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A Summary of Practices in the Conservation and Management of the Zhoukoudian Site in the New Era

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Abstract: The Zhoukoudian Site, a UNESCO World Heritage property, faces dual threats from natural weathering and historical legacies. In recent years, its conservation management model has undergone a strategic shift—moving away from singular emergency reinforcement toward "preventive conservation." By establishing a round-the-clock monitoring and early warning system, constructing a protective shelter over the Peking Man Cave, implementing 3D digital archiving, and restoring the surrounding ecosystem, the physical integrity of the site has been effectively safeguarded. Furthermore, supported by legal frameworks and the development of a new museum complex, the site has achieved an integrated approach to scientific research, education, and cultural tourism. Looking ahead, sustained efforts in securing continuous funding, relocating residents, and deepening technological applications remain essential to ensuring the sustainable preservation of this heritage.

Keywords: Zhoukoudian, UNESCO, Preventive conservation.

1. Introduction

The Zhoukoudian Site is a world-famous cultural site and a World Cultural Heritage site. Among contemporaneous Paleolithic sites worldwide, it possesses the richest content, the most complete materials, and the highest scientific research value. Its discovery is not only a rare piece of evidence concerning prehistoric human society on the Asian continent but also illuminates the process of human evolution.

Located in Zhoukoudian Town, Fangshan District, Beijing, approximately 50 kilometers from the city center, the site has yielded 27 localities containing various fossils and cultural relics from different periods since the start of large-scale excavations in 1927. It serves as a comprehensive, multidisciplinary research base for paleoanthropology, archaeology, paleontology, stratigraphy, chronology, environmental science, and karst studies.

In 1961, the Zhoukoudian Site was designated as a Major Historical and Cultural Site Protected at the National Level by the State Council. In 1987, it was inscribed on the World Heritage List by UNESCO. In 1992, it was awarded the title of "Youth Science Popularization Education Base" by the Beijing Municipal Government. In 1997, it was granted the title of "National Patriotic Education Demonstration Base" by the Publicity Department of the CPC Central Committee. In 2005, it was rated as a National 4A Tourist Attraction by the National Tourism Administration. In 2008 and 2010, it was successively evaluated as a National First-Class Museum and a National Archaeological Site Park by the National Cultural Heritage Administration. In 2011, it was awarded the title of "World Heritage Youth Education Base" by the UNESCO Asia-Pacific World Heritage Training and Research Centre. In 2012, it was honored as a "National Science Popularization Education Base" by the China Association for Science and Technology. It is one of the eight major parks of the China (Fangshan) World Geopark. [1]

2. Damage and Losses Suffered by the Zhoukoudian Site

(1) Damage Caused by Natural Factors

Since its discovery and excavation, the Zhoukoudian Site has long remained exposed to the elements, suffering from prolonged sun exposure, rainfall, wind erosion, and other natural forces. This has led to varying degrees of erosion, cracking, and structural loosening in some areas. The "Peking Man Cave" has been particularly severely affected by natural factors, with the geological strata of its rock walls suffering significant weathering. The damage caused by these natural factors has not only affected the appearance of the site but, more importantly, poses a threat to the safety of the precious fossils within, potentially leading to their loss or damage. [2]

(2) Damage Caused by Human Factors

Since its discovery, the Zhoukoudian Site has suffered damage due to human activities. Historically, especially during the Second World War, the invaluable "Peking Man" skull fossils unearthed from the site mysteriously went missing and remain unaccounted for to this day. This incident represents not only a profound loss to the field of archaeology but also a significant regret for the cultural heritage of the Chinese nation. Furthermore, with the ongoing development and population growth in the surrounding areas, environmental pollution near the site has intensified; phenomena such as acid rain pose latent threats to the site's preservation. Illegal excavation and looting have also inflicted a certain degree of damage upon the site in the past.

(3) Academic Research Implications and Economic Losses

The loss or damage of cultural relics signifies the absence of scientific research materials, inflicting immeasurable losses on the field of academic research. For a key tourist destination like the Zhoukoudian Site, damage to the site will directly impact the development of local tourism, thereby affecting economic revenue.

3. Conservation of the Zhoukoudian Site

(1) Conservation of the Zhoukoudian Site Fabric

In 1994, renovations were carried out on the Peking Man Cave and Locality 15. Weeds, shrubs, and trees that had grown on the four walls and floor of the Peking Man Cave for over half a century were cleared, the cave floor was leveled,

guardrails were repaired, and drainage systems were improved. Surface weeds and shrubs at Locality 15 were removed, and the unexcavated deposits were sorted in a protective manner. Since the signing of the co-construction agreement between Beijing Municipality and the Chinese Academy of Sciences in 2002, polluting enterprises around the site have been demolished or closed. In March 2004, the Zhoukoudian Site Administrative Office hired Deputy Director Gao Xing and Researcher Huang Wanbo as consultants, established a 27-member fossil locality survey team, and launched a comprehensive investigation. Detailed surveys were conducted on the current condition, coordinates, altitude, and other aspects of each fossil locality, and comprehensive records were documented.

In the same year, the Zhoukoudian Site Administrative Office commissioned the Liaoning Nonferrous Metals Geological Exploration Institute to design emergency reinforcement measures, which were approved and funded by the Beijing Municipal Administration of Cultural Heritage. Reinforcement work primarily targeted unstable rock and soil masses at six locations (Gezitang, Ash Layer of the Peking Man Cave, Roof Accumulation, Locality 3, Locality 12, and Locality 4). In 2005, key reinforcement efforts focused on the southern and northern walls of the Peking Man Cave, the southern vertical wall of Locality 3, and the entrance and ceiling of Locality 4. From 2009 to 2011, the Beijing Municipal Administration of Cultural Heritage organized a three-year large-scale field investigation and research project, conducting detailed geological surveys and mapping of the site's fossil localities. This survey documented the specific locations, geological features, and preservation conditions of over ten fossil localities, providing a scientific basis for subsequent conservation measures. In 2013, based on the survey results, detailed reinforcement and protection plans were formulated. For example, geological hazard mitigation was carried out at Locality 1 (Peking Man Cave), using methods such as anchoring and grouting to reinforce the rock mass and prevent weathering and collapse. At Locality 4 (Upper Cave), cracks were repaired and surface sealing was applied to prevent rainwater erosion. In 2018, a technologically advanced protective shelter was constructed over the "Peking Man Cave," covering an area of over 3,700 square meters, effectively reducing the impact of natural factors on the site.[3]

(2) Construction of the Protective Shelter over the Peking Man Cave

In 2015, the Zhoukoudian Site launched the construction project of the protective shelter for Locality 1 (Peking Man Cave), led by the Beijing Municipal Administration of Cultural Heritage, designed by the Architectural Design and Research Institute of Tsinghua University, and jointly participated in by multiple scientific research institutions and enterprises. The protective shelter adopts a large-span curved shell steel structure, covering an area of over 3,700 square meters, with a height exceeding 20 meters, capable of fully covering the Peking Man Cave and its surrounding areas. Ventilation and temperature control systems are installed inside the shelter to ensure the stability of the site environment. Meanwhile, the exterior of the shelter has been aesthetically treated to blend seamlessly with the surrounding natural landscape.

The design of the protective shelter adheres to two core principles. The first is the minimum intervention conservation strategy, which involves protecting only the minimum necessary area and height required for the site's preservation, avoiding unnecessary disturbance to the heritage itself. The second is the design approach of adapting to the existing terrain, skillfully integrating the shelter with the current topography so that the new structure harmonizes with the surrounding mountain environment. The shelter employs a vegetated roof system and a double-layer blade system (inner and outer layers) to meet requirements for drainage, lighting, and ventilation. Rainwater is discharged through the blades layer by layer—part flows into hidden rainwater ditches and drainage channels, while the remainder is directed to eaves gutters. The shelter's external surface is designed as a vegetated roof, planned to achieve full coverage within two years, further blending it with the environment. To enrich the presentation of the site, the project also incorporates digital virtual technologies such as sound, light, electricity, and VR, enhancing the spatial, technological, and interactive qualities of the site's exhibition.

The project underwent seven years of feasibility studies and three years of construction, receiving recognition through multiple awards. The protective shelter employs contemporary design techniques to reshape the overall spatial structure of the site environment, while utilizing high-tech digital means to present the site's ecological and cultural information. The design not only provides an optimal environmental and spatial atmosphere for researching and observing the Peking Man Cave but also ensures the sustainable development of this historical and cultural resource. During the formulation of the design scheme, relevant work including geotechnical engineering investigations, topographical surveying and mapping, and wind tunnel testing was conducted. Expert meetings were convened to deliberate on the conservation architecture, with in-depth discussions covering the interior and exterior landscape effects of the protective structure, foundation positioning and geotechnical surveys, structural design of the shelter, seismic performance design, and structural stability design. Ultimately, the completed protective shelter was officially opened to the public in 2018.

(3) Establishment of the Monitoring System for the Zhoukoudian Site

Since 2012, the Zhoukoudian Site Administrative Office has established a monitoring center, installing various sensors and monitoring devices to achieve 24-hour real-time surveillance of the site's environmental conditions. The monitoring content includes temperature, humidity, light, soil moisture, rock displacement, etc. In 2018, the early warning and monitoring system was further refined with the addition of high-definition cameras and drone inspection equipment, improving the accuracy and coverage of data collection. Simultaneously, monitoring data analysis software was developed, capable of automatically identifying anomalies and issuing alerts.

This system focuses on monitoring indicators such as rock mass stability, microenvironment, atmospheric environment, and vibration within the core area of the site, specifically targeting three key hominin fossil localities. It encompasses front-end data collection, information transmission, and the construction of a central server room, and has completed the development of modules for both heritage fabric monitoring and environmental monitoring. Additionally, a software system platform was developed, including the establishment of a software framework, real-time display of monitoring data based on maps, and modules for displaying the operational

status of monitoring equipment. These measures will help safeguard the cultural heritage value of the Zhoukoudian Site.

The system integrates both automatic monitoring equipment and manual monitoring methods, enabling round-the-clock, 24-hour uninterrupted real-time dynamic data collection and permanent storage regarding stability, surface subsidence, water accumulation, microenvironment, and other aspects. At the same time, scientific research has been strengthened, with comparative analysis of monitoring data conducted to ensure that the annual routine monitoring analysis reports are compiled in a more scientific and reliable manner. Furthermore, the system allows for flexible comparative analysis of collected monitoring data and simple descriptive statistical analysis, permitting administrators to download raw monitoring data and various analytical charts in flexible and secure ways.

Through the establishment of the monitoring and early warning system, issues such as data errors and the preservation of paper documents in existing monitoring work can be resolved, while also facilitating more comprehensive research. Moreover, the monitoring system not only oversees the heritage fabric itself but also includes the daily management activities of the heritage management or user units, thereby comprehensively enhancing the level of heritage protection and management. Therefore, the construction of a cultural heritage monitoring and early warning system is a crucial pathway to advancing heritage protection and management capabilities.

(4) Ecological Restoration of the Zhoukoudian Site

In 2012, Mr. Yang Haifeng, Director of the Site Administrative Office, put forward three requirements: First, public service facilities must be people-oriented. The design of the visitor walkways should integrate scientific rigor with rational planning to provide convenient access for audiences. Second, the design should highlight naturalness. Vegetation along the walkways and protective fences should blend harmoniously with the site's natural environment. Third, enhance coordination. Landscape design should emphasize a human-centric philosophy and remain consistent with the site's surroundings.

The environmental remediation project around the site was launched in 2012. Polluting industrial and mining enterprises within the protected area—such as cement plants, shaft kiln production lines, and coal mines—were gradually dismantled. Garbage and waste were cleared, and the natural landforms were restored.

To date, the natural ecological restoration project has continued to progress, with a large number of native plants introduced to increase the green coverage rate. Simultaneously, soil and water conservation efforts have been strengthened through the construction of drainage ditches and retaining walls to prevent soil erosion. Service facilities within the site, including signage, interpretation boards, and visitor walkways, have been upgraded and renovated to create a comfortable, safe, and well-serviced visiting environment. [4]

(5) Digital Conservation of the Zhoukoudian Site

In 2019, the Zhoukoudian Peking Man Site launched a comprehensive 3D digital mapping project. The project team employed advanced technologies and equipment such as laser scanning and photogrammetry to conduct omni-directional, high-precision 3D scanning and modeling of the site.

In 2020, the construction of the digital conservation system was completed, and a 3D digital archive of the site was established. The archive contains multi-source information including 3D models, high-definition images, and geological data, enabling virtual exhibitions and scientific research.

In 2023, an immersive exhibition showcasing the achievements of 3D digital conservation was launched, utilizing virtual reality technology to guide the public through experiences of 3D digitization and AI reconstruction—traveling back 500,000 years to listen to nature, touch history, and engage in dialogue with antiquity.

4. Cultural Presentation and Dissemination of the Zhoukoudian Site

The administrative authorities of the Zhoukoudian Peking Man Site have actively collaborated with universities to carry out science popularization education and external publicity initiatives, such as establishing teaching practice bases and producing the journal Peking Man.

Since 2012, the site has utilized modern technological means such as sound, light, and electricity to enhance the exhibition experience at the site museum. For instance, through virtual reality technology, visitors can experience the sensation of "entering" the Peking Man Cave within the museum. Interactive touch screens allow visitors to gain detailed insights into the background knowledge and research findings related to the site.

In 2018, a series of cultural events and exhibitions were launched, including the "Peking Man Culture Week" and "Paleoanthropology Science Lectures," attracting a large number of students and members of the public. Concurrently, the site's cultural value was widely promoted through social media and online platforms, expanding its social influence.

In 2023, the comprehensive construction of the Zhoukoudian National Archaeological Site Park was officially launched. With the Zhoukoudian Peking Man Site, the Jin Mausoleum, and the Shizi Temple Site as foundational elements, the project aims to develop the Zhoukoudian "Origin of Humanity" Cultural Park, further elevating the site's capacity for cultural presentation and dissemination.[5]

5. Legal Safeguards for the Zhoukoudian Site

1. Measures for the Protection and Administration of the Zhoukoudian Site: This is the primary regulatory document. It was issued by the Beijing Municipal People's Government on April 29, 2009, and came into effect on June 1, 2009. The Measures detail specific provisions for the protection and management of the Zhoukoudian Site, including the delineation of the protected area and construction control zones, the allocation of protection and management responsibilities, specific protection requirements, prohibited activities, and corresponding legal liabilities.

2. Law of the People's Republic of China on the Protection of Cultural Relics: As a national law, it provides the fundamental principles and legal basis for cultural heritage sites at all levels nationwide, including the Zhoukoudian Site.

3. Regulations of Beijing Municipality on the Administration of Cultural Relics Protection: This local regulation further refines the implementation rules of the national Law on the Protection of Cultural Relics within the Beijing area, setting more specific requirements for cultural heritage sites in Beijing, including the Zhoukoudian Site.

4. Measures for the Protection and Administration of Paleoanthropological Fossils and Vertebrate Fossils: Although this document primarily targets the protection and management of paleoanthropological and vertebrate fossils, it is applicable to the Zhoukoudian Site given the site's abundant presence of such fossils.

6. Relocation of the Zhoukoudian Site Museum and Delineation of Protection Scope

At the end of 2003, the Zhoukoudian Site Administrative Office commissioned the China Cultural Heritage Research Institute and other institutions to commence the compilation of the Master Plan for the Conservation of the Zhoukoudian Peking Man Site.

In 2005, the Master Plan for the Conservation of the Zhoukoudian Peking Man Site was officially approved by the National Cultural Heritage Administration, covering the planning period from 2005 to 2020. The plan explicitly delineated the protected area and the construction control zone.

In 2008, in accordance with the plan, the Zhoukoudian Site Museum was relocated out of the protected area and reconstructed near the original site. The new museum expanded its floor area to approximately 8,000 square meters, with the exhibition space increasing to over 3,000 square meters. Its functions were enhanced to include exhibition areas, research laboratories, multimedia classrooms, and more.

In 2023, the Beijing Municipal Administration of Cultural Heritage released the Conservation Plan for the Zhoukoudian Site (2021–2035), further expanding the scope of protection. The plan identifies 24 paleontological and archaeological localities and incorporates the site's environment—specifically the "Four Hills and One River" (i.e., Dragon Bone Hill, Fish Ridge, Chicken Bone Hill, Taiping Hill, and the Zhoukoudian River)—as well as all categories of excavated artifacts, historical and cultural relics, and significant archival documents into the comprehensive protection framework.

7. Conclusion

The conservation and management of the Zhoukoudian Site has achieved remarkable results in multiple aspects, including the improvement of legal safeguards and policy support, the relocation of the museum and clarification of protection boundaries, as well as the development of in-situ conservation and monitoring systems. These measures have effectively mitigated the damage caused by natural factors to the site. Furthermore, the implementation of ecological restoration and safety precautions has improved the overall environment and enhanced security. The construction of the protective shelter over the Peking Man Cave and digital conservation efforts have also provided technological support for the long-term preservation of the site. Meanwhile, through cultural presentation and dissemination activities, public awareness and interest in the site have been significantly increased. However, the protection of the site still faces several challenges, such as insufficient funding leading to slow progress in some conservation projects, a need for stronger technological innovation and professional talent cultivation due to inadequate application of new technologies, and the necessity to further raise public awareness of protection. Additionally, the relocation of residents within the protected area and environmental remediation have not been fully completed, requiring continued efforts.

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