THE JEHOL BIOTA

The Emergence of Feathered Dinosaurs, Beaked Birds and Flowering Plants

Editor-in-chief: Mee-mann Chang
Co-editors: Pei-ji Chen
Yuan-qing Wang
Yuan Wang
English editor: De-sui Miao

Shanghai Scientific & Technical Publishers

The Jehol Biota
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Published by Shanghai Scientific & Technical Publishers
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ISBN: 7-5323-7318-5/Q · 90
Printed in China

主　　编　张弥曼
副 主 编　陈丕基　王元青　王　原

责任编辑　叶　剑
装帧设计　戚永昌

地图审图号　沪S(2003)112号

上海科学技术出版社出版发行
(上海瑞金二路450号　邮政编码200020)
利丰雅高印刷（深圳）有限公司印刷
新华书店上海发行所经销
2003年12月第1版
2003年12月第1次印刷
书号　ISBN：7-5323-7318-5/Q·90
开本　889×1194　1/12
印张　17.5
插页　4
印数　1-2500
定价：350元

本书如有缺页、错装或坏损等严重质量问题，
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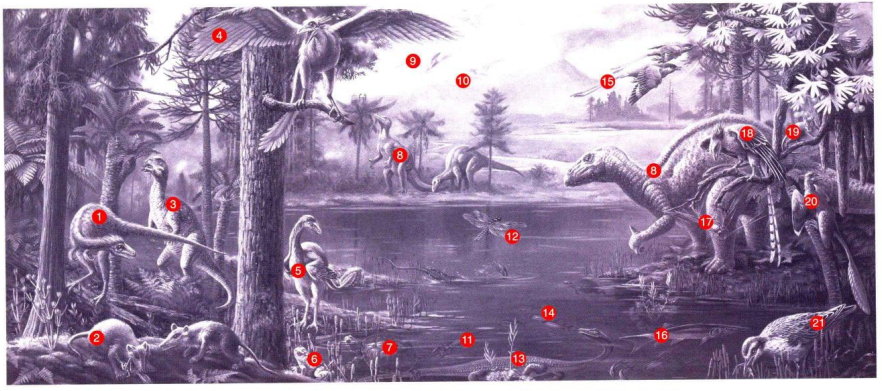
A PANORAMA OF THE JEHOL BIOTA Art: Xiao-lian Zeng/ KIB

Reconstruction of animal representatives of the Jehol Biota

1. *Sinosauropteryx prima* Ji et Ji, 1996 (¨feathered¨ dinosaur)
2. *Zhangheotherium quinquecuspidens* Hu, Wang, Luo et Li, 1997 (mammal)
3. *Psittacosaurus meileyingensis* Sereno, Zhao, Cheng et Rao, 1988 (dinosaur)
4. *Jeholornis prima* Zhou et Zhang, 2002 (bird)
5. *Caudipteryx dongi* Zhou et Wang, 2000 (feathered dinosaur)
6. *Callobatrachus sanyanensis* Wang et Gao, 1999 (frog)
7. *Manchurochelys liaoxiensis* Ji, 1995 (turtle)
8. *Jinzhousaurus yangi* Wang et Xu, 2001 (iguanodon)
9. *Haopterus gracilis* Wang et Lü, 2001 (pterosaur)
10. *Sinopterus dongi* Wang et Zhou, 2002 (pterosaur)
11. *Cricoidoscelosus aethus* Taylor, Schram et Shen, 1999 (crayfish)
12. *Aeschnidium heishankowense* (Hong, 1965) (dragonfly)
13. *Hyphalosaurus lingyuanensis* Gao, Tang et Wang, 1999 (aquatic reptile)
14. *Lycoptera* sp. (fish)
15. *Protopteryx fengningensis* Zhang et Zhou, 2000 (bird)
16. *Protopsephurus liui* Lu, 1994 (fish)
17. Araenidae indet. (spider)
18. *Confuciusornis sanctus* Hou, Zhou, Gu et Zhang, 1995 (bird)
19. *Eomaia scansoria* Ji, Luo, Yuan, Wible, Zhang et Georgi, 2002 (mammal)
20. *Microraptor gui* Xu, Zhou, Wang, Kuang, Zhang et Du, 2003 (¨four-winged¨ dinosaur)
21. *Yanornis martini* Zhou et Zhang, 2001 (bird)



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Sihetun Village
Photo: Jie Zhang/ IVPP

INTRODUCTION

Mee-mann Chang

Last decade has witnessed a renewed interest in the Jehol Biota both within the scientific community and among the general public worldwide. The numerous research papers on the Jehol Biota, published in the prestigious journals such as *Nature* and *Science*, have generated heated controversies among scientists and gained a widespread media frenzy. Here is a perfect example of Stephen J. Gould meeting Thomas S. Kuhn: a sudden "scientific revolution" has punctuated a long period of "normal science," with John Ostrom's revival of Thomas H. Huxley's theory of dinosaurian origin of birds as the new (or more precisely, renewed) paradigm. The discoveries of "feathered" dinosaurs in the Jehol Biota appear to have provided the direct evidence in support of the paradigm and therefore aroused public's intrigue in the notion of dinosaurs still being with us. Scientifically even more important is the Jehol Biota's well-preserved ancient biodiversity, which contains enormous amount of information on the paleoecosystem as well as many evolutionary issues.

We Chinese paleontologists have also had our turn of the wheel not only in those fabulous fossil finds but also in our poise to join our country's drive toward excellence in scientific research. To that end, I hope that this book bears some fruits. In the remainder of this chapter, I will present a brief history of the studies on the Jehol Biota, an outline of its main components, and a highlight of its scientific import.

"Jehol" is the transliteration of the two Chinese characters "热河" in the Wade-Giles romanization system of the Chinese language, which was used until 1979 when the spelling of proper nouns were officially adopted using the Pinyin (Chinese phonetic alphabet) system of romanization in the mainland of China. In the Pinyin system, these two characters are transliterated to "Rehe". However, we must abide by the "International Stratigraphic Guide" (1976) to continue to use the terms of Jehol Group and Jehol Biota (or Fauna). The literal meaning of the two Chinese characters "热河" is "Hot River", derived from many hot springs in the area. What are now called western Liaoning, northern Hebei and southeastern Inner Mongolia were municipally included in Jehol Province (Fig. 1) before 1956, when the provincial name was abolished. At present, the only historical reminder of the

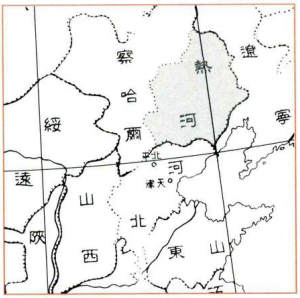

Fig. 1 Map of eastern China, the inset (taken from Ding, Weng & Zeng, eds., 1936. *New Map of Provinces of China*) showing the comparable area of the "Jehol Province" (shaded area), after which the Biota was named.

"Jehol" is the two characters engraved on a stone tablet in Rehe Hot Spring of the Chengde summer resort, originally built for the emperors of the Qing Dynasty to escape the midsummer heat in the Forbidden City (Fig. 2).

In his paper "Cretaceous Mollusca from North China" (1923), the American geologist Prof. Amadeus W. Grabau (Fig. 3) named the fossil-bearing strata in the vicinity of Lingyuan County (now Lingyuan city in western Liaoning Province) as "Jehol Series". And while studying the Mesozoic stratigraphy of China in 1928, he first used the name "Jehol Fauna". In 1962, after working on various deposits bearing the fossil fish *Lycoptera* from different areas of western Liaoning, Prof. Zhi-wei Gu (Fig. 4), a malacologist from the Nanjing Institute of Geology and Palaeontology, used the name "Jehol Group" for the strata containing the conchostracan *Eosestheria middendorfii* (previously known as *Bairdestheria middendorfii*), insect larva *Ephemeropsis* and fish *Lycoptera*. Accordingly, he called the biota "Jehol Biota" or, in short, the E.-E.-L. Biota (Fig. 5).

The late Mesozoic Jehol Biota and those comparable to it had a wide distribution over northern China, Mongolia, Transbaikalian region of Siberia, Korea, and Japan (Fig. 6). The size of this area almost approaches that of the present-day Europe. This late Mesozoic oasis provided favorable conditions for many ancient animals and plants to thrive. A series of NE/SW- oriented fault basins developed during the Yanshan Orogeny (mountain-building episode), and were filled with thick volcanic and fluvial-lacustrine deposits. It was probably because of the frequent volcanic eruptions that numerous plants and animals were rapidly buried and consequently, preserved as exquisite fossils. Their catastrophic misery has turned into our best luck today: we have collected not only complete skeletons but also soft parts , such as feathers, and featherlike structures preserved as impressions, and not only gizzard stones but also stomach contents, especially in Chaoyang and Beipiao regions of western Liaoning.

The earliest studied fossil from the Jehol Biota in western Liaoning is a small fish found in the vicinity of Lingyuan City. The material was collected by L'Abbé David, and named in 1880 by a French ichthyologist, H. E. Sauvage, as *Prolebias davidi*, then thought to be a Tertiary cyprinodont (pupfish). It was not until 1901 when the renowned British ichthyologist A. S. Woodward reassigned the fish to the Mesozoic *Lycoptera*, a genus endemic to Siberia, Mongolia, and northern China. To date, the described fossils of the Jehol Biota include over 60 species of plants, nearly 90 species of vertebrates,

Fig. 2 The Rehe Hot Spring in the Chengde summer resort. The two red characters on the stone tablet are "Jehol" in traditional Chinese.

and almost a thousand species of invertebrates. With the Jehol Biota being a hotbed of paleontological research at present, that number is increasing rapidly.

The Jehol Biota possesses the dual qualities that entice an unbridled enthusiasm from professionals and lay persons alike. The fossils are extremely well preserved, beautiful, and abundant. They have important implications on some key issues in evolution such as origin and early diversification of major groups like birds (Hou et al.,1995), mammals, and angiosperms (flowering plants), origin of avian flight, tempo and mode of evolution, paleobiogeography, paleoecology, and paleoenvironments.

The most notable among the recent fossil findings from western Liaoning are of course the "feathered" dinosaurs. Feathers had never been

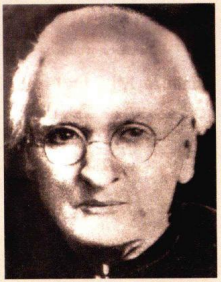

图3 Amadeus W. Grabau (1870~1946), an American geologist who proposed the "Jehol Fauna" in 1928. (Courtesy: Yuan-lin Sun/ PKU)

图4 Zhi-wei Gu (b.1918), a Chinese malacologist of the NIGP who proposed the "E.-E.-L. Biota" in 1962.

discovered previously in animals other than birds. Yet, feathers or featherlike structures have been found abundantly associated with a number of dinosaurs from Liaoning such as *Sinosauropteryx* (Chen et al.,1998), *Caudipteryx*, *Beipiaosaurus*, *Protarchaeopteryx*, *Sinornithosaurus*, and *Microraptor*. If we only look at the skeletons of these creatures, dinosaur workers would say without hesitation that they are dinosaurs. Yet all of them bear feathers or featherlike structures. Though somewhat bewildered at first, many paleontologists soon realized how significant these discoveries were: the feathers and featherlike structures found in those dinosaurs betrayed the dinosaurs' affinity to birds!

In fact, about 130 years ago, Thomas H. Huxley thought the dinosaur was the direct ancestor of birds. And a few daring scientists even predicted that feathers would sooner or later be found on dinosaurs. But that point of view had not received general acceptance. It was not until 1973 when Prof. John Ostrom at the Yale University studied the small theropod *Deinonychus*, and found that its skeleton was astonishingly similar to that of *Archaeopteryx*, the earliest bird. And he suggested that small theropods might be the ancestors of birds. Despite the many skeletal characters that relate dinosaurs with birds, for most people, nothing can be more convincing than actually seeing the dinosaurs covered with feathers. To those who are convinced that birds are direct descendants of dinosaurs, the feathered dinosaurs from western Liaoning are nothing but the "smoking gun". However, a vocal minority of leading paleornithologists still insists that birds came from a primitive group of reptiles called thecodonts. Besides, feathers and featherlike structures were found on dinosaurs that apparently could not fly. Then what are those feathers for? Were they for insulation, for camouflage, for courtship, or for defense? And how did the avian flight originate? Did the proto-birds attain their flight capability by walking and running on the ground and then raising their wings to fly ("ground-up" theory), or by gliding from the tree to learn how to fly ("tree-down" theory)? We cannot expect that all these questions, together with the origin of birds, be answered just with the discoveries of new materials. More careful and synthetic work has to be done before more persuasive hypotheses emerge on more solid ground. Admittedly, this kind of work is more tedious and less sensational, but it is truly exciting and intellectually stimulating. Contrariwise, clever argumentation and religious war are bound to be detrimental to the progress in science.

The fossil plants, especially angiosperms, from western Liaoning are also very interesting. The records of angiosperms can be traced back to the works of H. Yabe and S. Endo in 1930s. They described *Potamogeton jeholensis*. Due to the poor preservation of the material, little attention was paid to their work. Later, S. Miki (1964) questioned the identification of *Potamogeton*, and considered the plant as *Ranunculus* instead. More recently, Zheng-yao Cao and others (1997) and Shu-ying Duan (1997) reported monocots and fructification with carpels. Cao et al.'s *Liaoxia chenii* (Cyperaceae) and *Eragrosites changii* (Gramineae) were later designated as gnetales, a group of gymnosperm, by Shun-qing Wu (1999) and Shuang-xing Guo and Xiang-wu Wu (2000) while Duan's *Chaoyangia liangii* is probably also a gnetalean, not an angiosperm. Similar forms have been found in the Lower Cretaceous strata of Mongolia and were described by V. A. Krassilov (1982) under other names: *Cyperacites* sp., *Potamogeton*-like spike, and *Gurvanella dictyptera*.

Archaefructus liaoningensis was described by Ge Sun, D. L. Dilcher and others (1998) as an angiosperm although this is not yet unquestionably accepted by most paleobotanists. Its age, however, may not be the Late Jurassic, as these authors suggested, but is more likely to be the same, i.e., the Early Cretaceous, as that of the early angiosperms previously discovered from Europe, Mongolia and western North America. A more definite angiosperm *Sinocarpus decussatus* was described recently by Qin Leng and E. M. Friis (2003). Another significant plant from the Jehol Biota is a gymnosperm *Sequoia jeholensis*. And it is regarded as the oldest record of the genus. The genus is at present surviving only in California. For lacking cone and the leaf cuticular structure, it must be treated with caution at present. More recently, Zhi-yan Zhou and Shao-lin Zheng (2003) reported that the ovulate organs of *Ginkgo* from the Yixian Formation show striking similarities to those of the extant species *Ginkgo biloba*, indicating a morphological stasis in *Ginkgo's* reproductive structure for over 100 million years. With ever increased and better-preserved specimens, we anticipate more thorough paleobotanical research of the Jehol

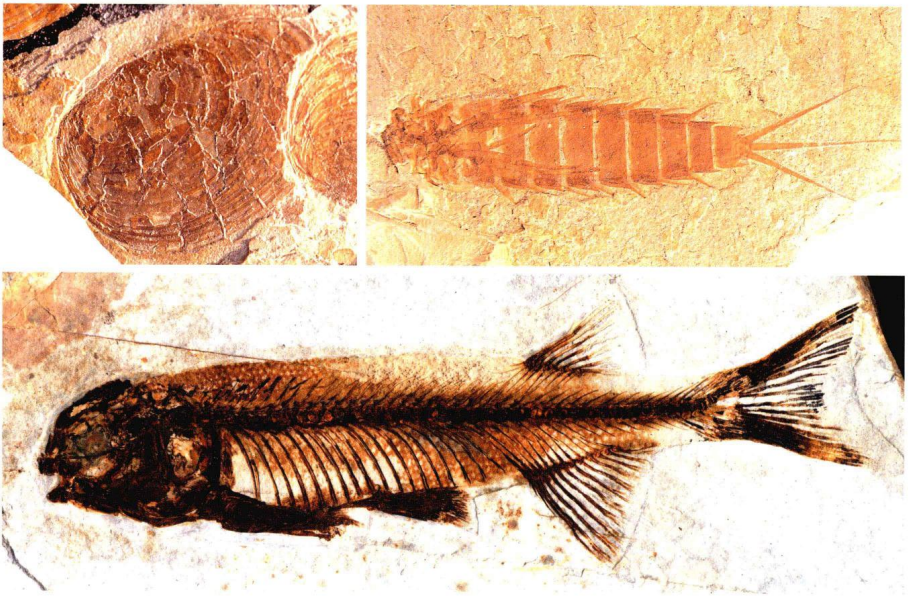

Fig. 5 Three representatives of the Jehol Biota in the early studies, the conchostracan *Eosestheria* (**Upper left**), insect larva *Ephemeropsis* (**Upper Right**) and fish *Lycoptera* (**Lower**). (Photo: IVPP)

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