

Research on the Collaborative Model of Fossil Resources Protection and Tourism Development of the Jehol Biota

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Abstract: The fossil resources of the Jehol Biota, as non-renewable natural heritage, their protection and rational development and utilization are of great significance for scientific research and local economic development. Based on the current situation of fossil resources of the Jehol Biota, this paper analyzes the contradiction between protection and tourism development, and proposes a model and strategy for coordinated development. Through measures such as establishing a fossil resource protection system, innovating tourism development models, strengthening scientific and technological support and popular science education, and improving the policy and legal system, a positive interaction between fossil resource protection and tourism development can be achieved, promoting the sustainable development of the local economy and cultural inheritance.

Keywords: Jehol Biota; Fossil Resources; Protection; Tourism Development; Collaborative Model.

1. Introduction

1.1 Research Background

Fossil resources, as the "time capsules" of the Earth's history, are not only the core materials of paleontological research, but also an important component of geological relics and natural heritage [1]. In recent years, with the rise of global ecotourism, fossil sites have gradually become important destinations for science education and cultural experience [2]. However, the excessive development of tourism activities may lead to the physical damage of fossil resources, microbial erosion and the decline in the quality of tourists' experience [3]. For instance, Jehol Biota, as one of the most renowned Early Cretaceous fossil groups in China and even globally, its abundant fossil

resources of birds, dinosaurs and plants have attracted a large number of tourists [4], but it also faces the contradiction between protection and utilization [5]. How to ensure the scientific value of fossil resources while achieving the sustainable development of tourism has become an urgent problem to be solved.

1.2 Research Status at Home and Abroad

Most of the traditional fossil resource management models focus on single protection or development, lacking systematic integration [6]. In recent years, scholars have begun to advocate the concept of "synergy between protection and utilization", advocating achieving a win-win situation through stakeholder participation, policy innovation and technological empowerment [7]. For instance, the community-based tourism practices carried out in the Beijing-Tianjin-Hebei region have shown that the active management of local residents can effectively reduce the illegal mining of fossils and enhance the tourist experience. China has introduced regulations such as the "Regulations on the Protection of Paleontological Fossils", but there are still deficiencies in local enforcement and cross-regional collaboration [8]. International comparative studies [9] show that Mongolia has achieved remarkable results in cross-border fossil resource management through cooperation projects with the European Union under the "Paleontological Fossil Protection Law", providing a reference for China. The application of digital technologies (such as 3D scanning and virtual reality) in fossil protection and display has gradually become widespread [10]. The management model based on the ecosystem combined with digital technologies can effectively reduce the direct interference of tourist flow to the fossil layer.

2. The Current Situation of Fossil Resources of the Jehol Biota

The Jehol biota, as one of the most abundant and unique biological communities on Earth during the late Mesozoic Era (about 130 to 120 million years ago), not only holds an important position in global paleontological research in terms of fossil resources, but also serves as a key clue for revealing the evolution of Mesozoic organisms, the structure of ecosystems, and the changes in ancient environments. This chapter will elaborate in detail on the current situation of fossil resources in the Jehol Biota from three aspects: the diversity of fossil species, the quality and integrity of preservation, and the current status of research and utilization.

2.1 Fossil Species Diversity: a Microscopic Museum of Biological Evolution

The rich variety of fossils in the Jehol biota can be regarded as a "microscopic museum of biological evolution". Here, not only are there a large number of fossils of primitive birds, feathered dinosaurs, early mammals and other vertebrates preserved, but also a rich variety of invertebrate (such as insects and crustaceans) and plant (such as ferns and gymnosperms) fossils are included. Among them, the fossils of primitive birds are particularly remarkable, such as *Confuciusornis* and *Sinosauropteryx*. Their discovery provides direct evidence for the origin and early evolution of birds. In addition, the discovery of feathered dinosaur fossils, such as those of the *Beipiaosaurus* and *Microraptor*, further confirms the significant role of feathers in the evolution from dinosaurs to birds, challenging the traditional understanding of the origin of birds.

2.2 Preservation Quality and Integrity: a Wonder of Nature

The reason why the fossils of the Jehol biota have extremely high scientific research value is largely attributed to their excellent preservation quality and integrity. Thanks to the special sedimentary environment at that time - lakes, rivers and volcanic ash covers, these fossils are often preserved in a three-dimensional form, and even soft tissue structures (such as feathers and skin traces) are retained, which is extremely rare in the fossil record. This preservation condition enables scientists to observe in detail the morphological characteristics, behavioral habits and even ecological niches of organisms, providing intuitive evidence for the reconstruction of the Mesozoic ecosystem. For

example, by analyzing the mouthpart structure of insect fossils, one can infer their dietary preferences. From the arrangement of scales in fish fossils, one can catch a glimpse of the flow characteristics of the aquatic environment.

2.3 Research and Utilization Status: the Leap from Exploration to Application

With the advancement of science and technology, the study of Jehol biota fossils has shifted from simple morphological description to interdisciplinary research such as molecular biology and paleoecology. The application of high-resolution CT scanning technology, isotope analysis and other methods enables scientists to deeply explore the microstructure, biochemical components and paleoenvironmental information inside fossils. Meanwhile, these fossil resources have also promoted the development of science popularization and education, becoming an important window for the public to understand the history of the Earth and the evolution of life. At the application level, the research achievements of the Jehol biota fossils not only enrich paleontological theories but also provide historical references for modern biodiversity conservation and ecological restoration. In addition, the rational development and utilization of fossil resources, such as the production of fossil replicas and popular science exhibitions, have also brought new growth points to the local economy.

3. Analysis of the Contradiction between Fossil Resource Protection and Tourism Development

The fossil resources of the Jehol biota, as a precious natural heritage, not only carry significant scientific research value but also contain huge potential for tourism development. However, there are often many irreconcilable contradictions between the protection of fossil resources and tourism development. This chapter will deeply analyze the specific manifestations and causes of these contradictions from two aspects: the goal conflicts between protection and development, and the practical predicaments between management and utilization.

3.1 Conflict between Protection and Development Goals: the Game between Scientific Value and Economic Interests

The goal of protecting fossil resources is to ensure the long-term preservation and

inheritance of their scientific value. It requires the adoption of strict protection measures, limiting human interference, and preventing physical damage and biological erosion of fossils. For instance, many fossils in the Jehol biota preserve exquisite feather structures or soft tissue traces, which are crucial for the study of biological evolution and cannot be restored once damaged. However, tourism development focuses on maximizing economic and social benefits, pursuing an increase in the number of tourists and an improvement in the tourism experience. To attract tourists, some fossil sites may be overdeveloped, large-scale tourism facilities may be built, and even tourists may be allowed to have direct contact with the fossils. These behaviors undoubtedly pose a potential threat to fossil resources.

The root cause of this kind of goal conflict lies in the diversified cognitive differences of resource values. Protectors emphasize the scientific non-renewability of fossils and advocate restricting their development. While developers pay more attention to the actual demands of the tourism market and tend to focus on the efficient utilization of resources. The differences between the two sides in goal setting lead to the difficulty in coordinating protection and development policies, often falling into the dilemma of "excessive protection leads to insufficient development, and excessive development leads to the failure of protection".

3.2 Practical Predicaments in Management and Utilization: the Dual Constraints of Institutional Deficiency and Ineffective Enforcement

At the management level, the contradiction between the protection of fossil resources and tourism development is manifested as the imperfection of the institutional system and the weakness of the implementation ability. Although China has issued regulations such as the "Regulations on the Protection of Paleontological Fossils", when it comes to regional fossil resources like the Jehol Biota, there are still problems such as lagging protection planning, unclear rights and responsibilities of management institutions, and the lack of cross-regional collaboration mechanisms. For instance, the Jehol biota is widely distributed and involves multiple administrative regions. There are differences in conservation standards and development policies

among different regions, resulting in fragmented resource management and making it difficult to form a synergy.

At the utilization level, the limitations of technical means and the blindness of market orientation have further exacerbated the contradiction. On the one hand, although digital technologies (such as 3D scanning and virtual reality) can reduce tourists' direct contact with fossils to a certain extent, their popularity and application effects are still limited by capital investment and talent reserves. On the other hand, the excessive pursuit of "fossil wonders" in the tourism market may give rise to low-quality and homogeneous tourism products, neglecting the in-depth exploration and scientific dissemination of the cultural connotations of fossils. If this continues, it will undermine the long-term appeal of fossil resources.

4. Construction of a Collaborative Model for Fossil Resource Protection and Tourism Development

The fossil resources of the Jehu Biota, as non-renewable natural heritage, the coordinated development between their protection and tourism development is the key path to achieving sustainable utilization of resources. This chapter will construct a collaborative model of fossil resource protection and tourism development from four dimensions: collaborative concept, institutional framework, technological application and community participation, aiming to balance the relationship between scientific protection and rational development and promote the harmonious coexistence of regional ecology, economy and culture.

4.1 Collaborative Concept: a Shift in Thinking from Opposition to Integration

Under the traditional model, the protection of fossil resources and tourism development are often regarded as opposing goals, resulting in a dilemma of "either-or" in policy-making and implementation. However, the core of the collaborative model lies in establishing the concept of "development while protecting and protection while developing", deeply integrating the scientific value, ecological functions and tourism experiences of fossil resources. This concept requires managers to go beyond a single perspective and re-examine the relationship between protection and development from the comprehensive benefits of ecosystem services,

cultural heritage inheritance and social and economic development. For instance, by designing eco-friendly tourism routes, tourists can appreciate the fossil wonders while understanding their scientific significance and ecological value. The education on the protection of fossil resources can be integrated into the tourism experience, enabling tourists to enhance their protection awareness imperceptibly and achieve the goal of "education through tourism". This will change the short-sighted behavior of merely pursuing tourism economic benefits while neglecting resource protection in the past. Unify protection and development at the conceptual level to lay an ideological foundation for subsequent practical operations.

4.2 Institutional Framework: Cross-regional Collaboration and Benefit-Sharing Mechanism

Institutional innovation is the guarantee for the implementation of the collaborative model. In view of the wide distribution range and diverse management subjects of the Jehol biota, it is necessary to construct a cross-regional collaborative management framework. This framework should first be led by the national or provincial level to formulate an overall plan for the protection and tourism development of the fossil resources of the Jehol biota, clearly defining the protection red line, development intensity and regional functional positioning, to avoid disorderly competition and redundant construction in different regions due to the lack of unified planning. At the same time, a benefit-sharing and compensation mechanism should be established. Through tax rebates, ecological compensation and other means, the protection costs and development benefits should be balanced to safeguard the rights and interests of local communities and indigenous people and enhance their enthusiasm for participating in protection. In addition, a collaborative cooperation platform among the government, research institutions, enterprises and communities should be established to form a closed-loop management of "research - protection - development - feedback", enabling all parties to closely collaborate in information sharing, decision-making, project implementation and other links, enhancing the scientific nature and execution efficiency of decision-making, and ensuring that the

protection of fossil resources and tourism development are effectively guaranteed at the institutional level.

4.3 Technology Application: Digital Empowerment and Intelligent Management

Digital technology provides innovative tools for the synergy between fossil resource conservation and tourism development. In terms of digital protection, the use of high-precision 3D scanning, virtual reality (VR) and other technologies to record and display fossils in a non-contact manner not only enables researchers to study the details of fossils more comprehensively and accurately, but also reduces the potential damage to fossils caused by direct contact with tourists. In the construction of the smart tourism system, a tourist flow monitoring and early warning system based on big data should be developed to grasp the number and distribution of tourists in real time, dynamically regulate the number of tourists and their behavior paths, reduce the pressure on the fossil environment, and avoid damage to the fossils caused by excessive concentration of tourists. At the same time, an integrated online and offline science popularization and education platform should be built. Through AR interaction, immersive exhibitions and other forms, the scientific knowledge of fossil resources should be presented to the public in a vivid and interesting way, enhancing the public's understanding and protection awareness of fossil resources. Digital technology should become a bridge connecting the protection of fossil resources and tourism development, achieving a win-win situation for protection and development.

4.4 Community Engagement: the Role Transformation from Bystanders to Guardians

The community is a key stakeholder in the synergy between fossil resource conservation and tourism development. Under the traditional model, communities are often excluded from decision-making, resulting in the difficulty for the achievement of protection and development to benefit local areas. The collaborative model emphasizes the dominant position of the community. By conducting skills training in areas such as fossil protection and eco-tourism, it enhances the professional quality and employment ability of community residents,

enabling them to participate in the protection of fossil resources and tourism development. Meanwhile, explore the local cultures related to fossil resources, such as traditional stories and folk crafts, and integrate them into the development of tourism products to make tourism activities more culturally rich and distinctive, and enhance the cultural identity and pride of the community. Furthermore, through means such as employment support and dividend mechanisms, community residents can directly benefit from the protection of fossil resources and tourism development, forming a positive cycle of "protection - development - benefit". This enables community residents to transform from onlookers of fossil resources to guardians and actively participate in the protection of fossil resources and tourism development. Provide a solid mass foundation for the implementation of the collaborative model.

5. Case Analysis: Practical Exploration of the Synergy between Fossil Resource Conservation and Tourism Development

The coordinated development of fossil resource protection and tourism development is not just empty talk on paper. Many regions at home and abroad have explored distinctive collaborative models through practice, providing valuable experience for other regions. The following selects two typical cases, namely the Chengjiang Fossil Site in Yunnan Province and the Burgess Shale Fossil Group in Canada, for in-depth analysis from the dimensions of collaborative mechanism, technology application, and community participation.

5.1 Chengjiang Fossil Site in Yunnan: a Model of the Integration of Scientific Conservation and Science Popularization Tourism

The Chengjiang Fossil Site, as China's first World Natural Heritage Site in the fossil category, possesses fossil resources of the early Cambrian Marine biota. Its collaborative model of protection and development has three highlights [11]. First, institutional innovation and multi-party collaboration. The local government, in collaboration with research institutions such as the Nanjing Institute of Geology and Palaeontology of the Chinese Academy of Sciences, has established a "research - protection - management" linkage mechanism and formulated the "Regulations on

the Protection of the World Natural Heritage of Chengjiang Fossil Site", clearly defining the standardized procedures for fossil collection, research, and display. Meanwhile, social capital is introduced to establish a tourism development company, which is responsible for the construction and operation of the fossil site museum and the science popularization education base, forming a collaborative governance framework of "government-led, scientific research support, and enterprise operation". Second, digital technology empowers protection and popular science. By using high-precision 3D scanning technology to digitally archive fossils and build a virtual fossil database, it not only reduces the damage caused by tourists' contact with fossils but also provides data support for scientific research. In tourism development, AR and VR technologies are employed to create immersive science popularization experiences. Tourists can "travel back" to the Cambrian ocean to observe the process of biological evolution, achieving an organic combination of protection and science popularization. Third, community participation and benefit sharing: The local government helps the residents of the surrounding communities transform into fossil site guides and handicraft makers through ecological compensation, skills training and other means, and directly participate in tourism services. For instance, cultural and creative products developed based on Cambrian organisms have an annual sales volume of over ten million yuan. Community residents have gained a stable income from them, forming a virtuous cycle of "protecting resources - developing tourism - giving back to the community".

5.2 Burgess Shale Fossil Group in Canada: International Standard Conservation and Tourism Development Synergy

The Burgess Shale fossil group, as a key evidence site of the "Cambrian Explosion", its collaborative model has exemplary significance internationally [12]. After being inscribed on the UNESCO World Heritage List in 1980, the Canadian government formulated the "Burgess Shale Fossil Group Management Plan", restricting fossil collection and scientific research activities, and requiring all research to be approved by the Heritage Committee. Meanwhile, a world-class fossil museum should be built, and constant temperature and humidity

technology should be adopted to protect fossil specimens to ensure that their scientific value is not affected by tourism activities.

Integration of eco-tourism and scientific research: Develop "Fossil Exploration" themed tourism routes. Tourists need to participate in professional training and, under the guidance of scientific researchers, conduct fossil observations and records. The obtained data will be uploaded to a global database for scholars' research. This model of "tourists as scientific research participants" not only satisfies the public's desire to explore but also provides data support for scientific research, achieving a deep integration of protection and development. The local indigenous people have integrated fossil resources into traditional culture, developed tourism products such as "Fossil Legend" dance and song performances and handicrafts, and the income is used for public welfare undertakings such as community education and environmental protection. For instance, indigenous tribes collaborate with the government to establish heritage management committees, jointly formulate tourism development rules, and ensure that community rights and interests are in line with the goals of fossil resource protection.

5.3 Comparison and Implications

Both cases indicate that the synergy between fossil resource protection and tourism development needs to be based on institutional innovation, enhance protection efficiency through technological empowerment, and achieve benefit sharing through community participation. China can draw on Canada's experience of deeply integrating scientific research with tourism, and at the same time give full play to the advantages of digital technology in popular science education. Canada can learn from China's practice in community participation and further strengthen the leading role of indigenous people in heritage management. In the future, global fossil resource areas need to seek a dynamic balance between protection and development, and construct a collaborative model of "scientific protection - sustainable tourism - community well-being" as a trinity.

6. Conclusion

Fossil resources, as important witnesses of the Earth's history, carry the mysteries of life evolution and the codes of ecological changes. The coordinated development of their protection

and tourism development is not only a key path for the sustainable utilization of resources, but also an inevitable choice to promote the harmonious coexistence of regional ecology, economy and culture. Through in-depth analysis of typical cases at home and abroad such as the Chengjiang Fossil Site in Yunnan Province and the Burgess Shale Fossil Group in Canada, this paper reveals the construction logic and practical path of the collaborative model of fossil resource protection and tourism development, providing important inspirations for the sustainable development of similar heritage sites worldwide. From the perspective of the collaborative mechanism, institutional innovation is the core guarantee for the implementation of the collaborative model. Whether it is the "research - protection - management" linkage mechanism led by the Chinese government or the strict protection system based on the World Heritage framework in Canada, both have laid the institutional foundation for the synergy of fossil resource protection and tourism development by clarifying the rights and responsibilities of all parties and regulating development behaviors. The application of technology provides innovative tools for coordinated development. The application of digital technology in the digital archiving of fossils, popular science education and eco-tourism not only enhances the efficiency of protection, but also enriches the tourism experience, achieving a win-win situation for protection and development. Community participation, as a key link of the collaborative model, has transformed community residents from bystanders of fossil resources to guardians through means such as benefit sharing and skills training, injecting endogenous impetus into collaborative development.

Looking forward to the future, the coordinated development of fossil resource protection and tourism development needs to further strengthen the combination of global vision and local practice. On the one hand, we should draw on international advanced experience, improve the institutional framework, enhance the level of technological application, and promote the deep integration of protection and development. On the other hand, it is necessary to base on the characteristics of local resources and the needs of the community, explore diversified collaborative models, and ensure that community residents can continuously benefit from collaborative development. Only in this

way can we protect the scientific value and ecological functions of fossil resources while achieving the economic and social benefits of tourism development, and enable this non-renewable natural heritage of fossil resources to regain new vitality and vigor in the inheritance and development of human civilization.

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