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Atmospheric Paleoart: A Case Study of the Murals in the Paleozoological Museum of China

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Abstract

Expansive works of paleoart in natural history museums have the power to set the atmosphere in a gallery space. In this sense, the artwork can be described as atmospheric. Atmospheric paleoart is usually thematically associated with the surrounding objects on display, where it can enhance the exhibition narrative and become an independent display object itself. Atmospheric paleoart also plays a significant role in the public understanding of paleontology. The Paleozoological Museum of China in Beijing contains three large murals as part of its key exhibition narrative. These expansive paintings were installed for the public opening of the museum in 1994, but they are poorly documented. Each mural showcases one of the three 'ages of life'– the Paleozoic, Mesozoic, and Cenozoic – as represented predominantly by prehistoric biotas from China. This paper provides a record of these important murals, focusing on their scientific and social value, while exploring perspectives on the development of paleoart in China.

Keywords: Paleoart; Mural; Atmospheric; Museum; Natural History; China; Paleontology

Introduction

The American natural history artist Walton Ford defined 'paleoart' (alternatively spelled 'palaeoart') as "the contemporary art of reconstructing the prehistoric past" (Ford in Lescaze 2017). One of the earliest examples of paleoart is *'Duria Antiquior, a More Ancient Dorset'* (1830) by Henry De la Beche. This painting depicts a Jurassic underwater scene populated by life restorations of fossil animals, including the famous 'sea dragons' discovered by Mary Anning (1799–1847) at Lyme Regis in the 1820s. However, the term 'paleoart' appeared much later than it was practiced. Debus and Debus (2002) claim the word 'paleoartist' was first used in print by Mark Hallett in his article 'Bring Dinosaurs to Life' in Volume 1 of 'Dinosaurs Past and Present' (Hallett 1986). Debus and Debus also proposed their own definition:

> *"Paleoartists are (modern) artists who create original skeletal reconstructions and/or restorations of prehistoric animals, or restore fossil flora or invertebrates, using acceptable and recognized procedure".*

One of the most fascinating aspects of the subject of paleontology is the scientific reconstruction and

restoration of long-extinct prehistoric creatures and the ancient ecosystems in which they lived. What did they look like? How did they move? How did they behave? These are the kinds of questions that are the initial motivation for many individuals to take an interest in the science of paleontology.

Although the early 1800s may have marked the beginning of paleoart, Georges Cuvier (1769–1832) had previously made remarkable contributions with the first restorations of *Mastodon*, *Palaeotherium* and *Anoplotherium*. Rudwick (1997) called these works "superb examples of his artistic skill" (p34).

Paleoart is often used to support scientific outreach and public education (Witton 2018), but it can also provide a valuable historical record showing how paleontological science has developed over time. The British geologist and paleontologist Gideon Mantell (1790–1852) was the first to establish a collaboration between paleontologists and artists. Based on Mantell's research, the artworks of George Scharf (1788–1860) and John Martin (1789–1854) from the 1830s provide evidence of a remarkable time in the history of paleontology. The artists restored the dinosaurs *Iguanodon, Megalosaurus*, and *Hylaeosaurus* from the Wealden of Tilgate Forest in Sussex and placed them into a prehistoric environment. Scharf's '*Reptiles Restored, the Remains of Which are to be Found in a Fossil State in Tilgate Forest, Sussex'* (1833) has been regarded as the "earliest known scientific attempt to piece a dinosaur together" (Dean 1999), but it was predated by an 1831 restoration of *Megalosaurus* published by Goldfuss (1826–1844).

In recent decades, the field of paleoart has undergone rapid development in the light of astonishing recent discoveries in paleontology (Smith and Wang 2017). Since its birth in the early 19th century, paleoart has been practiced in many different media, from traditional painting, sculpture, and reliefs to modern digital art and computer-generated imagery (CGI) in films and television documentaries (Witton 2018).

Most paleoart in museums is produced as manageable and portable works placed alongside selected specimens. In contrast, expansive two-dimensional paleoart that occupies an entire or substantial part of a museum wall is relatively rare. Traditionally, artwork like this is applied directly to the wall as a painted mural, while a modern technique uses digital (or scanned) artwork installed as printed wallpaper or panels (Smith *et al.* 2020). As well as being an independent feature of an exhibition, paleoart murals can form a backdrop to help set the scene and create an atmosphere in a gallery space or exhibition. Paleoart of this magnitude can therefore be defined as 'atmospheric paleoart'. It provides a valuable interpretation tool for curators and a visceral experience for visitors by depicting a prehistoric ecosystem or scene. It also provides an important historical record of scientific knowledge at the time of its creation.

A trio of expansive murals in the Paleozoological Museum of China (PMC) are poorly known outside China. These murals have contributed to the popularization of Chinese paleontology for 30 years, demonstrating the endeavors, ambitions and sometimes confusion of Chinese paleoartists. They also offer a spotlight on the state of paleontological knowledge in China in the early 1990s at a crucial time in the history of Chinese paleontology and dinosaur paleontology more broadly. Their content, scientific value, and social impact are all worthy of study. However, the artwork is also poorly documented – the murals are not widely known as they have never been discussed in popular or technical literature, nor formally reproduced or photographed. Here, we provide an overview of these overlooked murals and explore them in a historical China-focused context. We also highlight the value of 'atmospheric paleoart' as a tool

for 'transporting' museum visitors to prehistoric worlds represented by geological formations and the fossils they contain.

Atmospheric Paleoart: A Review

Atmospheric paleoart provides a spotlight on an entire prehistoric ecosystem or ecosystems. Arguably the most iconic and influential paleoart murals of this kind are 'The Age of Reptiles' and 'The Age of the Mammals' frescos in the Yale Peabody Museum of Natural History. Completed by Rudolph F. Zallinger in 1947 and 1967 respectively, these two remarkable artworks depict 365 million years of life evolution and biodiversity from the Devonian to modern times (Volpe 2007).

There are many other notable examples of large atmospheric paleoart in museums, including:

- Paintings by the famous paleoartist Charles R. Knight in the American Museum of Natural History (New York) and Field Museum (Chicago) have achieved global influence (Milner 2012), particularly, the c.30 large atmospheric murals created by Knight between 1926 and 1930 transformed the fossil galleries of the Field Museum (Czerkas and Glut 1982);
- A series of many large paintings depicting Mesozoic and Cenozoic scenes by Jay Matternes for the Smithsonian National Museum of Natural History in the 1950s, 60s and 70s (Carrano and Johnson 2019);
- A large vertical painting called *'Tower of Time'* painted by John Gurche for the National Museum of Natural History, Washington DC, in the 1980s (Parrish 2014);
- A 28-metre-long mural depicting a misty Cretaceous landscape of the South Gobi Desert painted by Mai Petrovitch Miturich Khlebnikov and Viktor Aronovitch Duvidov in 1986 for the Orlov Paleontological Museum of Moscow (Lescaze 2017);
- Two large murals by William Stout, inspired by John Gurche and Stanley Meltzoff (Stout 2009), produced for the Houston Museum of Natural History's *'The Life Before the Dinosaurs'* touring exhibition in 1991–1992;
- Large murals, reproduced from digital images by Raúl Martin, which mirror the poses of mounted dinosaur skeletons in the Jurassic Museum of Asturias, Spain.

The Paleozoological Museum of China Murals

The Paleozoological Museum of China (PMC) is the public-facing museum of the Institute of Vertebrate of Paleontology and Paleoanthropology (IVPP), part of the Chinese Academy of Sciences (CAS). The building operated as a storage and research center before opening to the public on 18th October 1994. The museum houses an approximately 2,000 m^2 exhibition space laid out across three floors inside a stepped pyramid-like building. A large paleoart mural runs along the length of each gallery to enhance the exhibition narrative.

History of the PMC Murals

Compared to other more well-known paleoartworks, the three murals in the PMC are relatively young. According to the memory of Li Rongshan (1943–2020) – a senior paleoartist who worked at the IVPP – the murals were produced during the spring and summer of 1994 (Li pers. Comm 2018; Li R, to Wang Q, pers. comm. 31st May 2018, IVPP, Beijing, an interview). This is a fast turnaround for a work of this scale and may explain some of the shortcomings of the murals (see below). As the principal artist, Li was responsible for color studies, and he drew the original sketches and painted small-scale versions of the murals. A group of apprentice artists from the China Central Academy of Fine Arts later produced the enlarged murals in oil paints based on Li's small-scale paintings.

The general exhibition layout was designed to give visitors a clear sequence of prehistoric times in a spatial narrative. The ground floor is concentrated on the Paleozoic Era, the first floor on the Mesozoic Era, and the second floor on the Cenozoic Era. Accordingly, fossils from each era are displayed in showcases along the north wall of each gallery, while the long south walls are almost entirely dedicated to the three giant murals (Figs. 1, 2). The exhibition narratives on the three floors are all designed to surround a central display of mounted skeletons, in a double-high atrium for the dinosaurs on the ground and first floors, and a group of mounted mammal skeletons in the middle of the second floor. These murals add atmosphere to the exhibition theme.

Many aspects of the murals are reminiscent of Zallinger's work. However, compared to the murals of Yale University, which depict prehistoric time back to the Devonian Period, the murals of the PMC extend further back to the Cambrian Period.

General Characteristics of the Murals

Four characteristics differentiate the PMC murals from other examples. First, whereas traditional murals are often painted directly onto the wall, the three PMC artworks are painted on large canvases, which were specially manufactured as whole pieces without extra stitch-work connections in the middle. This comfortably accommodates the panoramic view of the prehistoric worlds by linking adjacent geological periods together seamlessly. To present the flowing feeling of the lapse of time, the murals were mounted in an extremely elongated landscape format supported by wooden frameworks (Figs. 1, 2). Mounting an oversized canvas like this was a technical challenge, with

Figure 1. Photograph of the Mesozoic Era mural *in situ* in the Paleozoological Museum of China. Note the barrier-free display.

Figure 2. Photograph of the Cenozoic Era mural *in situ* in the Paleozoological Museum of China. Note the barrier-free display.

the risk of unbalanced tension between the wooden frameworks and canvases. However, during construction, the carpenters managed to equalize the tension to provide a smooth painting surface, and the quality of the mounting construction was successful; after 30 years the average tightness of the canvases is still well-maintained.

The second characteristic of the murals is the viewing direction. For example, Zallinger's murals match the arrangement of fossils in the gallery from left to right (Volpe 2007), with 'The Age of Reptiles' depicting a sequence from the youngest (Cretaceous) to the oldest (Devonian). On the other hand, 'The Age of the Mammals' sequence runs from the oldest (left) (Paleogene) to the youngest (right) (Quaternary). So, visitors experience the murals in opposite chronological directions. In contrast, all three murals in Beijing respect the customary reading habit timeline direction, from left (oldest) to right (youngest). However, since the PMC was originally designed as an institute's storeroom rather than a public museum, there is only one open staircase at the northwest end of the gallery, at the opposite end of the main entrance (and exit) at the southeast corner on the ground floor. This results in different directions of visitor flow and circulation on the different floors. On the ground floor, the exhibition narrative begins at the southeast entrance and visitors experience it anticlockwise around the central atrium. On the first and second floors, the circulation begins from the northwest staircase and visitors travel clockwise around the central displays. These different starting points and viewing directions force visitors to 'read' the murals from different directions: the Paleozoic mural on the ground floor is experienced from right to left, while the Mesozoic and Cenozo-

ic murals are experienced from left to right. This possibly leads some visitors to misunderstand the geological sequence.

The third character is a barrier-free display (Figs. 1, 2). To achieve a high visual impact and satisfactory conservation conditions, large murals are normally displayed out of reach. However, since the internal gallery spaces on each floor of the PMC are relatively low, the murals cannot be displayed above head height, and therefore they were installed at floor level. Additionally, since the internal gallery spaces are narrow, no barrier is installed in front of the murals. Positively, this offers the visitors a more intimate relationship with the murals, it provides a wonderful backdrop for photo opportunities and makes the depictions a more convenient reference for the fossils displayed nearby. Negatively, some lower parts of the painting have been damaged after 30 years of open display. Minor scratches and chips in the paintwork have been caused by visitors touching or leaning against the artwork, but these are repairable.

The final special aspect of the PMC murals is their China-specific focus (Tables 1,2,3). According to Prof. Zhanxiang Qiu, who was the director of the IVPP in the 1990s, the murals were intended to depict the most up-to-date Chinese paleontological achievements at the time (Qiu pers. comm. 2018, Qui Z, to Wang Q, pers. comm. April 2018, IVPP Beijing, an interview). Bearing in mind the subject of vertebrate paleontology in China was first developed by Chungchien Young in the 1920s–1930s (PSC 2014), and despite many significant subsequent discoveries by Chinese paleontologists, the field was still young compared to the long international history of vertebrate paleontology. To include as many significant Chinese discoveries as possible, Rongshan Li asked for help from IVPP paleontologists. According to Li, specialists on fish, amphibians, reptiles, and mammals offered generous assistance by listing the important species found and described in China before 1994 (Li pers. comm. 2018; Li R, to Wang Q, pers. comm. 31st May 2018, IVPP, Beijing, an interview). This informed the final selection of species to appear on the murals. Unfortunately, this selection process was not documented, which makes it difficult to provide confident identifications of some of the animals depicted. The artist has applied artistic romance and poetic narrative in conjunction with scientific rigor, and these details will be outlined in the following sections.

The Three Murals

Poetry of the Paleozoic World

The mural on the ground floor is dominated by a depiction of a busy Paleozoic ocean (Fig. 3). It measures 14 m long and 3.3 m high, so it is the tallest of the three murals, but also the shortest. It covers an area of 46.2 m^2. Thirty species are represented by 103 individual figures on this mural (Table 1), of which 28 species can be confidently or tentatively identified. The general layout of the mural has one main aim – to show the underwater scene and the landscape in one snapshot.

Paleozoic strata are widely distributed in China, and well-preserved fossil-bearing deposits of all six periods have been found and studied. Well-known examples include the Early Cambrian Chengjiang Biota in Yunnan Province, the Late Cambrian (Paibian Stage) and Ordovician trilobite faunas in Hunan Province, the Silurian Xiaoxiang marine fish fauna in Yunnan Province, the Devonian Zhongning freshwater fauna in Ningxia Hui Autonomous Region, the Carboniferous coal measures found widely in Northern China, and the Permian Dashankou tetrapod fauna in Gansu Province (Sullivan *et al.* 2015). These deposits represent both continental and marine sediments, but most of the Paleozoic fossils found in China were marine. Rongshan Li decided to focus on the underwater world while showing the land as a re-

Table 1. Summary of the content of the Paleozoic mural.

Period	Location	Geopark	Name	Number of Individuals
Cambrian	Guizhou Province		*Yinites* sp. (Early Cambrian)	1
	Hunan Province	Xiangxi Global Geopark	*Macropyge* sp. (Late Cambrian)	1
			Unidentified trilobite	1
Ordovician			Tabulate corals or stromatoporoid sponges	6
	South China		Crinoids	8
	Hunan Province		*Sinoceras chinense* (Middle Ordovician)	2
	Sichuan Province		*Strophomena* sp.	12
	Hunan Province		Acanthodians	6
Silurian	Hunan Province		*Hughmilleria wangi* (Early Silurian)	2
	Hubei Province		*Hanyangaspis* sp. (Middle Silurian)	3
	Yunnan Province		*Thelodus sinensis* (Late Silurian)	2
Devonian	Sichuan Province and Yunnan Province		*Lungmenshanaspis* sp. (Early Devonian)	3
	Yunnan Province		*Eugaleaspis change* (Early Devonian)	6
			Polybranchiaspis liaojiaoshanensis (Early Devonian)	2
			Parayunnanolepis xitunensis (Early Devonian)	3
	Yunnan Province or Europe and North America		*Youngolepis praecursor* (Early Devonian) or *Dipterus* sp. (Middle Devonian)	1
	Yunnan Province		*Bothriolepis tungseni* (Middle Devonian)	3
	Sichuan Province		*Kiangyousteus yohii* (Middle Devonian)	1
	Cleveland, USA		*Dunkleosteus* sp. (Late Devonian)	1
	Greenland, Denmark		*Ichthyostega* sp. (Late Devonian)	1
	Canada or Yunnan Provicne		*Eusthenopteron* sp. (Late Devonian) or *Youngolepis praecursor* (Early Devonian)	2
			Favosites sp.	6
	Hunan Province		*Cyrtospirifer sinensis* (Late Devonian)	4
			Atrypida brachiopods	6
Devonian or Carboniferous	Cleveland, USA or Yunnan Province		*Cladoselache* sp. (Late Devonian) or *Cladodus yunnanensis* (Carboniferous)	1
Carboniferous	China		Carboniferous forest	
Permian	Zhejiang Province		*Sinohelicoprion changhsingensis* (Late Permian)	1
			Eosaurichthys chaoi (Late Permian)	1
Permian – Triassic	Northwest China		Unidentified therapsids	3
			Paleonisciform fish	14
Total Number			**30 (Identified: 28)**	**103**

Table 2. Summary of the content of the Mesozoic mural.

Period	Location	Geopark(s)	Name	Number of Individuals
Permian – Triassic	North and Northwest China (Xinjiang, Inner Mongolia, Shaanxi Province and Shanxi Province)		*Shihtienfenia permica* (Late Permian)	1
			Unidentified therapsid (Late Permian)	1
			Jimusaria sinkianensis (Late Permian)	1
			Lystrosaurus sp. (Early Triassic)	2
			Proterosuchus yuani (Early Triassic)	1
			Hazhenia concava (Early Triassic)	1
			Urumchia lii (Early Triassic)	1
			Eumetabolodon sp. (Early–Middle Triassic)	1
			Santaisaurus yuani (Early Triassic)	1
			Sinokannemeyeria sp. (Middle Triassic)	1
			Sinognathus gracilis (Middle Triassic)	1
			Shansisuchus shansisuchus (Middle Triassic)	1
	Hunan Province		*Lotosaurus adentus* (Middle Triassic)	1
	Guizhou Province, Anhui Province or Tibet	Guanling Fauna National Geopark, Guizhou; Xingyi Global Geopark, Guizhou	Unidentified ichthyosaur or *Himalayasaurus tibetensis* (Late Triassic)	1
Jurassic	Yunnan Province	Lufeng Dinosaur National Geopark (the age was identified as Late Triassic when the mural was produced)	*Lufengosaurus huenei* (Early Jurassic)	4
			Sinosaurus triassicus (Early Jurassic)	1
			Sinoconodon rigneyi (Early Jurassic)	1
			Bienotherium yunnanense (Early Jurassic)	1
			Morganucodon heikuopengensis (Early Jurrassic)	1
			Microchampsa scutata (Early Jurassic)	1
			Pachysuchus imperfectus (Early Jurassic)	1
	Xinjiang	Qitai Petrified Wood and Dinosaur National Geopark	*Bellusaurus sui* (Middle Jurassic)	2
			Monolophosaurus jiangi (Middle Jurassic)	1
	Sichuan Province	Zigong Global Geopark	*Angustinaripterus longicephalus* (Middle Jurassic)	2
			Sinobrachyops placenticephalus (Middle Jurassic)	1
			Chengyuchelys zigongensis (Middle Jurassic)	1
			Teleosaurus sp. (Middle Jurassic) or *Peipehsuchus teleorhinus* (Early Jurassic)	1
			Hsisosuchus chungkingensis (Middle Jurassic)	1
			Huayangosaurus taibaii (Middle Jurassic)	1
			Omeisaurus sp. (Middle Jurassic)	5
			Shunosaurus lii (Middle Jurassic)	1
			Gasosaurus constructus (Middle Jurassic)	2
	Sichuan Province and Chongqing City		*Tuojiangosaurus multispinus* (Late Jurassic)	1
			Mamenchisaurus sp. (Late Jurassic)	5
			Yangchuanosaurus shangyouensis (Late Jurassic)	2
			Late Jurassic neornithischian or *Agilisaurus louderbacki* (Middle Jurassic)	1
	Germany		*Archaeopteryx* sp. (Late Jurassic)	1

Cretaceous	England and western area of Liaoning Province	Chaoyang Fossil National Geopark, Liaoning; Jinzhou Fossil and Granite National Geopark, Liaoning	Unidentified *Iguanodon* (Early Cretaceous)	1
			Cathayornis yandica (Early Cretaceous)	1
			Psittacosaurus sp. (Early Cretaceous)	4
			Lycoptera davidi (Early Cretaceous)	5
			Ikechosaurus sp. (Early Cretaceous)	1
			Unidentified theropods (Early Cretaceous)	3
	Inner Mongolia and Xinjiang	Erenhot National Geopark, Inner Mongolia; Bayannur National Geopark, Inner Mongolia	*Wuerhosaurus homheni* (Early Cretaceous)	1
			Dsungaripterus weii (Early Cretaceous)	3
			Kelmayisaurus petrolicus (Early Cretaceous)	1
			Unidentified ornithischians (Early Cretaceous)	3
			Pinacosaurus granger (Late Cretaceous)	3
			Oviraptor philoceratops (Late Cretaceous)	1
			Protoceratops andrewsi (Late Cretaceous)	2
	Shandong Province	Zhucheng Dinosaur National Geopark; Laiyang Cretaceous National Geopark	*Shantungosaurus giganteus* (Late Cretaceous)	1
			Tsintaosaurus spinorhinus (Late Cretaceous)	1
			Unidentified tyrannosaurid (Late Cretaceous)	1
			Unidentified saurischian (Late Cretaceous)	2
			Unidentified dinosaur carcasses (Late Cretaceous)	3
			Unidentified mammals (Late Cretaceous)	5
Total Number			**56 (Identified: 47)**	**94**

Table 3. Summary of the content of the Cenozoic mural.

Period	Location	Geopark(s)	Name	Number of Individuals
Paleogene	Anhui Province	Tianzhushan Global Geopark	*Heomys orientalis* (Paleocene)	1
	Guangdong Province		*Lofochaius brachyodus* (Paleocene)	1
			Bemalambda nanhsiungensis (Paleocene)	2
			Yantanglestes datangensis (Paleocene)	1
	Henan Province		*Uintatherium insperatus* (Eocene)	2
	Inner Mongolia	Erenhot National Geopark; Siziwang National Geopark	*Rhinotitan mongoliensis* (Eocene)	2
			Archaeomeryx sp. (Eocene)	1
			Embolotherium sp. (Eocene)	3
	Northern China		*Amynodon* sp. (Eocene)	2
	Xinjiang		*Dzungariotherium* sp. (Oligocene)	1
Neogene	Gansu Province	Linxia Global Geopark	*Platybelodon grangeri* (Miocene)	3
			Kubanochoerus gigas (Miocene)	1
			Chilotherium wimani (Miocene–Pliocene)	1
			Amphimachairodus palanderi (Miocene)	2
			Tsaidamotherium hedini (Miocene)	3
			Hipparion sp. (Miocene–Pliocene)	10
			Dinocrocuta gigantea (Miocene)	5
			Hezhengia bohlini (Miocene)	2

Quaternary	Gansu Province		*Stegodon zdanskyi* (Early Pleistocene)	1
	Hebei Province		*Coelodonta nihowanensis* (Early Pleistocene)	1
	Hunan Province		*Ailuropoda wulingshanensis* (Early Pleistocene)	2
	Beijing	Fangshan Global Geopark	*Megaloceros (Sinomegaceros) pachyosteus* (Middle Pleistocene)	1
	Beijing	Fangshan Global Geopark	*Homo sapiens* (Late Pleistocene)	3
	Heilongjiang Province	Qinggang Mammoth National Geopark	*Mammuthus primigenius* (Late Pleistocene)	8
	Northern China		*Ovis ammon* (Pleistocene–Holocene)	2
			Vulpes lagopus (Pleistocene–Holocene)	1
Total Number			**26**	**62**

Figure 3. The full Paleozoic Era mural. It is 14 m long and 3.3 m high, covering an area of 46.2 m^2.

mote background. In the design, he attempted to apply a strong poetic description to harmonize the changing time, environment, and species. A diagonal structural line, running from the upper-left corner to the lower-right corner, provides a system to organize the contents: the right upper side for land and the left lower part for the ocean. Firstly, the expansive lower foreground illustrates a continuous section of the underwater fauna from the Cambrian to the Permian. Secondly, the upper land portion is gradually transferred from small-scattered islands on the left side to a larger integrated part on the right. From remote backgrounds to medium ground, this deep perspective view demonstrates a diverse landscape that changes from the earlier bare ground to dense Carboniferous forests, and then to the more arid landscape of the Permian. Thirdly, estuaries, alluvial fans, bays and freshwater lakes are cleverly used to cut the land into complicated formations, which offer further flexibility for the artist to depict different ecological niches.

Before 1994, studies on the Paleozoic in China were rare in comparison to the volume of studies published in more recent years, and many studies were unpublished. Allowing for this restriction, Li tried to depict the most significant discoveries as dramatic moments within the artistic composition to improve the vividness and diversity of the paintings.

Illustrated in the foreground, the central piece of the mural features five great predators of the Paleozoic Ocean. *Dunkleosteus* is the main focus (Fig. 4). Although this placoderm was not found in China, it is nevertheless an iconic extinct animal, likely to arouse visitors' interest. It is joined by a *Kiangyousteus yohii* (Fig. 4), a Chinese member of the same family, Dinichthyidae, first discov-

Figure 4. Detail from the center of the Paleozoic mural showing three prominent predators. From left to right, *Cladoselache* sp. (or *Cladodus yunnanensis*), *Kiangyousteus yohii*, and *Dunkleosteus* sp.

ered by Senxun Yue in Jiangyou County, Sichuan Province in 1953 (Liu 1955). Here, the balance between a Chinese focus and international discoveries is notable.

To the left side of *Dunkleosteus* is a large shark, which could be *Cladoselache* sp., identified from the blade-like spine in front of its dorsal fin (Fig. 4). The best specimen of this species was found in the Late Devonian of the Cleveland Shale, USA. So, it could be a figure to honor the discoveries by paleontologists from North America, or it could represent *Cladodus yunnanensis*, the only member of Cladoselachidae found in China. This species was named from limited tooth fossils from the Carboniferous deposit of Zhanyi, Yunnan Province in 1964 (Chen and Cui 1989).

To the right of *Dunkleosteus*, beyond a small reef, a *Sinohelicoprion changhsingensis* fights the turbulent waves (Fig. 5). This species, named in 1963, is one of three *Helicoprion*-like specimens from China. The shark, often preserved only as tooth whorls, was characteristic in the Permian Sea (Liu and Chang 1963; Jin 2006). To the left of the shark is a *Eosaurichthys chaoi,* probably swimming too close to the dangerous predator like an innocent youngster aimlessly following a powerful gang leader.

Behind the predators, several important marine species are depicted as small figures in the background. Some play significant roles in science and culture. On the right side, two *Youngolepis praecursor* venture onto the land assisted by their lobefins (Fig. 6). One plucky individual has already climbed up onto the shore while the other watches behind cautiously. Further to the right, there is a small lagoon linked to the sea by a narrow waterway, in which an early amphibious tetrapod *Ichthyostega* sp. and the lungfish *Dipterus* sp. face each other (Fig. 6). These two animals, of which the former was found in Greenland and the latter in Europe and North America, may be included in the mural to honor the works of early western paleontologists, or just to depict a more global narrative of the history of life. The early tetrapod crawls onto a rock protruding out of the water, and the fish floats on the surface with its typical heterocercal tail visible. In a romantic anthropomorphic way, this dramatic face-to-face expresses

Figure 5. Detail from the right side of the Paleozoic mural. From left to right, the brachiopod *Cyrtospirifer sinensis*, unidentified coral, *Eosaurichthys chaoi*, *Sinohelicoprion changhsinensis*, and in the far distance a school of paleonisciform fish and three unidentified therapsids. Note also the dense Carboniferous forests on the left side.

Figure 6. Detail from the center-right section of the Paleozoic mural depicting a poetic scene of vertebrates 'venturing towards the land'. From left to right, two *Youngolepis praecursor* (*or Eusthenopteron* sp.), an amphibious early tetrapod *Ichthyostega* sp., and a *Dipterus* sp. (or *Youngolepis praecursor*).

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a subtle metaphor – the bravery and hesitation of these first evolutionary pioneers of the land.

Youngolepis was named and studied by Meemann Chang in the 1980s. This fish was originally put in the Subclass Crossopterygii along with *Latimeria* and *Eusthenopteron*, which suggests that they may have been able to move on land. However, Chang's research concluded that *Youngolepis praecursor* was unable to climb on land (Chang 1982). Before 1994, this new theory had only shaken but not yet overthrown the current thinking. Therefore, the restoration of this species on the mural is still highly similar to *Eusthenopteron* in terms of outward appearance and behavior. Nowadays, Chang's study has been widely accepted and new research has suggested that *Youngolepis praecursor* is more closely related to lungfish (Lu *et al.* 2016). In addition to being re-classified as a dipnomorph along with *Dipterus*, modern restorations depict it with a heterocercal tail. Because there is no accurate documentation of the murals the identification of some of the species is tentative, and they could be reinterpreted to identify the fishes climbing on the land as Tetrapodomorpha such as *Eusthenopteron*, rather than *Youngolepis praecursor*. Meanwhile the *Dipterus* could be re-identified as *Youngolepis praecursor* instead (Lu *et al.* 2016). The interesting point is that no matter which scientific interpretation is applied, *Youngolepis praecursor* is always present in the mural as an iconic species that highlights Professor Chang's important contribution, for which she was awarded the L'Oréal-UNESCO Award for Women in Science in 2018.

The 'sea scorpion' *Hughmilleria wangi* was found in 1992 by Junqing Wang in the Xiaoxiyu Formation of Hunan Province. However, it was not described until 2007. The study suggested that it was the oldest eurypterid arthropod discovered in China (Tetlie *et al.* 2007). The mural recognizes the importance of the original discovery in 1992, before its publication, and includes the species as a pair of tiny figures in the distance, close to the beach (Fig. 3). There are further Paleozoic fish in the background, such as *Eugaleaspis changi, Thelodus sinensis, Hanyangaspis* sp. and *Lungmenshanaspis* sp. (Liu *et al.* 2018).

Towards the far upper right corner, depicted on the remote landscape, are three therapsid-like tetrapods standing on the bank of a freshwater lake, in which a group of palaeonisciform fish swim nearby (Fig. 5). In the 1930s, scientists discovered the Permian deposits at Yumen, Gansu Province, which contains a biota later named as the Dashankou Fauna. In the 1950s and 1960s, palaeonisciform fossils were found in the Upper Permian deposits in Gansu Province, Xinjiang Uygur Autonomous Region and Shaanxi Province (Qian and Wang 2004). This remote scene could be Li's recognition of his colleagues' ongoing work on the Dashankou Fauna. Subsequently, this site turned out to be one of the most important fossil localities in the world for the study of lower tetrapod faunas: *Sinophoneus yumenensis* in 1996, *Biseridens qilianicus* in 1997 and *Raranimus dashankouensis* in 2009. These publications by the IVPP reinforce Li's poetic thought (Li and Cheng 1999; Liu *et al.* 2012; Liu *et al.* 2018).

Unlike the busy murals full of life made by Zallinger, Burian, and Stout, the PMC Paleozoic mural is comparatively empty. In the foreground portion of the ocean, there are only nine prehistoric fishes, three trilobites, and a few other invertebrates, which gives the impression of a rather lifeless Paleozoic Ocean. Notably, a 'Cambrian Explosion' scene is unexpectedly absent. Li only expressed the Cambrian Period towards the bottom left of the mural with three trilobites, a *Yinites,* a *Macropyge,* and an unidentified species (Fig. 7).

However, by 1994, one of the best Early Cambrian deposits, the Chengjiang Maotianshan Shale in Yunnan Province, had already been recognized

Figure 7. Detail from the left side of the Paleozoic mural showing a reef comprising Cambrian, Ordovician and Silurian organisms. From left to right, *Strophomena* sp. (x12), unidentified crinoids (x8), unidentified tabulate corals or stromatoporoid sponges (x6), *Sinoceras chinense* (x2), unidentified acanthodians (x6), the trilobites *Yinites* sp. and *Macropyge* sp., and an unidentified trilobite.

for ten years. As one of the most important fossil sites for the study of the Cambrian Explosion, the Chengjiang localities share fame with the Burgess Shale in Canada. Why didn't the artist emphasize the Chengjiang Fauna on the mural? The reason may be to respect scientific rigor. The Burgess Shale was discovered by Charles Walcott in 1909, so Chengjiang was comparatively unexplored (Sullivan *et al.* 2015). Research on the Maotianshan Shale has been carried out since 1984, and although more than 200 species have now been discovered, only 76 species had been described before 1994. Further, the most typical species, including four species of *Anomalocaris*, the extremely bizarre *Hallucigenia fortis*, and the earliest known potential ancestor of all vertebrate animals, *Haikouichthys ercaicunensis,* were all described after 1994. Although scientists in China worked hard to evidence the Chengjiang Fauna as one of the most excellent records of the Cambrian Explosion, this was not disclosed to the public until China Central Television broadcast news about the Chengjiang Maotianshan Shale on 2nd August 1996. Therefore, it is arguable that Li probably did not obtain enough materials about the Chengjiang Fauna at that time to inform the mural. He may have cautiously avoided the 'Cambrian Explosion' scene in consideration of the ongoing scientific development, instead expressing the Cambrian scene more modestly by merging it into the ocean of later periods.

In general, the Paleozoic mural blurs the boundaries between different geological periods. The artist has composed a great piece of prehistoric poetry about evolution and diversity.

Prophecies of the Mesozoic World

The mural on the first floor represents the Mesozoic Era, with dinosaurs making up the dominant content (Fig. 8). It is 25.65 m long and 2 m high, covering an area of 51.3 m^2, so it is the largest of the three murals in both length and area. There are 56 species represented by 94 individual figures on the mural (Table 2). Among

Figure 8. The full Mesozoic Era mural. It is 25.65 m long and 2 m high, covering an area of 52.3 m^2.

these, 47 species can be identified. The IVPP's early efforts in the study of dinosaurs, especially those by Chungchien Young and Zhiming Dong, provided enough material to populate the mural. The artist depicted the Mesozoic environment in a typically Zallingerstyle, with the three periods – Triassic, Jurassic and Cretaceous – combined as a continuous landscape with large plants strategically placed to mark the boundaries (Volpe 2007). The most important Chinese Mesozoic fossil sites are included (Table 2). This mural also contains a series of prophecies on the development of Chinese paleontology.

The whole mural is divided into three equal sections representing each of the three geological periods (Triassic, Jurassic and Cretaceous). The left part represents Late Permian to Early–Middle Triassic deposits from Xinjiang, Inner Mongolia and Shanxi (Northern China) (Fig. 9), and the Late Triassic Lufeng Fauna from Yunnan Province (Southern China) (Fig. 10). A large fern tree separates this part of the mural to indicate the end of the Triassic (Fig. 10). Therapsids and early reptiles dominate the Late Permian to Early–Middle Triassic scene. Well-known land vertebrates, such as *Lystrosaurus* sp., *Jimusaria sinkianensis, Sinognathus gracilis, Sinokannemeyeria* sp., *Hazhenia concava, Urumchia lii, Shansisuchus shansisuchus, Proterosuchus yuani, Eumetabolodon* sp. and *Santaisaurus yuani* are depicted (Fig. 9). The strange pseudosuchian *Lotosaurus adentus* (Fig. 10) carries a low sail-like structure on its back, which makes it look superficially reminiscent of (but distantly related to) a Chinese ver-

Figure 9. Detail from the Early Triassic section of the Mesozoic mural (including some Late Permian creatures on the left side). From left to right, Shihtienfenia permica, unidentified therapsid, *Lystrosaurus* sp., *Proterosuchus yuani* (behind rock), *Jimusaria sinkianensis*, *Hazhenia concava* (in front of rock), *Eumetabolodon* sp. (on rock in foreground), *Sinokannemeyeria* sp. (top), *Urumchia lii* (middle), *Santaisaurus yuani* (front), and *Sinognathus gracilis* (partly cropped).

Figure 10. Detail from the Middle Triassic and Late Triassic (now dated as Early Jurassic) sections of the Mesozoic mural. From left to right, *Lotosaurus adentus*, *Shansisuchus shansisuchus*, unidentified ichthyosaur (leaping in the distance), Lufengosaurus huenei (x4), *Sinoconodon rigneyi*, *Bienotherium yuannense*, *Morganucodon heikuopengensis*, *Microchampsa scutata*, *Sinosaurus triassicus*, and *Pachysuchus imperfectus*.

sion of *Dimetrodon*. On the extreme left side, two figures clearly inspired by Burian's depiction of *Scutosaurus* and *Sauroctonus* remark on the first prophecy **(**Fig. 9). The *Scutosaurus*-like creature is *Shihtienfenia permica*, a member of Pareiasauridae studied by Chungchien Young and Xiangkui Ye in 1963. However, Li was strongly influenced by Burian's phenomenal depiction of the encounter between a *Scutosaurus* and *Sauroctonus*, and he discussed with IVPP scientists whether any similar therapsid predator could potentially have lived alongside *Shihtienfenia permica*. No such discovery existed in 1994, but Li's colleagues were positive about his brave idea, and so an unidentified *Sauroctonus*-like dinocephalian therapsid was added near to the herbivore, as a pointer to possible future discoveries (Fig. 9). Dramatically, in 1996 Zhengwu Cheng and Shuan Ji described *Sinophoneus yumenensis,* the first dinocephalian fossil ever found in China (Li J 2009). So, Li's prediction did not have to wait long to be fulfilled.

Another interesting feature of the Triassic section is a small ichthyosaur in the distant background, which appears not so much to be jumping out of the sea as floating in the sky (Fig. 10). A possible identity for this ichthyosaur is *Himalayasaurus tibetensis*, which was described by Zhiming Dong (1972). As one of the most renowned early ichthyosaur discoveries in East Asia, the fossil of *Himalayasaurus tibetensis* was displayed as a key object in the Beijing Natural History Museum for a long time, and Rongshan Li had already painted a restoration of it for that museum. Given its importance, it is unusual that this species was depicted as such a tiny figure, and in the wrong scale relative to the surrounding context. Therefore, it could be argued this figure represents some other species. In 1957, Chengzhi Hu discovered the fossils of the sauropterygian *Keichousaurus hui* on the stone wall of a village house in Guanling County, Xingyi City, Guizhou Province. This was the first Triassic marine reptile fossil ever found in Asia. Since then, although the study of Triassic marine reptiles was carried out in this area, it was not productive until a group of paleontologists, led by Jun Liu and Chun Li, made a series of import-

ant discoveries in 1999. Their efforts crowned the Guanling area as one of the most significant fossil sites for marine reptiles in the world. At present, IVPP publications on the Guanling Triassic fauna have unveiled many new species, such as *Qianichthyosaurus zhoui, Qianosuchus mixtus* and *Odontochelys semitestacea* (Li 2014). The small figure of an ichthyosaur in the mural could be a modest prediction of future findings of Chinese Triassic marine reptiles or just a reminder to museum visitors that there were marine environments (and vertebrates) during the Triassic in most parts of southern China while North China was already terrestrial.

Possibly the most important dinosaur in China – *Lufengosaurus huenei* – was found in 1938 by Chungchien Young. It was among the first dinosaurs to be discovered and described by Chinese paleontologists independently from Western scientists (Wang *et al.* 2018; Young 1939). This species became an icon of the Lufeng Dinosaur Fauna of the Lufeng Formation in Yunnan Province. *Lufengosaurus* is the most prominent dinosaur in the Triassic section of the mural (Fig. 10). In 1994, the Lufeng Formation was still recognized as Late Triassic but has since been revised to Early Jurassic (Young 1939, 1941; Wang *et al.* 2018). Therefore, the fern tree on the mural is a misplaced border between the Triassic and Jurassic, which reflects the ever-changing subject of paleontology. Next to the root of the fern tree is a large reptile (Fig. 10). It could represent *Pachysuchus imperfectus,* studied by Chungchien Young in 1951 from very limited material. It was regarded at the time as a kind of phytosaur but was later reinterpreted as a dinosaur (Sun *et al*. 1985). However, phytosaurs have nostrils positioned close to the eyes, whereas the nostrils of the animal in the artwork are situated at the end of the snout, more like a crocodile. Could this just be a mistake? Li (pers. comm. 2018; Li R, to Wang Q, pers. comm. 31st May 2018, IVPP, Beijing, an interview) could not recall from memory. However, this raises the point that during the early stages of paleoart in China, artistic expression and scientific accuracy still struggled to synchronize.

The Jurassic section of the mural is occupied by many dinosaurs discovered in the Dashanpu locality, Sichuan Province since the 1970s (Table 2). Depicted with rich vegetation and groups of dinosaurs roaming the horizon, this section represents the summit of dinosaur diversity and size (Figs. 11, 12). Two large individuals, *Mamenchisaurus* sp. and *Yangchuanosaurus shangyouensis*, form an unforgettable combat scene (Fig. 12). Another interesting figure is a small jade-colored feathered *Archaeopteryx* (Fig. 12). As a species never found in China, it is obviously another nod to the work of Western paleontology pioneers (Dong and Tang 1983; Dong 1985).

The Jurassic section is linked to the Cretaceous scene. The Jehol Biota, located mainly in the western area of Liaoning Province, represents the Chinese fauna of the Early Cretaceous. Although this fossil site is now globally famous for its ground-breaking discoveries of feathered dinosaurs and Mesozoic birds (plus many other new species), it was poorly known in 1994. The scientific community had to wait two more years until the stunning discovery in 1996 of the first feathered dinosaur *Sinosauropteryx prima* (Chen *et al.* 1998). Dozens of other feathered species were subsequently described from Liaoning Province (Sullivan *et al*. 2015), but these are absent in the mural (Fig. 13). Therefore, this section looks unattractive and bleak compared to the rest of the mural.

The landscape is depicted as a bare bank of a brook (Fig. 13), which is different from our current understanding of this ecosystem, formed by large lakes surrounded by dense vegetation (Wang *et al.* 2018). Typical species, like a group of *Lycoptera davidi* fish, can be identified clearly in the foreground. Nearby, a bird, *Cathayornis*

Figure 11. Detail from the Jurassic section of the Mesozoic mural. From left to right, *Bellusaurus sui* (pair in background), *Monolophosaurus jiangi, Sinobrachyops placenticephalus* (partly hidden in the undergrowth), *Tuojiangosaurus multispinus, Chengyuchelys zigongensis* (emerging from the water), *Teleosaurus* sp., *Angustinaripterus longicephalus* (pair in flight), *Omeisaurus* sp. (herd in background), *Hsisosuchus chungkingensis*, and *Shunosaurus lii*. Note how the position of the Monolophosaurus tail appears to have been adjusted, with the original position marked by a slightly blurred area that connects the body to a 'floating' tail tip that remains above the pair of *Bellusaurus*. A similar artifact suggests the *Huayangosaurus* head and neck may have also been significantly adjusted.

Figure 12. Detail from the Jurassic section of the Mesozoic mural. From left to right (excluding background creatures), *Tuojiangosaurus multispinus, Mamenchisaurus* sp., *Yangchuanosaurus shangyouensis, Archaeopteryx* sp.

Figure 13. Detail from the Cretaceous section of the Mesozoic mural. From left to right, an *Iguanodon*-like dinosaur, unidentified theropods (x3 in background), *Cathayornis yandica, Lycoptera davidi* fish, *Psittacosaurus* sp. (pair in background), *Ikechosaurus* sp., *Psittacosaurus* sp. (pair in foreground), *Wuerhosaurus homheni*, and *Dsungaripterus weii*. Note also the blossom tree at the bottom left.

yandica, perches on the muddy bank (Fig. 13). It was described in 1992 as one of the first Mesozoic birds ever found in China (Zhou *et al.* 1992). It is the only feathered species in the Jehol Biota scene, hinting at the spectacular array of feathered dinosaur and bird fossils that would later be unearthed from Liaoning Province to reshape our understanding of dinosaur diversity, behavior, and evolution (Smith and Wang 2017). Further to the right of the mural, a smooth-skinned *Oviraptor* is depicted roosting on a nest (Fig. 14). We now know bird-like oviraptorosaur dinosaurs like *Oviraptor* were also covered in feathers (Persons *et al.* 2014).

Another interesting part of this section of the mural is two strange species. One is a tree full of white flowers standing in the foreground as the border between the Jurassic and Cretaceous, and behind it, an *Iguanodon*-like dinosaur approaching the brook (Fig. 13). In 1994, no flowering plants or *Iguanodon*-like dinosaurs were known from the Jehol Biota. However, in 1998, *Archaefructus liaoningensis* was described by Ge Sun in the Early Cretaceous deposit of Beipiao, Liaoning Province, as the first flower on Earth (Sun *et al.* 2002). Further, in 2001, the hadrosauroid *Jinzhousaurus yangi* was described by Xiaolin Wang and Xing Xu (Wang and Xu 2001). Although the large arbor blossom tree on the mural is very different from the tiny hydrophytic *Archaefructus*, these remarkable figures stand as impressive predictions (Zhou and Wang 2010).

These scenes are followed by a disastrous view of mass volcanic eruptions, suffocated dinosaurs and unidentified mouse-like mammals feeding on dinosaur carcasses. This is the end of the age of dinosaurs represented by the Wangshi Fauna from Shandong Province. In this Late Cretaceous scene, *Tsintaosaurus spinorhinus* is a star (Fig. 14). As one of the best-known dinosaurs from China, this strange-looking hadrosaur with a spine on its head was found in Laiyang City, Shandong Province, and was named by Chungchien Young in 1958. The spine was later reinterpreted as part of a larger crest (Prieto-Márquez and Wagner 2013), so the mural preserves a historical record of an outdated

Figure 14. Detail from the Cretaceous section of the Mesozoic mural. From left to right: *Kelmayisaurus petrolicus*, *Pinacosaurus granger*, Oviraptor sp., an unidentified tyrannosaurid dinosaur, *Protoceratops andrewsi*, and *Tsintaosaurus spinorhinus*.

depiction of this dinosaur.

Alongside the *Tsintaosaurus* is a Tyrannosaurid-like theropod (Fig. 14). *Tyrannosaurus* is an iconic and well-known North American dinosaur, and probably the most famous dinosaur in the world. Several Chinese species of Tyrannosauridae had been named before 1994, although they were based on sparse material and are considered *nomina dubia* today, so this animal might be a reference to these. The largest member of the family ever found in Asia – *Zhuchengtyrannus magnus* – was later described in 2011 (Hone *et al.* 2011).

Pertinence of the Cenozoic World

The mural on the second floor depicts the Cenozoic Era with mammals as the central focus (Fig. 15). It is 22 m long and 2 m high, covering an area of 44 m^2. There are only 26 species on the mural, represented by 62 individual figures, and all the species can be confidently identified (Table 3). Three periods, Paleogene, Neogene, and Quaternary, are combined in a continuous landscape, with large animals – *Dzungariotherium* and *Stegodon* – placed to mark the boundaries between the periods. With no obvious predictions or poetic metaphors, this mural is a pertinent reflection of the state of mammal paleontology in China before the 1990s.

Broadly speaking, this mural feels much emptier than the others, and although the landscape is as deep as the other murals, it generally lacks details. The early Paleogene (Paleocene and Eocene) is the only section covered by dense vegetation (Fig. 16). The late Paleogene (Oligocene) looks like the landscape of the present-day Africa savannah (Fig. 17), the Neogene (Miocene and Pliocene)

Figure 15. The full Cenozoic Era mural. It is 22 m long and 2 m high, covering an area of 44 m^2.

Figure 16. Detail from the Paleogene section of the Cenozoic mural. From left to right, *Yantanglestes datangensis*, *Uintatherium insperatus* (pair), *Archaeomergx* sp., and *Rhinotitan mongoliensis* (pair).

Figure 17. Detail from the Paleogene section of the Cenozoic mural. From left to right, *Embolotherium* sp. (x3), *Amynodon* sp., and *Dzungariotherium* sp.

looks like an oasis in the modern Gobi Desert (Figs 18, 19), and the Quaternary (Pleistocene and Holocene) landscape is depicted as an ice age (Figs 2, 20). Compared to the sparse vegetation, the topographic features are relatively rich. The artist has tried to fuse forests, rivers, ponds, hills, mountains, deserts, and glaciers together. Individual animals are placed in different ecological niches. For instance, an *Amynodon* sp. is portrayed in water to highlight its hippo-like semiaquatic lifestyle (Savage and Long 1986) (Fig. 17). The giant prehistoric panda *Ailuropoda wulingshanensis* is depicted living in a bamboo bush, with a similar behavior and distinctive color as modern pandas (Fig. 20). However, the transitions between the different ecological niches are not always smooth.

Figure 18. Detail from the Neogene section of the Cenozoic mural depicting a watering hole scene. From left to right, *Platybelodon granger* (x3), *Kubanochoerus gigas*, and *Chilotherium wimani*.

Figure 19. Detail from the Neogene section of the Cenozoic mural. From left to right, *Tsaidamotherium hedini* (x3, including one under attack), *Amphimachairodus palanderi* (x2), a herd of *Hipparion* sp., and a pack of Dinocrocuta gigantea feeding.

Figure 20. Detail from the Quaternary section of the Cenozoic mural. From left to right, *Stegodon zdanskyi, Ailuropoda wulingshanensis*, *Megaloceros (Sinomegaceros) pachyosteus* and *Ovis ammon*. The *Stegodon* was included to echo the skeleton displayed as a centerpiece in the gallery. Note the abrupt change in the landscape from grassland to ice field.

The bamboo bush growing around *Ailuropoda* appears to link with the desert too abruptly. There is also a scene of *Megaloceros (Sinomegaceros) pachyosteus* – this deer with giant antlers stands on a patch of grassland only as big as its shadow (Fig. 20). Next to its tiny niche, there is an extensive ice field that passes abruptly behind the deer (Fig. 20). This kind of sudden change is absent in the other two murals and could confuse or mislead visitors.

The mural also has a strong mammal bias. There are no birds, reptiles, fish, amphibians, or invertebrates, despite extensive Cenozoic fossil records of these animals in China. For instance, Lianhai Hou identified about 108 bird species from the Pleistocene deposit of Zhoukoudian, Beijing since the 1960s (Hou 2018). The mural has therefore failed to demonstrate this biodiversity. The reason for the absence of non-mammal groups is unknown, but during the 20th century it was typical for Cenozoic scenes to focus on mammals to the exclusion of other taxa, so Li may have simply been following in the footsteps of earlier paleoartists in this regard.

Another strong feature of the Cenozoic mural is its strict China focus. If *Archaeopteryx*, *Dunkleosteus,* and perhaps *T. rex* in the other murals provide windows onto international paleontology, this same window is shut in the age of mammals. Most of the figures on the mural are from northern China except for a small group on the far left of the mural, including *Lofochaius brachyodus, Bemalambda nanhsiungensis and Yantanglestes datangensis* (Fig. 15), which were discovered from Nanxiong, Guangdong Province in Southern China. The relevant scientific studies on these deposits were led by Mingzhen Zhou in the 1960s (Li C 2009; Wang 1976; Tong et al. 2003), and this small southern group represents the entire Paleocene scene on the mural. Adjacent to them, the

Eocene and Oligocene are represented by some of the largest herbivores – *Uintatherium insperatus* (Fig. 16), *Rhinotitan mongoliensis* (Fig. 16), and *Embolotherium* sp (Fig. 17) (Wang et al. 1999).

Almost all the animals representing the Neogene are from Linxia Basin, Gansu Province in Northern China, where a well-preserved Cenozoic stratigraphic sequence from Oligocene to Holocene has been known since the 1950s. The significant *Platybelodon* Fauna (Fig. 18) and *Hipparion* Fauna (Fig. 19) are all depicted. A hunting scene between *Machairodus palanderi* and *Tsaidamotherium hedini* provides an eye-catching centerpiece (Deng et al. 2004) (Fig. 19).

The Quaternary part is composed of a few large individual figures including *Stegodon zdanskyi* (Fig. 20), *Megaloceros (Sinomegaloceros) pachyosteus* **(**Fig. 20), *Coelodonta nihowanensis* (Deng 2015) and *Mammuthus primigenius* (Fig. 2). Among them, the *Stegodon zdanskyi* image echoes the central exhibition in the associated gallery, of which an entire skeleton of this animal is on display, discovered in Gansu Province by Junyi Xie in 1973. Regarded as one of the most prominent achievements in Chinese paleontology (Li 1994), this animal is portrayed as an outstanding figure on the mural (Fig. 20). There are three small figures of *Homo sapiens* on the right end of the mural, appear to be excited about building a fire (Fig. 2). They apparently represent the dawn of the 'Age of Man'. However, the iconic Peking Man (*Homo erectus pekinensis*) is inexplicably excluded (Wu and Xu 2015).

Li managed to use the 26 species found in China to fill the mural. However, given the available space, it would have been possible to include several iconic species from elsewhere in the world, which some visitors might expect to see in the mural. For example, well-known prehistoric mammals such as *Megatherium* or *Glyptodon* from Argentina, *Arsnoitherium* or *Basilosaurus* from Egypt, and the semi-aquatic *Pakicetus* from neighboring Pakistan, could have been added to enrich the entire mural, as in the other two murals.

This mural was the last one to be completed and it seems likely that both the time and patience of the young artists from the China Central Academy of Fine Arts had worn out by this time. The paint is the thinnest and the shade, color, and texture of each figure is noticeably diminished compared to the other murals.

Paleoart Memes, Copying, and Quality

Despite their many obvious original artistic creations, the murals in Beijing also manifest similarities with previous famous works of paleoart, which could be considered problematic. According to British paleoartist Robert Nicholls, the imitation of paleoart can be divided into two types: pure copying and meme perpetuation (Nicholls pers. comm. 2018, Nicholls R, to Wang Q, pers. comm. 23rd April 2018, IVPP Beijing, an interview)and see Witton *et al.* 2014). The former is an absolute copy of the original images, while the latter uses the original images as a strong reference for pose, composition, posture and color (Witton 2018). Both approaches can be seen on these murals (Nicholls pers. comm. 2018; Nicholls R, to Wang Q, pers. comm. 23rd April 2018, IVPP Beijing, an interview).

The Paleozoic mural is not particularly heavily affected by copying or meme perpetuation. The figures of trilobites, orthoceratids and acanthodians (Fig. 7) are similar to famous works by Burian from the 1970s (see Špinar 1972, p56–62) so they were probably used as a loose reference, but this mural appears to mostly reflect Rongshan Li's original creation.

The Mesozoic mural contains several pure copies. In the Permian-Triassic scene (Fig. 9), *Shihtienfenia permica* and the unidentified therapsid are direct copies of *Scutosaurus* and *Sauroctonus* by

Burian (see Špinar 1972, p86–87). Two individuals of the three *Lufengosaurus* in the background (Fig. 10) are direct copies of *Plateosaurus* from Zallinger's Age of the Reptiles mural (see Volpe 2007, p35). In the Cretaceous scene, an *Iguanodon*-like dinosaur (Fig. 13) is a direct copy of British paleoartist John Sibbick (see Norman 1991, p161), and other dinosaur species (e.g. *Protoceratops*) have been inspired by Sibbick's artwork (Fig. 14). There are also some paleo-meme perpetuations in this mural. In the Jurassic scene, the pose of the *Teleosaurus* sp. raising its head towards the sky (Fig. 11) contains references to Burian's image of *Steneosaurus bollensis* (see Špinar 1972, p109). The facial expression of the largest *Gasosaurus constructus,* near the blossom tree, appears to be inspired by Neave Parker's *Tyrannosaurus rex* (see Lescaze 2017, pp194, 205). The blue and green color of the *Archaeopteryx* sp. (Fig. 12) is also inspired by Burian (Špinar 1972, p115). To the right end of the mural, a few emaciated dinosaur carcasses (Fig. 1) are heavily inspired by Ely Kish's work depicting dead *Diplodocus* (see Lescaze 2017,).

On the Cenozoic mural Burian's work has been widely referenced for many of the prehistoric mammals, notably the *Uintatherium insperatus* (Fig. 16), *Dzungariotherium* sp. (Fig. 17)*, Platybelodon granger* (Fig .18), *Amphimachairodus palanderi* (Fig. 19), *Megaloceros pachyosteus* (Fig. 20), *Coelodonta nihowanensis* (Fig 2), and *Mammuthus primigenius* (Fig. 2). Although it is difficult to identify any direct copies of other artists' work on this mural, meme perpetuation is ubiquitous.

Copying and meme perpetuation are widespread in the field of paleoart, especially in the work of non-specialist illustrators employed to depict prehistoric animals (Witton 2018). However, this practice undermines the rigorous scientific approach used by professional paleoartists and overlooks new research (Witton 2018). The murals in Beijing must be interpreted in context, and 'paleoart' was still a budding concept in China when the murals were composed in 1994. Although Chengru Feng established scientific art in the Chinese Academy of Sciences as early as the 1920s, these earliest works were mainly depictions of botanical specimens (Science in Art Frame n.d.). Reconstruction of prehistoric creatures was not systematically considered by Chinese scientists until the discovery of *Lufengosaurus* by Chungchien Young in 1938. In 1940, Young drew a reconstruction of the *Lufengosaurus* (Young 1941). Although the image was only an outline of the body around a skeleton, it could be considered the first paleoart made by a Chinese scientist.

Before the 1990s, the field of Chinese paleoart had limitations, including a lack of international communication, a lack of understanding of the modern paleoart process, and marginal attention from the broader scientific society. Therefore, it naturally became a standard approach for the early generation of Chinese paleoartists to learn by simulation and copying established Western paleoartists. Despite these restrictions, they still endeavored to create original impressive paleoart where necessary, while referencing the works of established Western paleoartists for some of the creatures. This important effort of the early generation should therefore be recognized.

Another obvious problem of these murals is the painting quality. The murals were painted relatively quickly, based on Li's scaled-down paintings, by inexperienced apprentice artists from the China Central Academy of Fine Arts. The obvious difference in the painting skills in the young artists' work could neither match Li's vision nor satisfy the IVPP's expectations. Li had to repaint many of the individual figures afterward, working until the very last minute before the official opening of the gallery. However, Li did not have enough time

to complete all the repainting work: "I still feel disappointed. They are unique, but I didn't have time to make them perfect," he remarked (Li pers. comm. 2018, Li R, to Wang Q, pers. comm. 31st May 2018, IVPP, Beijing, an interview)

)). This explains why the general quality of the murals is compromised, and the quality varies between the different murals and across parts of the same mural. It is sometimes obvious where one painting style begins and another ends, so Li's subsequent effort to improve the quality of individual figures has slightly damaged the holistic artistic effect.

Geoparks in China

The murals provide a snapshot of paleontological knowledge in China in 1994, and they record some important fossil-bearing sites in China known at the time. There is a growing list of almost 300 National Geoparks in China (289 according to Xu and Wu [2022]; 272 according to Luan and Wang [2022]). By 2022, 41 were designated UNESCO Global Geoparks (Luan and Wang 2022; Xu and Wu 2022), and an additional six new sites in 2024 increased the tally to 47. Thirty-two of the National Geoparks in China are categorized as significant for their paleontology (Luan and Wang 2022) and each is regarded as an "important fossil site" (Xu and Wu 2022). In addition, there are many other non-protected major fossil sites in China, Sullivan *et al.* (2015) list 79 in total. The murals predate the establishment of UNESCO Global Geoparks, as well as the National Geoparks of China, but several of these important sites are represented in the murals (Tables 1,2,3).

Conclusions

The PMC murals are an integral feature of the museum that provides a visual narrative of paleontology and geological 'deep time' in China. The murals are an adherent agent that synchronize its exhibits, spaces, stories, and people as one holistic system. They help non-professionals to 'read' the enigma of fossils and the vast and complex time scale. Moreover, they help to create a particular atmosphere in the museum by transporting its galleries into a prehistoric world setting. Although the animal figures on the mural may appear out-of-date, and despite certain deficiencies in the quality of the painting and the issue of originality, the murals still provide high social and scientific values.

First, it can be argued they are the only large-scale paleoart murals in any museum that represent the entire process of evolution. The exceptional content of the whole evolutionary history of life during the Phanerozoic Eon fits the exhibition narrative of the museum spatially and chronologically, which provides considerable support to aid the visitors' understanding. Second, they provide a loyal record of the early development of vertebrate paleontology in China. By depicting figures of prehistoric animals and ecosystems found in China from different sites, including important National and Global Geoparks, the murals provide a visual interpretation and documentation for the objects displayed in the thematic galleries. Third, as a significant part of the atmospheric narrative in the museum, they have provided a comprehensive service of science popularization to the public since 1994, increasing the impact and efficiency of informal learning.

Further, the murals reflect the practical application of different museology and space study theories. The prolonged layout of these murals creates a continuous vision that is like the experience when a person watches a movie or walks through a city. This phenomenon makes people 'feel surrounded, enveloped and potentially annihilated' (White 2012, p221), which echoes the concept of the 'Immersive Museum'. It also creates '...an art of relationship… to take all the elements that go to create the environment… and to weave them together in

such a way that drama is released' (Cullen 1968). Based on these experiences, 'a powerful effect of synaesthesia between knowledge, imagination and association will be encouraged' among the visitors, a concept in museums known as 'minds-on' exhibition, which suggests a heuristic and self-orientated learning experience where the visitors can actively create their own stories (Wang and Lei 2016). These theories share a common idea, that to capture the visitors' attention and to facilitate social and cultural activities, tangible objects in the museum should be closely integrated. Through this, people are more likely to perceive the physical attributes of a gallery and the psychological echo of the exhibition as an interconnected entity (Hakvoort 2013). The PMC murals have certainly not disappointed their curators in this respect.

Today a new generation of Chinese paleoartists is emerging, represented by Chuang Zhao from the Pecking Nature Science Organization (PNSO), Yong Xu and Xiaocong Guo from the IVPP, and Chungtat Cheung from the Dino-Soar Studio in Hong Kong. They are taking advantage of the scientifically productive time for paleontology in contemporary China to compose innovative paleoart works. The growing influence of their works suggests their effort is generating a new trajectory for international paleoart development. However, this new achievement should not cast a shadow on the old, and the murals in the Paleozoological Museum of China preserve a considerable milestone in the early phase of Chinese paleoart that remains worthy of wider awareness and merit. Like all atmospheric paleoart in museums, the PMC murals enhance the exhibition narrative and play a vital educational role by placing the surrounding fossils into a broader context. They provide visitors with a visual window into our *prehistoric past* at particular times and places, simultaneously recording a cultural snapshot of the state of *paleontology* in a specific historic time and place. So, despite some shortcomings evident in these murals, the PMC plans to keep them as a permanent memorial of the development of paleontology in China.

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Author Contributions

Wang Qi devised the concept for this work and generated an early draft of the article with input from Wang Yuan and Adam Smith. Wang Yuan and Wang Qi identified the species and geological settings in the murals, compiled the tables, and organized high-resolution photographs to be taken of the murals. After Wang Qi passed away, Adam Smith adapted the paper into its final form with input from Wang Yuan. Specifically, Wang Qi led the 'Introduction' section, 'The Three Murals' section, and the 'Conclusions' section with input from Wang Yuan and Adam Smith. Wang Yuan led the 'History of the PMC Murals' section with input from Wang Qi. Adam Smith led the 'Atmospheric Paleoart: A Review' section, the 'Paleoart Memes, Copying, and Quality'

section, and the 'GeoParks in China' section, with input from Wang Qi and Wang Yuan. All three co-authors contributed to editing the whole manuscript. Adam Smith cropped the mural images into individual figures and wrote the figure captions.

Conflict of interest statement

The authors declare that there are no conflicts of interest associated with this study.

References

Carrano MT, Johnson KR (2019). Visions of lost worlds: The paleoart of Jay Matternes. Washington DC: Smithsonian Books.

Czerkas SM, Glut DF (1982). Dinosaurs, Mammoths and Cavemen: The art of Charles R. Knight. New York: E P Dutton

Chang M (1982). The braincase of Youngolepis, a lower Devonian crossopterygian from Yunnan, southwestern China. Unpublished PhD Thesis, Stockholm University.

Chen Y, Cui G (1989). ,A general introduction of prehistoric fishes of Yunnan (in Chinese). Sichuan Journal of Zoology. 8(1): 27–29.

Chen P, Dong Z, Zhen S (1998). An exceptionally well-preserved theropod dinosaur from the Yixian Formation of China. Nature. 391: 147–152.

Cullen G (1968). The concise townscape, 5th ed. London: The Architectural Press

Hone D et al. (2011). A new, large tyrannosaurine theropod from the Upper Cretaceous of China. Cretaceous Research. 32: 495–503. https://doi.org/10.1016/j.cretres.2011.03.005

Dean D (1999). Gideon Mantell and the discovery of dinosaurs. Cambridge: Cambridge University Press

Debus AA, Debus DE (2002). Paleoimagery: The evolution of dinosaurs in art. Jefferson: McFarland & Company, Inc., Publishers

Deng T, Wang X, NI X, Liu L, Liang Z (2004). Cenozoic stratigraphic sequence of the Linxia Basin in Gansu, China and its evidence from mammal fossils. Vertebrata PalAsiatica. 42: 45–66.

Deng T (2015). Chinese Neogene rhinoceroses. Shanghai: Shanghai Scientific & Technical Publishers

Dong Z, Tang Z (1983). Note on the new Mid-Jurassic ornithopod from Sichuan Basin, China. Vertebrata PalAsiatica. 21: 168–172.

Dong Z (1972). An ichthyosaur fossil from the Qomolangma Feng (Mt. Everest), region. Memoirs of IVPP Academia Sinica. 9: 7–10.

Dong Z (1985). A Middle Jurassic labyrinthodont (Sinobrachyops placenticephalus gen. et sp.

nov.) from Dashanpu, Zigong, Sichuan Province. Vertebrata PalAsiatica. 23: 301–306.

Goldfuss GA (1826–1844). Petrefacta Germaniae tam ea quae in Museo Universitatis Regiae Borussicae Fridericiae Wilhelmiae Rhenanae servantur quam alia quaecunque in Museis Hoeninghusiano Muensteriano aliisque extant, iconibus et descriptionibus illustrate. Dusseldorf: List & Francke

Hakvoort G (2013). The immersive museum. ITS'13, Proceedings of the 2013 ACM international Conference on Interactive Tabletops and Surfaces. 463–468. https://doi.org/10.1145/2512349.2514598

Hou L (2018). The bird fossils in Zhoukoudian site determined my research field. http://www.beijing.gov.cn/renwen/zt/zkd/ksz/t1558299.htm. Retrieved on 3rd Apr. 2019. (in Chinese)

Jin F (2006). An overview of Triassic fishes from China. Vertebrata Palasiatica. 44: 28–42.

Lescaze Z (2017). Paleoart: visions of the prehistoric past. Köln: Taschen

Li C (2009). The story of the fellow of Chinese Academy of Sciences – Zhou Mingzhen. In Gao X & Zhang Y (eds), An article collection of the 80 years anniversary of IVPP of Chinese Academy of Sciences. Beijing: China Ocean Press. (in Chinese)

Li C (2014). Diary of a digger – a paleontologist's journey into the wild. Shanghai: Shanghai Scientific & Technical Publishers. (in Chinese)

Li J, Cheng Z (1999). New anthracosaur and temnospondyl amphibians from Gansu, China – the Fifth Report on Late Permian Dashankou lower tetrapod fauna. Vertebrata Palasiatica. 37: 234–247.

Li J (2009). The people and story about the research of primitive tetrapods of Permian and Triassic in China.. In Gao X & Zhang Y (eds), An article collection of the 80 years anniversary of IVPP of Chinese Academy of Sciences. Beijing: China Ocean Press. (in Chinese)

Li J (1994). The "Yellow River Elephant" Stegodon – the largest prehistoric elephant of China. China Nature. 5–7. (in Chinese)

Liu J, et al. (2012). The horizon of Dashankou Fauna and the Permo-Triassic strata in Northern Qilian area, China. Vertebrata PalAsiatica. 50: 373-381.(in Chinese)

Liu X, Chang M (1963). The discovery of Helicoprionidae fossil in China. Vertebrata PalAsiatica. 7: 123–129. (in Chinese)

Liu X (1955). The first discovery of Arthrodira fish fossil in China. Acta Paleontologica Sinica. 3: 19–97. (in Chiense)

Liu Y, Gai Z, Zhu M (2018). New findings of galeaspids (Agnatha) from the Lower Devonian of Qujing, Yunnan, China. Vertebrata PalAsiatica. 56: 1–15.

Lu J, Zhu M, Ahlberg PE, Qiao T, Zhu YA, Zhao W, Jia L (2016). A Devonian predatory fish provides insights into the early evolution of modern sarcopterygians. Science Advances. 2: e1600154. DOI: 10.1126/sciadv.1600154

Luan F, Wang F (2022). Classification, spatial distribution pattern, forming reasons, and driving forces of National Geoparks in China. Geoheritage. 14:52. https://doi.org/10.1007/s12371-022-00675-y

Milner R (2012). Charles R. Knight: The artist who saw through time. New York: Abrams

Norman D (1991). Dinosaur! London: Boxtree Limited.

Parrish M (2014). Memories of John Gurche at the National Museum of Natural History. Journal of Natural Science Illustration. 2014: 1.

Persons WS IV, Currie PJ, Norell MA. (2014). Oviraptorosaur tail forms and functions. Acta Paleontologica Polonica. 59(3): 553–567.

Prieto-Márquez A, Wagner JR (2013). The 'unicorn' dinosaur that wasn't: A new reconstruction of the crest of Tsintaosaurus and the early evolution of the lambeosaurine crest and rostrum. PLoS ONE 8(11): e82268. https://doi.org/10.1371/journal.pone.0082268

PSC (Paleontological Society of China) (2014). The history of paleontology of China. Beijing: China Science and Technology Press. (in Chinese)

Qian Y, Wang Y (2004). Chinese academic canon in the 20th century – Biology, Paleontology. Fuzho: Fujian Education Press

Qui Z, to Wang Q, pers. comm. April 2018, IVPP Beijing

Rudwick M (1997). Georges Cuvier, fossil bones and geological catastrophes: New translations and interpretations of the primary texts. Chicago: The University of Chicago

Savage R, Long M (1986). Mammal evolution: An illustrated guide. New York: Facts on File Publications

Science in Art Frame (n.d.) – the first scientific art exhibition of the Chinese Academy of Sciences, Exhibition, 18th May – 5th June 2018, Beijing Natural History Museum

Smith AS, Wang Q (2017). Dinosaurs of China: Ground shakers to feathered flyers. Nottingham: Nottingham City Council

Smith AS, Wang Q, Evans R (2020). From China to Nottingham: The making of Dinosaurs of China. Journal of Natural Science Collections. 7: 3–16.

Špinar Z (1972). Life before man. London: Thames and Hudson

Stout W (2009). William Stout: prehistoric life murals. Santa Cruz: Flesk Publications

Sullivan C, et al. (2015). From fish to human: The march of vertebrate life in China. Beijing: Popular Science Press

Sun A, Cui G, Li Y, Wu X (1985). A verified list of Lufeng saurischian fauna. Vertebrata PalAsiatica, 23: 1–12.

Sun G, Ji Q, Dilcher D L, Zheng S, Nixon K C, Wang X (2002). Archaefructaceae, a new basal angiosperm family. Science. 296: 899–904.

Tetlie E, et al. (2007). A new Silurian eurypterid (Arthropoda: Chelicerata) from China. Paleontology. 50: 619–625.

Tong Y, et al. (2003). Yuesthonyx, A new tillodont (Mammalia) from the Paleocene of Henan. Vertebrata PalAsiatica. 41: 55–65.

Volpe R (2007). The age of reptiles: The art and science of Rudolph Zallinger's great dinosaur mural at Yale, Peabody Museum of Natural History. New Haven: Yale University.

Wang B (1976). Late Paleocene mesonychids from Nanxiong Basin, Guangdong, Vertebrata PalAsiatica. 14: 259–262.

Wang Q, Lei Y (2016). Minds on for the wise: rethinking the contemporary interactive exhibition, Museum Management and Curatorship. 31: 331–348.

Wang X, Xu X (2001). A new Iguanodontid (Jinzhousaurus yangi gen. et sp. nov.) from the Yixian Formation of Western Liaoning, China. Chinese Science Bulletin. 46: 1669–1672.

Wang Y, Guo J, Wang J (1999). A review of Chinese brontotheres. In Wang Y & Deng T (eds), Proceedings of the Seventh Annual Meeting of the Chinese Society of Vertebrate Paleontology (pp. 139–147). China Ocean Press: Beijing

Wang Y, Ge X, Xing L, Xie D, Ma N (2018). Listening to the stories of fossils. Beijing: Popular Science Press. (in Chinese)

White G (2012). On immersive theatre. Theatre Research International. 37(3): 221–235.

Witton M (2018). The paleoartist's handbook:

Recreating prehistoric animals in art: Marlborough: The Crowood Press

Witton MP, Naish D, Conway J)2014(. State of the Paleoart. Paleontologia Electronica. 17(3): 5E.

Wu X, Xu X (2015). The secrets of the prehistoric human. Beijing: Foreign Language Teaching and Research Press. (in Chinese)

Xu K, Wu W (2022). Geoparks and geotourism in China: A sustainable approach to geoheritage conservation and local development—a review. Land. 11: 1493. https://doi.org/10.3390/land11091493

Young CC (1939). The process and meaning of the discovery of Lufengosaurus, Science, 23: 693–696. (in Chinese)

Young CC (1941). The collection, preparation and study about the Lufengosaurus huenei. Original manuscript and hand-drawing, in Chamber of Bone Study. 340. (in Chinese)

Zhou Z, Wang Y (2010). A study about the biodiversity of vertebrate animals in Jehol Biota and the comparison with other biotas. Science China. 40: 1250–1265. (in Chinese)

Zhou Z, et al. (1992). Preliminary report on a Mesozoic bird from Liaoning, China. Chinese Science Bulletin. 37: 1365–1368.