	581–618
Tang	618–907
Five Dynasties and Ten Kingdoms	907–979
Song	960–1279
Northern Song	960–1127
Southern Song	1127–1279
Liao	916–1125
Jin	1115–1234
Yuan	1271–1368
Ming	1368–1644
Qing	1644–1911
Republic of China	1912–1949
People's Republic of China	1949

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# Dunhuang Art: The Treasure of the Silk Road

*Duan Wenjie*

THE ANCIENT CARAVAN route linking China with the West is known as the Silk Road, a great conduit of commercial and cultural exchange stretching 7,500 km from Chang'an (present-day Xian) to Rome. Chinese silk, which gave the route its name, was transported to the West, while wool, dyestuffs, gold, and silver—along with cultural ideals—traveled east. Among these, the religious culture of Buddhism left a lasting and profound mark on China. Under the open-door policy of Tang dynasty Emperor Li Shih-min, the Silk Road flourished as a meeting ground between East and West during the great era of the Tang civilization (618–907 C.E.), when Chinese feudal culture reached its height and spread its influence throughout the world.

Dunhuang is strategically located at the far western limit of early Chinese settlement, at the point where the two branches of the Silk Road converge. It was the first trading town reached by foreign merchants entering Chinese territory from the west and thus became the repository for a cultural exchange that encompassed the art, literature, and religions of China, Central Asia, and the West. This vigorous meeting of cultures produced a wealth of art and artifacts at various points along the Silk Road, especially at those towns where Buddhist monks stopped off on their pilgrimages to India. Dunhuang was the last stop in China on the great pilgrim route. On the cliff face above the river they excavated cave temples, or grottoes, to serve as lodging, as centers of worship, and as repositories for documents, sacred works, and works of art. Because of its strategic location, the grottoes of Dunhuang came to be the largest and greatest of the Buddhist grotto complexes along the Silk Road, with a history spanning one thousand years. As such, Dunhuang can be seen as a microcosm of Chinese medieval culture, reflecting the broad multinational, multi-ethnic influences that gave it such distinctive character.

During its height, Dunhuang culture gave rise to a wealth of architecture, sculpture, murals, paintings on silk, calligraphy, wood-block prints, embroidery, literature, music, opera, and other art forms. Although the contents of the library cave have unfortunately been dispersed to museums in the West, the grottoes still contain a trove of paintings and statuary that exemplify religious and historical themes and artistic

techniques as they evolved over a one-thousand-year period of Chinese art. The murals, covering 45,000 m<sup>2</sup>, fall into the following categories:

- revered images: images of each of the divinities worshiped in Buddhist temples; these murals are the most numerous and are executed with the highest degree of artistic skill;
- Buddhist scriptural tales: (1) stories of the life of the Buddha, (2) stories of previous lives, and (3) karmic stories; these murals draw the viewer into their fantastic realm;
- Chinese mythical themes: images of the creator Fuxi, the creator Nuwa, the Royal Sire of the East, the Queen Mother of the West, the Vermilion Bird of the South, the Dusky Warrior of the North; these figures, along with other deities, have entered the cave art;
- images evolved from sutras: large-scale murals depicting the Buddhist utopia, a world of great joy and splendor;
- Buddhist history: these murals combine historical figures with Buddhist tales, including stories from India and Central Asia, as well as Zhangye, Jiuquan, and other locales;
- portraits of donors: images of those who funded the grottoes, murals, and sculptures—among them, portraits of individuals from every social class and ethnic group, as well as merchants of various nationalities; and
- ornamentation: geometrical patterns depicting plants, animals, heavenly bodies, and people in ornamental design.

The mural art of Dunhuang reflects the daily life of medieval Chinese of all classes, as well as that of people from countries throughout Asia. Noteworthy are scenes of the manufacture of goods, social life, the commercial trade between China and the West, the meetings of princes, the succession of Chinese emperors, the worship of the Buddha at Turfan, the travels of the Princess of Huige, and more. The mural art of Dunhuang is a mirror of Chinese history, described by one specialist as a library contained in wall paintings. The art of Dunhuang has added inestimably to our understanding of medieval life in China.

The murals, sculpture, and architecture of the grottoes also illustrate the ways in which grotto art originating in India was adapted under Chinese influence. Departing from the Indian model, the Chinese introduced wooden architectural structures to achieve the effect of an audience hall of a Chinese palace. Moreover, Chinese mythical themes were incorporated into the decorative patterns, enriching their content and adding to their scope. As the Indian Buddhist tales were illustrated with Chinese characters, clothing, and customs, a hybrid was created that exemplified the exchange and merging of cultures through which the arts flowered.

Following the traditions of the Han and Jin dynasties, the artists of Dunhuang combined realism with imagination, achieving an expressive quality by outlining figures and features, which were then filled in with color. Using this uniquely Chinese method, the artists of Dunhuang put

their imprint on the Indian Buddhist subject matter. Moreover, they absorbed and adapted expressive techniques and themes introduced from the Persian and Greek, as well as Indian, heritage—e.g., the portrayal of the beauty of the human figure or characteristic styles for depicting divine images.

Ultimately, the creative blending of themes and artistic techniques established a new Chinese style of Buddhist art; by the fifth century c.e., the style had itself become a source of influence on Western, Central Asian, and Indian culture.

The grottoes of Dunhuang, in which history is crystallized, has been listed by Unesco as a World Heritage Site. The mission of the Dunhuang Academy is to preserve, study, and promote the site. The task of preservation—the Dunhuang Academy's first priority—has been advanced greatly by domestic and international cooperation in recent years, the evidence of which was borne out by this conference.

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On behalf of the Dunhuang Academy, the author extends gratitude to all individuals and institutions who have contributed to the study and preservation of the site.

# An Overview of Protection of Grottoes in China

*Huang Kezhong*

**M**OST OF CHINA'S grottoes are rock-cave temples, which served as centers for Buddhist worship after Buddhism spread eastward from its roots in India. The earliest grottoes date back to the second century C.E., during the Han dynasty. The major excavation period occurred from the fourth to the ninth century, during the Northern Wei, Sui, and Tang dynasties. While most of the grottoes were completed during this period, excavation continued into the Ming and Qing dynasties.

The grottoes are concentrated at sites along the ancient Silk Road and the Yellow River and Tangtze River basins. The best-known sites include the Mogao grottoes at Dunhuang in Gansu Province; the Yungang grottoes at Datong in Shanxi Province; the Longmen grottoes at Luoyang in Henan Province; the Maijishan grottoes at Tianshui in Gansu; the Buddha cliff statue at Dazu in Sichuan; the Kizil grottoes in Xinjiang; and the Yulin and Bingling grottoes, both in Gansu. The total number of grotto and cliff-statue sites nationwide exceeds 250; among these, 30 are listed as cultural relic protection sites at the national level, while 94 are listed at the provincial level and 124 at the municipal and county levels.

The grotto art—architecture, wall paintings, and sculpture—provides vivid documents for the study of China's social economy, politics, religion, art history, and architectural construction methods of the Middle Ages. Drawing on the traditions of Indian grotto art, Chinese grotto art developed under the influence of Han dynasty customs and artistic traditions. During the later phases of grotto carving, elements of Taoism and Confucianism were integrated into the dominant Buddhist imagery.

Grotto caves are typically classified according to function: tomb cave, pagoda or temple cave, lecture room cave, meditation room, monk's cell, Buddha hall. The sites can also be classified according to the properties of the rock: sandstone, conglomerate, limestone, crystalline rock. The rock body types most commonly selected for carving—conglomerate and limestone—were thick, complete, and homogeneously stratified. The preferred rock type was not too hard to be easily cut; ideally, it had an internal stability and had not undergone any tectonic changes.

The condition of the grottoes has deteriorated over the centuries due to human and natural causes such as erosion by efflorescent salts, which has led to large areas of collapse at the Mogao and Maijishan grottoes at various historical times. The Kizil grottoes remain threatened by a pattern of gullies that crisscross the top of the cliff. The Jiaoshan cliff statue, at Zhenjiang in Jiangsu Province, was severely destabilized during the torrential rains of 1990, which caused the Yangtze river to rise. Efflorescence of the statues and carvings at the Yungang grottoes and in the Bingling Temple is advancing at an alarming rate, while the granite statues in Quanzhou and in the Qingdao area near the seashore are eroding as a result of winds from the sea. Acid rain is exacerbating the efflorescence of sculptures in Dazu, Xiangtang Shan, and Siwangshan.

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## History of Consolidation and Restoration Efforts

Much of the key work of the last thirty years has focused on emergency repair and consolidation of grottoes located near active earthquake zones, where the threat of collapse is greatest. Much has been accomplished during this time to preserve the cultural heritage. For example, a reinforced concrete facade installed at the Mogao grottoes in the 1960s prevented the collapse of large areas and protected fragile wall paintings from exposure. The disadvantage of this consolidation structure is that its appearance is too artificial and is aesthetically unappealing. In this case, it was difficult to honor the principle of “no change of the status quo ante,” as stipulated in the Cultural Relics Protection Laws.

The Maijishan grottoes, which were in an equally precarious condition, underwent consolidation in the 1970s. Over a five-year period, various approaches were tested repeatedly, including pillar supports, grouting consolidation, and protection measures against rock movements. A plan that combined grouting consolidation and crevice grouting was adopted. Although this approach was less visually intrusive than the facade at Mogao, problems remained—e.g., the cement-sprayed surface layer covered the ancient architectural pillar holes, and the concrete shell increased moisture within the rock caves. In the stabilization projects at Longmen and Yungang grottoes, chemical grouting measures were used with attention to restoring the grottoes as closely as possible to their original condition.

The restoration projects undertaken at some grottoes generated controversy. For example, at Xumishan grottoes—where the Buddha figures were exposed to sun and rain after the collapse of the rock caves—restoration of rock eaves and walls was performed in the 1980s, according to the appropriate scientific methods, as deemed necessary. However, some aspects of the restoration were not harmonious with the surroundings, and details were introduced that were not authentic. This is an area where further improvement is needed.

In recent years, the preliminary study for the maintenance of the Leshan Buddha statue examined the use of modern scientific and technological means, art historical documents, traditional and modern materials, and new techniques with the aim of providing a solid scientific foundation for the restoration of the statue.

A comparison of approaches to Chinese cultural relic protection and maintenance with international regulations, such as those spelled out in the Venice Charter, shows that most international and domestic strategies aim at minimal intervention, historical authenticity, and documentation before and after maintenance.

The formulation of a specific national cultural relics policy is especially urgent because China is not only a large country with abundant cultural relics but also a developing country with rapidly expanding capital construction. Unless protection priorities are established and laws enforced, cultural relics will be damaged by economic development. For example, in 1969 a railway was illegally constructed in the area of the fifteen-hundred-year-old Longmen grottoes. The shock of explosions during the railway construction, and vibration from the train itself, caused collapse of some caves and aggravation of water-seepage problems. The railway was eventually moved out of the protection area.

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## Preliminary Research

Research has focused on assessment of the value of the grottoes and their historical development, collection of records documenting the history of protection and restoration, assessment of damage, monitoring of the environment, and evaluation of construction technology and materials. This preliminary research, which has won wide attention, has brought together specialists in history, archaeology, art, architecture, engineering, the sciences, and cultural relics protection, who share a commitment to establishing a solid foundation for conservation and subsequent maintenance.

The results of the study show that damaging natural effects include water seepage and related problems caused by rainfall, river water, and underground water; instability of rock precipices; earthquakes; rock efflorescence; and erosion by wind and sand. Human factors contributing to the deterioration of grottoes include changes in the internal microclimate due to tourism; environmental pollution; local mining, which may cause ground subsidence; and shock caused by explosions.

The nature of this damage has dictated the following approaches to research:

1. Rock sculptures and geological phenomena are recorded in plane, elevation, and section drawings by using close-range photogrammetry.
2. Geological engineering mapping—which routinely records factors such as the strata, lithologic character, tectonic effects, hydrology, and physical geology—is expanded to include rock sculpture damage, crevice distribution, areas of endangered rock, salt efflorescent condition of sculpture, seepage point locations, and so on.
3. In some unstable areas, precise gauges are used to monitor crack formation.
4. Research on salt efflorescence of rock sculptures involves classification of relevant factors and long-term monitoring of

meteorological conditions as well as seepage and permeation. Using samples of profile sections of efflorescence of rock sculptures, a series of tests—chemical analysis, differential thermal analysis, X-ray diffraction analysis, spectral analysis, and scanning-electron-microscope examination—is conducted to establish the physical and mechanical properties of the rock. The results of these laboratory analyses provide the basis for conclusions concerning the nature of damage due to efflorescence. The extent of efflorescence of rock sculpture is investigated by using point-load intensity tests to obtain the tensile strength and tensile-strength index of the rock, whereas sonic wave analysis is used to indicate the efflorescent range of the surface. Efflorescence depth is studied by analysis of the resistivity of the surface of the rock sculpture; and lithofacies variation is measured by variation of the chemical elements with increasing depth.

5. Some of the geophysical exploration methods used include direct-current resistivity for exploring the seepage path and the depth of bedrock on top of the rock caves; sonic waves to measure the efflorescent range of the rock body, the location of large crevices, and the effects of chemical grouting; micro-bathymetry to measure the thickness of mantle rock, the direction of propagation of crevices, and the penetration depth of protective materials; and the shallow seismic method to explore crevice development in the depth of the rock body, internal defects of rock sculptures, and the archaeology of the site. A Fathometer is employed to locate the position, size, and shape of subaqueous caves under the seat of the Buddha; radar assists in identifying buried rock caves. A nuclear moisture gauge allows for nondestructive investigation of density and moisture of rock sculpture.
6. Seismographs of various kinds are used to measure the dynamic stability of grottoes with respect to nearby explosions and locomotive and motor vehicle vibration. Natural seismic investigation can be conducted on the rock caves to assess the effects of seismicity on the caves.
7. For the assessment of environmental geology of rock caves excavated (as most were) on precipitous slopes, the three-dimensional, finite-element method is used to calculate rock body stability. In order to establish a structural model of the rock body, the joint fissures are measured to provide a basis for analyzing permeation channels and their paths. Statistical analysis can be undertaken on geometric parameters of the structural planes. A picture of the network of structural planes of the rock body and the connected network system can be obtained by setting up a probability model and conducting computer simulation on the structural plane network. These data then provide the foundation for rock body stability



analysis, identification of permeation channels, and treatment of seepage.

Environmental monitoring has been designed to address specific problems, such as dust and harmful gases containing SO<sub>2</sub> and NO<sub>x</sub> that are emitted from cement factories, power plants, and lime mines in the neighborhood of the South and North Xiangtang Shan grottoes at Handan, Hebei Province. A project for monitoring hydrology and underground water was established at Longmen grottoes, where the drying up of springwater and declines in the flood-discharge capacities of rivers are posing a threat to the safety of the grottoes. At the Mogao and Yungang grottoes, large-scale monitoring efforts—undertaken jointly by the Dunhuang Academy, the Yungang Grottoes Management Institute, the Chinese National Institute of Cultural Property, and the Getty Conservation Institute—have focused on sand flow and coal dust pollution.

Further preliminary research has been conducted to establish the feasibility of a consolidation and maintenance plan for the rock caves and to evaluate consolidation materials. At the Yulin grottoes, for example, a method of bolting and chemical grouting was tested to establish whether the grouting material can form pores inside the conglomerate layer. From tests conducted on consolidation materials, including bolt grouting, crevice grouting, and anti-efflorescent coatings for rock surfaces, good results were obtained on inorganic grouting material used for grouting crevices under humid conditions, and antiweathering polymeric material for rock sculptures.

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## Approaches to the Protection and Maintenance of Grottoes

Vestiges of traditional protection and maintenance measures left over from successive dynasties remain functional at many of the grottoes. Eaves and doors were constructed to protect sculptures from exposure to rain and sun, as can be seen today in the Tang dynasty shelters at Longmen grottoes. Drainage systems were also installed at many sites, such as the combination of open channel and underground drainage devised to protect the rock sculpture at the Dazu grottoes. At the Kizil grottoes, mortar and wooden bolts were used to reinforce the cave face and precipitous slope. These are just a few of the many examples of historical protection efforts devised.

Modern approaches draw on traditional technology while also incorporating new materials and techniques. A key focus today is on protecting grottoes from various types of erosion by water. For example, drainage systems can be installed on top of caves to prevent seepage of surface water. Groundwater drainage can be constructed in front of the caves; by lowering the underground water level, moisture and dew inside the caves is reduced or eliminated. The construction of eaves protects the carved rock from damage due to direct sunlight, sand, and acid dust; the eaves also help to moderate humidity changes.

Historically, concrete retaining walls were constructed to address the problem of collapse or slippage of the rock body of the caves. These

methods are not used today because they are visually intrusive and mar the original historical features of the site. Instead, bolt-grouting is used for reinforcing areas with crevices and dense concentrations of caves. Although the bolt-grouting method represents an improvement, it, too, partially alters the features of the caves and obscures some historical traces. The reinforced steel net shield method has recently been replaced by chemical coating materials.

Another approach to treating fractures in carved stone, fissures in precipice walls, and collapse is by grouting adhesion. The preferred grouting materials are acrylic ester, epoxy resin, and inorganic chemical materials, which approximate the physical and mechanical properties of the rock. These materials are durable, resistant to cold, waterproof, and easy to apply; they achieve a solid bond; and they solidify at room temperature. Nondestructive sonic measures are used to examine indicators of the grouting effectiveness, such as depth, range, rock body density, and deformation.

For relatively well-preserved carved rock, with only slight efflorescence, protective measures focus on limiting potentially harmful environmental factors. Protective coatings are applied directly to stone statuary only in cases where severe efflorescence threatens the statues with complete collapse. Any plan for applying such coatings should identify the relevant efflorescent agents and the performance parameters of the coating material—e.g., transparency, absence of color, good chemical stability, good penetration, solidification strength, and antiflaking and antiglare properties. Preferred coating materials currently used are high-molecular organic polymer materials such as organosilicones, methyl methacrylate, and polyurethane. Some inorganic materials that are being successfully used are high-modulus potassium silicate and various compound materials.

Laboratory tests have been conducted on the properties of these materials to evaluate variations along the direction of depth, as well as pore ratio, permeability to water vapor, compressive and tensile strength, and erosion resistance. Materials testing has also investigated surface hygroscopic coefficient, capillary hygroscopic coefficient, maximum hygroscopic rate, permeability, antiaging properties, resistance to heat and cold, mechanical and chemical stability, recoating performance, and other parameters. Long-term field monitoring stations have been established to maintain ongoing evaluation.

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## Discussion

Three considerations remain for discussion: laws and public policy regarding protection of the grottoes; the controversies surrounding the principle of “no change of the status quo ante”; and the combination of traditional techniques and materials with modern consolidation measures.

The point has been made previously in this paper that the development of modern industry, capital construction, the tourist industry, environmental pollution, and the changing microclimate in the area of the grottoes have accelerated the deterioration of the rock caves to an alarming degree. The work of conservation specialists alone cannot remedy these problems. Cooperation is needed from all sectors of society,

particularly from government at all levels in the establishment and implementation of laws for the protection of cultural relics.

The agenda for conservation organizations is to define the grottoes' protection area, specifying the key protection area, general protection area, and limited construction zone. Moreover, environmental protection regulations must be established, with administrative departments overseeing construction and environmental protection. Long-term environmental monitoring stations have been established in severely polluted grotto areas to identify the major causes of pollution. Data gathered from these stations provide the basis for developing criteria for levels of harmful substances in the atmosphere surrounding the site.

It is likewise essential to limit the construction of new factories and other sources of pollutants in the protection area, while also monitoring pollution from newly enlarged enterprises. Reasonable pollution-treatment regulations must be formulated, along with a plan for managing sources of pollution. Further research on the appropriate environment for grottoes must include assessment of temperature, humidity, and control of visitors.

In planning the maintenance and consolidation of grottoes, it is important to be prudent in interpreting the principle of "no change of status quo ante." Many cases present ambiguities that cannot be decided on the basis of this principle alone. For example, the construction of facades on eaves on the cliff face has aroused controversy because they alter the original features of the grottoes. Yet, in some cases, such architectural interventions are necessary to protect fragile statuary from airborne dust and from sudden changes in temperature or humidity that accelerate the weathering process. Also, the metal frame type of shelter, fitted with lightweight synthetic textile net, provides effective control of the microclimate but has a disharmonious appearance.

The restoration of the Leshan Buddha is another problematic case. Maintenance undertaken in the 1960s altered the Buddha's original features—nose, eyes, mouth, and lower jaw—in significant ways, and therefore restoration is indicated. But, the question is, to which historical period should it be restored? Photos of the Buddha taken during the period of the Republic of China show the figure to be inaccurately restored, while documents from the Qing dynasty period show the figure to be severely damaged, with many cavities on the face. In view of this situation, according to the restoration principle, it is better not to restore the Buddha.

In the 1970s, the severely damaged waist of the open-air Buddha statue in Cave 20 at Yungang was restored with a rock material similar to the original. In the past, Chinese restoration specialists have advocated mixing the spurious with the genuine, so afterwards viewers cannot tell which part of the statue has undergone restoration. However, many international cultural relic protection specialists believe, to the contrary, that newly added parts must be clearly defined. At present, the majority view here is that restored parts of cultural relics should not be strikingly visible when viewed at a distance, though some difference may be noted close up.

Evidence of the *statue quo ante* must be obtained prior to restoration, to be followed by detailed recording and documentation.

There is much to value in traditional maintenance technology—e.g., the drainage and antiseepage systems, shelters and eaves, the principle of minimal intervention, and use of original material to maintain style and structure. Some traditional measures can be discarded, such as the use of gold size on the surface of the carved rock, which caused erosion by trapping moisture, or the use of iron rods as reinforcement, which ultimately caused fissures when the rods rusted. The use of new materials and technology must, above all, preserve the effects of the *status quo ante*; and they must be reversible so later generations can replace them with even more effective consolidation measures.

# Fifty Years of Protection of the Dunhuang Grottoes

*Fan Jinshi*

**T**HE GROTTOS in the Dunhuang area comprise the Mogao grottoes, the West Thousand Buddha (Xiqianfo) caves, and the Yulin grottoes near Anxi. Like a great many of the grottoes of China, these are Buddhist temples that were cut into cliffs along river banks. The Daquan River flows past the front of the grottoes.

The Dunhuang grottoes were carved into a conglomerate of the Quaternary Jiuquan system. Because the loose conglomerate rock was not suitable for fine carving, murals and clay-plastered polychrome statues were produced to depict the concepts of Buddhism. Each cave contains a combination of polychrome sculptures, murals, and architectural structures. These artworks were made over a thousand-year period from the fourth to the fourteenth century, when Dunhuang was a sacred center of Buddhism. Among the three grotto sites, 549 caves contain wall paintings and painted sculptures, and more than 250 caves contain other forms of art (Dunhuang Cultural Relics Research Institution; Li Yongning 1981, 1982). Altogether, these sites are of extraordinary artistic, historical, technological, and economic value. The Mogao grottoes in particular are one of the world's most famous large-scale cultural heritage sites. After fifteen centuries, some of the rock temples of the Dunhuang grottoes have undergone severe damage due to historical and natural causes. The cliff rock has fractured, sculptures have fallen over, and paintings have been damaged by flaking, peeling, and salt efflorescence (Fan 1993).

In January 1944, the Dunhuang National Art Research Institute was established by the Chinese government, initiating a new stage in the preservation of ancient relics. Since the 1950s, extensive emergency repairs have been carried out and scientific techniques of preservation applied.

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## The Pioneering Years (1943–50)

Fifty years ago, in the midst of China's war with Japan, some ten staff members of the Dunhuang National Art Research Institute began the work of preserving the grottoes under the leadership of Chang Shuhong, the institute's director at the time. Conditions were difficult due to limited financial support, lack of equipment, and the remote, windy, and sandy

environment of China's northwestern frontier. Yet the team accomplished a tremendous amount of work. They constructed an enclosing fence 850 m long to control visitors, connected several caves with walkways, removed sand that had accumulated inside more than three hundred grottoes, removed the clay beds built by Russian refugees who had occupied the caves in 1921, made preliminary renovations, and installed wooden windows and doors in some of the rock temples to protect the artwork from human damage and erosion by blowing sand. In the course of this work, they also discovered six more caves and more than three hundred scrolls of sutras (Dunhuang Cultural Relics Research Institution 1977). For the purpose of site management, they supplemented and developed a new cave-numbering system based on an existing one, made an inventory of the grottoes' contents, produced a written description of the site, organized exhibitions, instituted guided tours, and arranged for security guards to be responsible for the safety of the grottoes. All of these efforts formed the initial framework for the present program of site protection, research, and presentation. All of the protection measures at that time were rudimentary to some degree. Nevertheless, they effectively prevented looting and vandalism of the caves. The eight years of hard work by these pioneers brought to light once more the importance of these cultural treasures to the heritage of the world.

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### Remedial Conservation Period (1950–80)

Although much work was accomplished during the previous period, deterioration due to either natural or human causes had yet to be addressed. Destabilization of the cliffs, salt efflorescence on the paintings and statues, and deterioration of the roofs of certain caves were advancing at an alarming rate.

In 1950, the Dunhuang National Art Research Institute was reorganized as the Dunhuang Cultural Relics Research Institution (now the Dunhuang Academy), and the first site-management department was founded. A series of comprehensive surveys was carried out to evaluate the impact of the natural environment on the grottoes, the deterioration of the caves and cliffs, features of the architecture, and the condition of existing wooden structures. On the basis of this survey, a comprehensive, full-scale renovation of the Mogao grottoes was begun in 1951.

At that time in China, traditional technology and craftsmanship were being revived. Earlier techniques were thus applied to the restoration of the damaged caves, the removal and replacement of components, the substitution of materials, and the restoration of fallen structures. Five Song dynasty wooden facades of Mogao caves 427, 431, 435, 437, and 444 were replaced and restored to their original shape (Zhao 1955). Rotten wood frames within some statues were replaced, and tilted statues were straightened. Clay was applied to the edges of wall paintings that had separated from the wall, and the paintings were secured with anchor pins and the application of grouting to effectively prevent further detachment. In 1965, experimental reinforcement work on the cliff face was carried out to reinforce a 200 m long middle section of the southern caves 232–260, using

columns of rock construction and wooden planks. Stabilization of the precarious cliff face, made fragile over the centuries by extensive excavation of the caves in weak strata, was carried out from 1963 to 1966. Stone pillars were used to support overhanging rock at the top of the cliff face, and retaining walls were built to prevent block failure around the crevices. This project resulted in reinforcement of more than 570 m of the cliff face and 358 caves. At the same time, the walkways between caves of the same or different levels were connected, permitting access to several hard-to-reach caves while retaining the simplicity of their external appearance. With available technology, this million-yuan project resulted in the effective reinforcement of the southern portion of the Mogao grottoes to the greatest extent possible (Sun 1994).

Meanwhile, the most recent scientific technology began to be incorporated into the conservation work at Mogao. For example, testing of and experiments on the conglomerate using polymer materials (polyvinyl alcohol and polyvinyl acetate solutions) as adhesives led to the restoration of some of the previously untreatable flaking and salt efflorescence of the wall paintings (Li Yunhe 1993a). To prevent abrasion by windblown sand, experiments were conducted using grass barriers and windbreak fences (Ling 1993). Studies on the techniques of removing and transferring wall paintings were also conducted (Li Yunhe 1993b). The purposes of these studies were to expose the hidden wall paintings and to install paintings that had been removed from remote, endangered sites.

For the long-term protection of grottoes from damage by natural processes and human factors while the caves were in use, we took the following remedial measures:

1. Following the ancient practice of building shelters outside and laying floor tiles inside the caves, doors and cement floors were installed in some caves to prevent abrasion from wind-blown sand and damage due to sunlight, dust, and visitors.
2. Sand and dust that had accumulated in front of and inside the caves were removed to prevent it from further entering the caves and damaging the wall paintings.
3. Weather stations were set up to monitor the environmental patterns around the Mogao grottoes (Sun 1993).
4. Descriptive pamphlets were published and explanatory plaques installed around the grotto site. Visitor regulations were drawn up and tour guides provided to explain the site to the visitors, monitor their conduct, and keep them from damaging the caves.
5. A system of regular grotto inspection was established to detect any damage caused by natural processes or human factors and to facilitate immediate emergency repairs to damaged caves.

Many national laws and regulations regarding the protection of cultural relics, including grotto sites, were formulated and promulgated before the 1960s. They included provisional management regulations and

procedures, a list of major cultural sites, and temporary procedures for the repair and management of ancient buildings and cave temples. According to the Law and Regulations on Cultural Relics, the Dunhuang grottoes—including the Mogao grottoes, the West Thousand Buddha caves, and the Yulin grottoes—were listed as key national cultural protection sites. The establishment of these laws not only raised the prestige of the Dunhuang grottoes and resulted in society regarding them with greater importance but also put them under legal protection, which promoted and assisted in their conservation.

Renovation at this time consisted of a full-scale emergency repair to save and preserve those caves that were on the verge of collapse, as well as damaged wall paintings and statues. The data gathered during this first stage provided the foundation for identifying and achieving a preliminary understanding of the types of damage present. The conservation and management experience obtained during this period also helped those involved to develop a functional management plan. All these factors served to establish a good basis for entering the scientific stage of conservation work.

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### Scientific Conservation Period (1980 to Present)

In the previous stage, it was necessary to carry out emergency measures to mitigate against the severe damage threatening the safety of the grottoes and their cultural relics. It was realized that such renovation and reinforcement should be performed only on endangered areas, since unevaluated measures can sometimes lead to harmful side effects and cause further damage. The conservation measures that were undertaken were appropriate to the available scientific technology at the time, and the emergency repairs helped to stabilize seriously threatened grottoes.

Certainly, long-term management and safety of the Dunhuang grottoes cannot be limited to renovation and reinforcement measures; it should focus on scientific conservation with a primary emphasis on prevention. During this phase, therefore, the conservation team formulated a long-term scientific plan, trained conservation technicians, instituted protection measures, adopted advanced technologies, expanded international cooperation, and improved management to ensure greater development of conservation work than in the previous stage. The work carried out during this period emphasized (1) an interdisciplinary approach and the application of advanced technology, (2) scientific research on mechanisms of deterioration and techniques of restoration, and (3) development from microprotection at a local level to macroconservation of the entire site. During this period, the work focused primarily on environmental monitoring and visitor management.

### Environmental monitoring and research of the site

The natural environment in which the caves are located is very complicated. During this period, various scientific approaches were undertaken to understand the characteristics of the grotto sites, the natural environment



in which they are found, and the relationship between these factors. Studies were also conducted on the deterioration of and causes of damage to statues and wall paintings in the grottoes.

#### **Approaches to environmental monitoring**

The present conditions of the caves, sculptures, and murals inside the caves are complex, and their management and protection are affected by environmental factors. Several scientific approaches were taken to monitor the cave relics and their natural environment from diverse aspects, as follows:

**Weather monitoring.** A fully automated weather station was installed above the Mogao caves to measure temperature, humidity, ground-surface temperature, wind direction, wind speed, sunlight, and precipitation. Accurate data collected over four years reveal the basic characteristics of weather patterns and provide scientific data for studying the microenvironment and the causes of deterioration inside the caves (Li and Zhang 1993; Miura 1993).

**Microenvironmental monitoring.** Caves of different sizes, different depths, different levels, with and without doors, and open or restricted to visitors were selected for long- and short-term monitoring of the microenvironment inside the caves using fully or semiautomated equipment. The data obtained provided scientific evidence for the study of the preservation of murals and sculptures, causes of deterioration, the effects of visitors on the caves, and the study of the optimum environment in the caves (Zhang and Wang 1993).

**Hydrogeology.** Systematic analyses were carried out on the chemical components of the ground-surface water from the Daquan River and on the cliff rock of the Mogao caves. Results show that the ground-surface water has a high content of soluble salts. Dampness in the caves on the lower level was found to be brought about by the capillary movement of irrigation water that permeated into the lower levels of the caves and damaged the paintings. Studies also showed that the precipitation that infiltrates downward into the upper layer of the Mogao caves, along with the pressure exerted by the overlying rock, led to the delamination and thinning of roofs in caves at the upper level (Zhang Mingquan 1993).

**Engineering Geology.** Surveys were carried out to study the structure and stratigraphy of the Mogao grottoes and damage to them. Studies of the physical and mechanical properties of the cliff rock were also conducted (Zhou 1993). Tectonic and seismic analyses, and earthquake predictions in recent years, indicate that there could be an earthquake of 6.5 to 7 on the Richter scale in the Hexi Corridor area in the future. For this reason, mechanical-type concrete strain gauges were installed at observation points along major crevices in the Mogao bedrock to monitor stability. A seismic recorder was set up to record seismic activity, analyze vibration resistance of the cliff rock and reinforcement structures, and evaluate earthquake hazards in the region (Yao 1993).

**Wind monitoring.** Wind direction and speed, windblown sand on the plateau, and the quantity of sand transported were continuously monitored using the weather station data and monitoring devices.

### Material analysis of the paintings and polychrome sculpture.

Analysis was performed on the support layer, the ground layer, and the pigment layer of the wall paintings and the polychrome statues. The types, structures, and characteristics of the binding media mixed in the pigments were also scientifically analyzed (Guo 1993b; Xu 1993; Li Shi 1993).

## Investigation and treatment of causes of deterioration

Deterioration to the art within the grottoes caused by different factors posed the most difficult problems. The conservation team first considered the most severe deterioration, such as discoloration of the wall paintings, obscuring of the art by windblown sand, and salt efflorescence. Experiments were conducted to prevent and remedy these processes, and the measures applied were evaluated.

### Search for the causes of deterioration

Damage by windblown sand is severe, and large amounts of sand enter the grotto area. This has not only led to the annual accumulation of 3,000 m<sup>3</sup> of sand at the base of the cliff and on the walkways; it has also caused abrasion of the cliff and left many precarious, overhanging rocks that threaten the safety of the site. Sand and dust have also polluted and abraded the surfaces of the wall paintings and polychrome statues. In less severe cases, partial flaking of paint layers has occurred, leading to loss of luster. In severe cases, all of the paint has flaked off (Ling Yuquan 1993).

Salt efflorescence—one of the most common forms of damage to the wall paintings—can cause cracking, flaking, and even detachment of the plaster ground of the murals. Cave 53 at the lower level of the Mogao grottoes is a typical example of a cave that has suffered severe damage due to salt efflorescence (Guo 1993a). Comprehensive analyses of the geological structure of the site and the chemical components of the plaster ground layer, along with monitoring data on the microclimate, indicate that underground water seeped into the cave, raising the humidity and dissolving the soluble salts in the rock. Damage to wall paintings also occurred when water-evaporated salts crystallized between the rock and the clay plaster layer, and at the bases and tops of the murals.

Discoloration of paint pigments is very common in grottoes of various periods, especially in those painted during the Tang and Sui dynasties. To understand the current conditions of the pigments and the processes and causes of discoloration, the authors conducted two types of studies. In one, a chromometer was used in certain caves twice a year to monitor color change in pigments. In this way, it was possible to document the current condition of different colors and quantitatively monitor the process of discoloration. These data can also be used to assess the appropriateness of different conservation measures. In another study, the causes and mechanisms of discoloration of red lead, cinnabar, and hematite in red pigments were analyzed, based on pigment and chemical analyses from past studies (Li Zuixiong 1993a, 1993b).

The team also conducted preliminary studies on the causes of wall-paint blistering, which had led to detachment of the paint layer (Duan 1993).

#### **Consolidation materials**

Both large areas of flaking at the pigment layer and salt efflorescence at the plaster ground layer of the wall paintings need to be treated. Studies of suitable adhesives are also important. In the 1960s, two polymer materials—polyvinyl alcohol emulsion and polyvinyl acetate emulsion—were selected by testing and were used extensively in the restoration of many murals that had undergone flaking and efflorescence (Li Yunhe 1993a). With the limited research resources available at that time, only a few field tests were conducted. Now, thirty years later, scientific procedures have been carried out to evaluate the effectiveness of and to develop new applications for these synthetic emulsions. Efforts were also made to develop new consolidation materials and methods (Li Shi 1993).

#### **Abatement of deterioration**

Immediate care for the deterioration caused by flaking of paint layers, salt efflorescence of the plaster ground, sand abrasion of the grottoes, water erosion of the cliff rock, and detachment of the murals is necessary. In compliance with the conservation principles of ensuring the safety of cultural relics and of “restoration to the original state,” work was carried out according to the following two guidelines: First, continue to use restoration materials and technologies that have proven effective over many years and have undergone many experimental evaluations. Second, formulate conservation programs for each type of deterioration on the basis of scientific monitoring and studies of the causes of deterioration in consultation with experts in sand control, structural engineering, and geology and by repeated field testing. For example, in order to treat the deterioration at the Yulin grottoes, comparisons were made with past work at the Mogao and Maijishan grottoes. Based on investigation, repeated consultations, and test results, anchoring cables were used to reinforce the cliff rock, crevices were grouted with a mixture of high-molar-ratio potassium silicate solution and coal ash, and the slope was stabilized with reinforcement techniques.

#### **Tourism and site management**

The rich cultural resources at the Dunhuang grottoes, improvement in local transportation conditions, and an increase in Chinese tourism have attracted a growing number of visitors from around the world, increasing the fame of this cultural site. People have become more and more interested in Dunhuang, which has led to a greater appreciation of the grotto sites and promotion of the efforts to conserve them. As additional caves open to the public each year, however, the appearance and environmental conditions of the grottoes have begun to change significantly. The increase in visitors has led to increases in traffic, garbage, discharge of waste water

and sewage, and residual waste from vehicles and boilers. It has also raised the temperature, humidity, and the amount of carbon dioxide inside the caves and has affected the stability of their microenvironments. Some visitors have damaged the site intentionally or carelessly, and some have even stolen relics. All of these factors are contributing to the deterioration of the site and threatening the preservation of the cultural relics.

Our responsibility, as conservation professionals, is to utilize scientific management principles, methods, and systems to ensure the protection of the cultural relics, to solve the conflict between protection and use, and to do a good job of preserving cultural heritage. For such an important site as Mogao, the guiding principle in opening the site to visitors has been to stress protection as the main objective while encouraging its active use. Management standards here ensure the safety of the cultural sites, maintain their original appearance, and permit scientific studies of them. Based on these principles, site-management work has been carried out in the following areas:

**Meeting public demand.** Many visitors travel long distances and look forward to seeing the art treasures at Dunhuang. The desires of these visitors must be respected. When visitors are pleased with their experience, they will help to promote the protection of the site. To explain the art and history of the caves to international visitors with different specialties, different levels of experience, and different languages, tour guides have been professionally trained and provided with a range of foreign language skills (English, Japanese, French, Russian, German, etc.). Most of them were trained in domestic foreign-language schools, and some were sent to Japan for language training. More than forty tour guides have mastered specific languages and can provide specialized explanations. Various pamphlets are provided; and special volumes of art books, pictures, slides, and souvenirs are also available.

**Visitor management.** To avoid damage or destruction of the cultural relics resulting from lack of knowledge about conservation on the part of visitors, the grottoes are opened by area and each cave by turn, limiting the number of caves open at any one time and restricting the number of people allowed to enter each cave per visit. The entrance charge has also been increased to reduce the number of visitors, and restriction signs (such as no smoking and no photography) have been posted, as required by national law. Visitation regulations and policies have also been updated.

**Scientific preventive measures.** As part of this plan, a collaboration was formed between the Dunhuang Academy and the Getty Conservation Institute. The conservation team set up automated or semi-automated monitoring stations to monitor temperature, humidity, wall temperature, and carbon dioxide levels in order to understand the effects of visitors on the microenvironment of the caves. A particle-velocity monitoring system was applied to measure vibrations in the grotto caused by tourists, motor vehicles, and airplanes at an airport located 15 km from the site. The team also established several indices of atmospheric quality in the grotto area to monitor the level of pollution. Through international

contracts, aluminum doors donated by Sir Ran Ran Shaw of Hong Kong were installed in most of the caves. In addition, the team constructed fences, protective glass screens, and fire-detection facilities. They also installed voice-, microwave-, and magnetic-activated alarm systems and posted a dog at the northern end of the site to prevent damage and theft.

**Enhancing visitors' experience.** Due to limited space inside the caves, the fragile murals cannot withstand a substantial increase in visitors and unlimited visitation. To ease the pressure of rising tourism rates and, at the same time, to fulfill the requirements of the visitors, a program was initiated to increase the number of scenic locations at the Mogao grottoes without changing the site's original appearance. The Dunhuang Conservation Display Center, financed by the Japanese government, is one such example.

**Establishing comprehensive archives.** The conservation team established archives documenting the contents and condition of each cave, its murals, polychrome statues, and architecture by means of descriptive documents, photographs, and drawings. Periodic inspection of the grottoes is conducted to document changes. Documentation by videotape recording and surveying was also carried out. Research has begun on compiling information about the murals and the condition of the sites by use of computer-information storage systems.

**Setting up a rigorous site-management system.** Strict control has been established for various uses of the caves, including opening the caves for visitation. Rigorous systems have been formulated for site management and job descriptions; management of cave facilities; periodic site inspections; control of site sanitation, water supply, and power; registration of cave use; checkout and check-in of cave door keys; visitation rules; and tour-guide work regulations. These systems are constantly being updated and revised in the course of practice.

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## References

- Duan Xiuye  
1993 Research and control of blister damage in Cave 3 of the Mogao grottoes. *Collected Papers on Dunhuang Research* 1:286–92. Lanzhou: Gansu Minzu Chubanshe (Gansu Nationalities Publishing House).
- Dunhuang Cultural Relics Research Institution, Data Office  
1977 Index of Dunhuang documents stored at the Dunhuang Cultural Relics Research Institution. *Wenwu Ziliao Congkan*. Cultural Relics Materials Series. Beijing: Wenwu Chubanshe (Cultural Relics Publishing House).
- Fan Jinshi  
1993 Preservation and repair of the Dunhuang Mogao grottoes and their future prospects. Dunhuang Yanjiu Wenji. *Collected Papers on Dunhuang Research* 1:10–11. Lanzhou: Gansu Minzu Chubanshe.

- Guo Hong**
- 1993a Research on efflorescence damage to the wall paintings, Cave 53 of the Mogao grottoes. *Collected Papers on Dunhuang Research* 1:295–98. Lanzhou: Gansu Minzu Chubanshe.
- 1993b Research report on bedrock and plaster ground of Cave 194 of the Mogao grottoes. *Collected Papers on Dunhuang Research* 2:125–27. Lanzhou: Gansu Minzu Chubanshe.
- Li Shi**
- 1993 Initial findings on cementation materials in Dunhuang wall paintings. *Collected Papers on Dunhuang Research* 2:14–17. Lanzhou: Gansu Minzu Chubanshe.
- Li Shi and Li Yunhong**
- 1993 Experiments on aging of polyethylene glycol and polyethylene acetate emulsions illumination in special environments. *Collected Papers on Dunhuang Research* 2:206–12. Lanzhou: Gansu Minzu Chubanshe.
- Li Shi and Zhang Yongjun**
- 1993 Atmospheric monitoring in the Mogao grottoes at Dunhuang. *Collected Papers on Dunhuang Research* 1:53–55. Lanzhou: Gansu Minzu Chubanshe.
- Li Yongning**
- 1981 Dunhuang Mogao tablets and problems relating to them, 1. *Dunhuang Yanjiu* (experiments edition): 56–63.
- 1982 Dunhuang Mogao tablets and problems relating to them, 2. *Dunhuang Yanjiu* (experiments edition): 108–19.
- Li Yunhe**
- 1993a Initial study of restoration of Mogao grotto wall painting. *Collected Papers on Dunhuang Research* 2:244–46. Lanzhou: Gansu Minzu Chubanshe.
- 1993b Techniques for removing multiple layer wall paintings. *Collected Papers on Dunhuang Research* 2:255–57. Lanzhou: Gansu Minzu Chubanshe.
- Li Zuixiong**
- 1993a Effects of light and moisture on discoloration of red lead, cinnabar and hematite. *Collected Papers on Dunhuang Research* 1:295–98. Lanzhou: Gansu Minzu Chubanshe.
- 1993b Humidity is the major factor in discoloration of red lead. *Collected Papers on Dunhuang Research* 1:295–98. Lanzhou: Gansu Minzu Chubanshe.
- Ling Yuquan**
- 1993 Research on windblown sand damage to cliff tops at the Mogao grottoes of Dunhuang. *Collected Papers on Dunhuang Research* 1:134–35. Lanzhou: Gansu Minzu Chubanshe.
- Miura, S.**
- 1993 The climate of the Mogao grottoes at Dunhuang. *Collected Papers on Dunhuang Research* 1:61–63. Lanzhou: Gansu Minzu Chubanshe.
- Sun Rujian**
- 1993 Some problems in the preservation of Mogao grotto wall paintings. *Collected Papers on Dunhuang Research* 1:13–14. Lanzhou: Gansu Minzu Chubanshe.
- 1994 Review of reinforcement projects at the Mogao grottoes. *Dunhuang Yanjiu* 2:14–23.
- Xu Liye**
- 1993 Report of X-ray analysis of polychrome inorganic pigments in the wall paintings of the Mogao grottoes. *Collected Papers on Dunhuang Research* 2:23–27. Lanzhou: Gansu Minzu Chubanshe.

**Yao Zeng**

- 1993 Elastic dynamic characteristics of adjoining rock of Mogao at Dunhuang. *Collected Papers on Dunhuang Research* 1:376–80. Lanzhou: Gansu Minzu Chubanshe.

**Zhang Mingquan**

- 1993 Salt damage to Dunhuang wall paintings and its geological background. *Collected Papers on Dunhuang Research* 1:356–61. Lanzhou: Gansu Minzu Chubanshe.

**Zhang Yongjun and Wang Baoyi**

- 1993 Analysis of experiments on the impact of visitors on cave environments. *Collected Papers on Dunhuang Research* 1:34–38. Lanzhou: Gansu Minzu Chubanshe.

**Zhao Zhengzhi**

- 1955 Dunhuang grottoes survey report. *Wenwu Cankao Ziliao* (Cultural Relics Reference Materials) 2.

**Zhou Zhonghua**

- 1993 Elastic wave tests of adjoining rock in the Dunhuang grotto group. *Collected Papers on Dunhuang Research* 1:368–73. Lanzhou: Gansu Minzu Chubanshe.

# Projects of the Getty Conservation Institute and the State Bureau of Cultural Relics

## The Mogao and Yungang Grottoes

*Neville Agnew and Huang Kezhong*

THE GETTY CONSERVATION INSTITUTE'S China projects, initiated formally in 1989, are a collaboration between the Getty Conservation Institute (GCI) and the State Bureau of Cultural Relics (SBCR) of the People's Republic of China, based in Beijing. These multi-faceted projects involve conservation activities, research, and training at two important ancient Buddhist sites: the Mogao grottoes, a World Heritage Site in Gansu Province; and the Yungang grottoes in Shanxi Province.

The Getty Conservation Institute and the State Bureau of Cultural Relics of the People's Republic of China's Ministry of Culture first began exploring the possibility of collaboration in 1986. In May 1988, at the invitation of the SBCR, Luis Monreal, then director of the GCI; and Miguel Angel Corzo, then GCI Special Projects director, made a preliminary visit to China, at which time the Mogao and Yungang grottoes were identified as possible sites for a joint conservation project. In September of that year, a joint team was formed to examine the sites and their problems and discuss the objectives and specifics of a conservation program. The team consisted of representatives from the GCI—Monreal; Frank Preusser, then director of the Scientific Program; and Neville Agnew, then deputy director of the Scientific Program—joined by Huang Kezhong, then chief of grottoes in the SBCR, and site representatives Xie Tingfan of Yungang and Fan Jinshi, Li Zuixiong, and Li Yunhe of Mogao.

The United Nations Educational, Scientific, and Cultural Organization (UNESCO), within the scope of the World Heritage Convention and as the relevant international organization, supported the initial establishment of the collaboration through H. Leo Teller, UNESCO's representative in China. The result of the 1988 discussions was an agreement, signed in January 1989, to begin a three-phase conservation project, the first phase to take place over a period of eighteen months and the others to follow for one year each. The project work began formally at the end of 1990.

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### Project Objectives

The essential elements of the collaboration and design of the project were discussed in 1988 during visits to Mogao and Yungang, then later refined and set forth in the formal agreement. These included:



1. assessing and studying causes and mechanisms of deterioration of the sites due to climate, environment and pollution, and geological and hydrological factors;
2. jointly undertaking site interventions based on studies, particularly those that would address generic problems in China;
3. providing technical and scientific assistance and advice to the State Bureau of Cultural Relics and staff at the two sites;
4. providing conservation-related technical training to staff in a number of areas of need; and
5. disseminating information on conservation through publications and an international conference, to be held in China, on grotto conservation and management.

The Getty Conservation Institute's decision to be involved in significant interventions at Mogao and Yungang was based on evidence that much of the deterioration at the sites was so severe as to degrade the quality of the historic art and, in some places, fundamentally threaten the sites. Emphasis on scientific studies and technical assistance was therefore focused on the most pressing needs of the sites.

That decision still stands today and is fully endorsed by the SBCR and staff at the two sites. Until now, interventions of several kinds and technical training have been the thrust of the effort. With the site management training course held at Yungang in October 1992, the fourth of the five elements listed here was addressed, and the 1993 conference at Mogao fulfilled the last objective.

The collaboration has been exemplary, both at the institutional level (the SBCR was the overall authority, with the Dunhuang Academy and the Yungang Custody Committee as site partners) and the personal level. The agreement with the SBCR secured support for GCI travel and accommodations while in China. The labor, materials, skills, and staff contribution at the two sites have been no less impressive. The GCI provided specialist skills and technical and scientific advice where needed, as well as instrumentation and materials unavailable in China.

The SBCR successfully tapped a number of state and provincial organizations for support: the Institute for Desert Research of the Academia Sinica, based in Lanzhou, undertook studies for sand control at Mogao; the Datong Environmental Protection Agency participated in pollution monitoring at Yungang; the Architectural Division of the China National Institute of Cultural Property designed temple facades for several grottoes at Yungang in connection with site presentation and pollution mitigation initiatives; and the Shanxi Province Geophysical Institute provided geological and hydrological information at Yungang.

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## Work Completed

The following summarizes activities at the two sites until the end of 1993. (Elsewhere in these proceedings, descriptions of certain component projects of the collaboration are presented in greater detail.)

## Mogao

The following activities have taken place at the Mogao grottoes:

- constructing a synthetic-fabric wind fence, approximately 3.5 km long, to control sand;
- establishing a vegetation fence, using local desert-adapted plants with drip irrigation, to provide a long-term solution to sand migration;
- installing a solar-powered, autonomous meteorological and environmental monitoring station and two cave monitoring stations to record microclimate and assess the effects of visitors on the atmosphere within the monitored caves;
- undertaking color monitoring, along with technical training, to provide information on the pigment color stability of wall paintings;
- undertaking measurement and monitoring of cracks and fissures, with technical training, to address questions of geological stability of the cliff;
- providing dust monitoring within selected caves to relate the effectiveness of the wind fences and dust filters on the doors of the grottoes;
- undertaking analysis of environmental monitoring data and providing training in computing and data reduction to help the Dunhuang Academy staff develop independence in scientific monitoring; and
- performing various preliminary tests and installations, including filters and sweeps on doors for dust control; thin-roofed cave reinforcement using lightweight, synthetic geotextiles; tests on sand and rock stabilization for the cliff slope to address erosion; consultation on grouting technology and materials to stabilize the cliff; and engineering consultancy and advice in relation to the cliff face stability.

## Yungang

The following activities have taken place at Yungang:

- intensive monitoring of pollutants and particulates, initially over one month, with training in the use of equipment for additional sampling by Yungang staff over a twelve-month period;
- installing an environmental monitoring station and providing preliminary training in equipment handling, maintenance, and data reduction;
- conducting a geophysical and soil-depth study of the cliff top and Ming dynasty fort area, and introducing neutron probe and dielectric probe instrumentation for moisture monitoring in the cliff rock;

- providing engineering consultancy and advice in relation to moisture seepage and monitoring;
- developing plans for control of water infiltration and seepage into the geological strata of the cliff, using information provided in part by the provincial geophysical institute;
- conducting a preliminary design study for the pagoda facade at Cave 19 in conjunction with architects from the China National Institute of Cultural Property;
- conducting a one-year study of the pigments and binding media of the polychromy in Cave 6;
- providing a formal, two-week-long training course for site managers from other sites in China in October 1992; and
- installing two drainage test areas, each 50 × 50 m above the grottoes, using modern geosynthetic drainage materials to function with existing open-channel surface drains.

By the end of 1993, the collaboration had achieved

- solutions to some of the major problems afflicting the sites, or had demonstrated how these may be solved and what is required to do so;
- training in a number of scientific and technical areas, and in the management of sites;
- enhanced self-sufficiency in site conservation in China;
- furthering of the scientific study and understanding of the conservation of outdoor sites generally; and
- dissemination of the knowledge through publications and the 1993 conference.

### **The 1993 conference**

The international conference on the conservation of grotto sites, Conservation of Ancient Sites on the Silk Road, held in Dunhuang 3–8 October 1993, was attended by some two hundred delegates from thirty countries worldwide. With more than sixty papers presented on art history, science, management, and conservation techniques, the conference was a signal event in bringing together East and West for the benefit of the cultural heritage of China and beyond.

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### **Formal Evaluation of the Collaboration Project**

Evaluation of the collaboration between the GCI and the SBCR was envisaged from the beginning to be essential to the project. The purpose of the evaluation was, as with all such assessments, to learn from past experience to be able to improve on possible future undertakings. The evaluation team comprised three independent evaluators chosen by the GCI and three independent evaluators from within China. Their charge was to visit the sites, interview the project staff, and assess the overall projects in terms of

design, implementation, results, and areas for improvement. Specifically, the evaluators were asked not to judge the performance of individuals or project teams but rather to assess the overall aspects of the project that were relevant to the attainment of common objectives.

Preliminary meetings were held in China and in the United States, to brief the evaluators on their objectives and to work out the logistics of the two-week trip to the sites of Mogao and Yungang, with wrap-up meetings in Beijing.

The evaluation trip occurred in July 1994. Allowing time for report writing, and translations from English into Chinese and vice versa of the independent reports of the GCI and the SBCR, the final meetings were held in Los Angeles in June 1995. These were attended by directors from the GCI and the SBCR and project leaders, as well as certain evaluators.

The results of the evaluation process were most useful to both sides in that they established a methodology for evaluation of collaborative projects of this type, examined the project design and objectives, addressed the implementation of the project, and evaluated the results achieved and their effectiveness.

The findings of the joint evaluation overall were favorable in each of the categories of evaluation, while identifying certain weaknesses of logistics, coordination, duration of campaigns, and sustainability that need to be addressed in any future collaborative undertakings.

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### **Future Collaboration between the GCI and the SBCR**

Following the evaluation and the subsequent meetings in China in late 1995, the parties concerned are in the process of discussing future needs in conservation of the cultural heritage in China. During 1996, implementation of this work will have begun, building on the solid base of collaboration and friendship established in previous years of work by the Getty Conservation Institute and the State Bureau of Cultural Relics in the People's Republic of China.