NOTES

Liaoxiornis delicatus gen. et sp. nov., the smallest Mesozoic bird

HOU Lianhai[1] and CHEN Peiji[2]

1. *Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing* 100044, *China*;
2. *Nanjing Institute of Geology and Paleontology, Chinese Academy of Sciences, China*

Abstract Recently, a very small and complete bird specimen was collected from the *Confuciusornis*-bearing Yixian Formation. This finding represents a new kind of Mesozoic bird, named *Liaoxiornis delicatus*. It is characterized by a short skull with teeth, a long neck and a very small sternum with only posterior process; the humeral head is not internally curved, and the hindlimbs are longer than the forelimbs. *Liaoxiornis delicatus* is not only much smaller than *Confuciusornis*, but also smaller than *Cathayornis* and other early Cretaceous birds. It is the smallest bird known from Mesozoic deposit. *Liaoxiornis* provides new evidence indicating that the early adaptive radiation of birds is complicated.

Keywords: **Mesozoic, early bird, evolution of birds.**

RECENTLY, large findings of Chinese Mesozoic birds have caused great attention in the world[1]. While the *Confuciusornis* was further studied, one very small primitive bird has been collected. The skull was buried laterally. The postcranial skeleton was preserved dorsal-ventrally. Its forelimb has a advanced character and shows a relatively good flight ability, while its hindlimb with a relatively long femur shows primitive character; it has a long tail. All these indicate the disequilibrium in the evolution of early birds. The discovery of the small bird has also proved the varieties of the differentiation and the complexity of the evolution of the early birds and provides new important element for the famous erhol group.

Class Aves

Subclass Sauriurae

Liaoxiornis gen. nov.

Type species: *Liaoxiornis delicatus* sp. nov.

Diagnosis: Very small in body size, skull high and short, more than 6 teeth on each side of upper and lower jaws. The proximal end of the humerus not internally curved. The sternum small, mainly gingko-leaf-shaped, with low keel. No dorsal process on the schium. Pubis with a small pubic process. The femur longer than humerus, Phalange 3 (including claw) longer than the tarsometatarsus.

Locality, horizon and age: Dawangzhangzi, Lingyuan, Liaoning Province; Yixian Formation; Late Jurassic.

Etymology: "Liaoxi" is Chinese Pinyin, which means the western part of Liaoning Province, where the fossil was discovered.

Liaoxiornis delicatus sp. nov. (figures 1—3).

Fig. 1

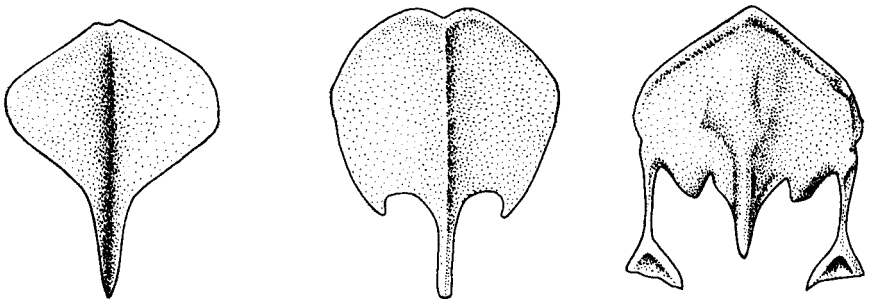

Fig. 2. Comparison of sternum of *Liaoxiornis delicatus* (a) with those of primitive enantiornithes (b) from Beipiao and *Cathayornis yandica* (c).

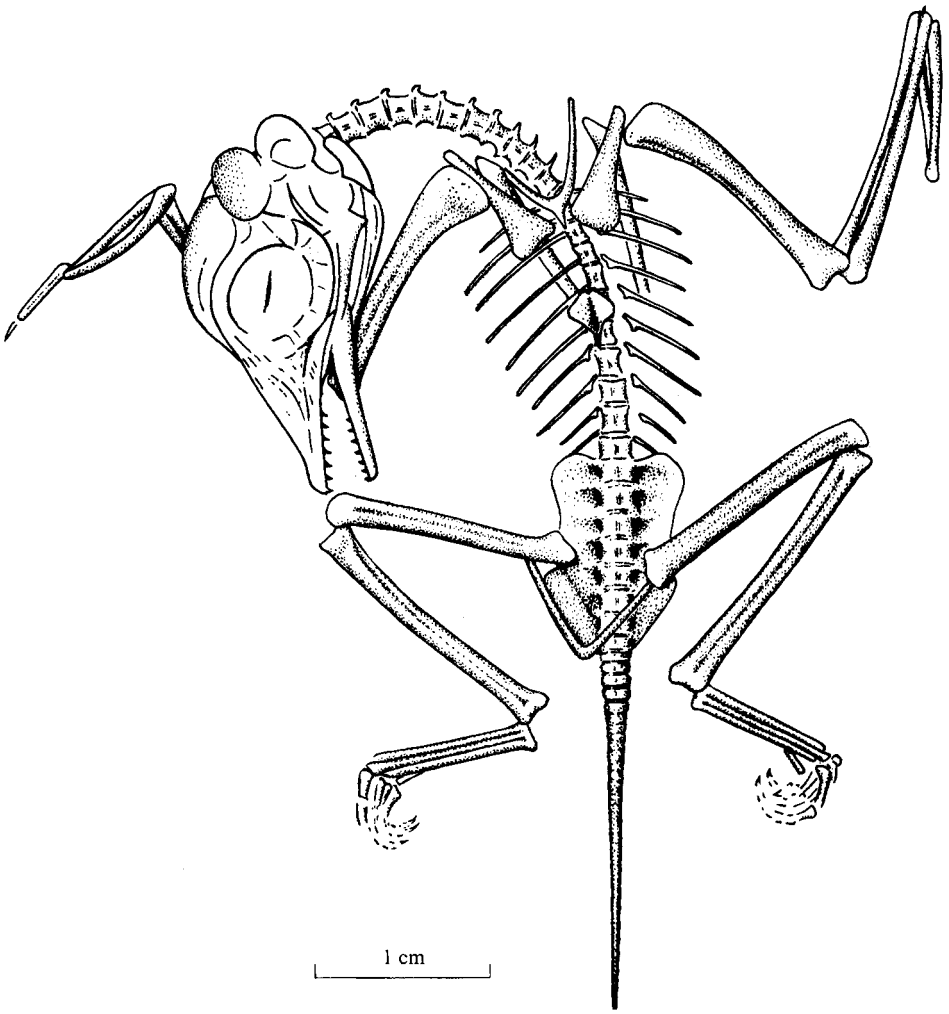

Fig. 3. Line drawing of the *Liaoxiornis delicatus* skeleton.

Type specimen: A complete skeleton *in situ* (130723).

Specific diagnosis: As for genus.

Etymology: "delicatus" in Latin means small.

Measurements: The skull is 24 mm long, and (including lower jaw) 12 mm high. The sternum is 6 mm in length and 4 mm in width. The lengths of other structures are as follows: spine bone, 65 mm; neck, 15 mm; tail, 25 mm (pygostyle 18 mm long); humerus, 15 mm; ulna, 17 mm; carpometacarpus, 8 mm; coracoid, 7.5 mm; clavicle branch of the furcule, 7 mm; femur, 16 mm; tibiotarsus, 18 mm; tarsometatarsus, 11 mm; digits (including claws), 13 mm.

There are 5 teeth on the lower jaws of *Liaoxiornis*, and there are 6 teeth on the maxilla and premaxittae. The teeth of *Liaoxiornis* are similar to those of the other early birds[2].

Description: The skeleton of *Liaoxiornis* is incomplete. The skull is well preserved, and some bones are preserved as clear impression. Skull is tall and short with large orbits. The sternum is gingko-leaf-like in outline in ventral view unlike that of all other birds. Both tail and pygostyle are long; the latter is about 3/4 of the tail in length. The antorbital foramen is small. The orbital parts of the frontals are thick. The parietal is well developed in the posterior of skull. The occipital foramen is posteriorly located as in *Confuciusornis* and *Archaeopteryx*[2]. An angle of the mandibular is present between dentary and angular. The dentary is short. The angular and surangular are very long. A prominent retroarticular process is present on articular. The neck is long and the number of cervical vertebrae is estimated to be more than 10. Cervical vertebral centrum is broad. Only one cervical rib is preserved. A dorsal vertebra is well preserved, and its centrum is round with high neural spine. All eight sacral vertebrae are not fused, and the centrum of the sacral vertebrae is broad with long transverse processes. Four free caudai vertebrae are probably present. The pygostyle is very long.

The forelimb is relatively advanced. The proximal ends of metacarpal 2 and metacarpal 3 are fused, and the carpometacarpal basic is composed of fused carpals and macarpals. The number of pralarx reduces in digits of the forelimbs. The ulna is longer than the humerus. The humerus still retains some primitive features, such as no tuberosity and pneumatic fosse at the proximal end. The bones of the shoulder girdle are very small. The furcular process of furcular is very short. The sternum has low keel process, and only a posterior process is present.

The bones of the pelvis are all preserved. They are similar to those of the other early birds[3], but the ischium is short, and has no dorsal process. The pubis has no pubic foot in the distal portion.

The structure of the hindlimbs is more primitives compared with that of the forelimbs. The femur is longer than the hurmerus. The ratio of femur to tibiotarsus is small. The tarsometatarsus is short, slightly longer than 1/2 length of the tibiotarsus, and fused at its proximal end. Metatarsus 3 is the longest. Digit 3 (with claw) is longer than the tarsometatarsus. The claw of Digit 3 is long but not strongly curved.

Discussion: Although *Liaoxiornis delicatus* is very small in body size, it is not a juvenile. Its skull and postcranial skeletons are well developed. Only a few Mesozoic birds were known until the end of the 1980s. In the 1990s[4], discovery of a number of Mesozoic birds has started a new stage in understanding of avian the evolution of early birds. *Confuciusornis* fauna is the oldest and most primitive terrestrial fauna[1]. *Liaoxiornis* is a new member of *Confuciusornis* fauna. It is not only the smallest bird of Mesozoic, but also provides new, important evidence for the early avian evolution[3,4]. The skull of *Liaoxiornis* is high and short but its lower jaw has a clear retroarticular process. The humeral structure of *Liaoxiornis* is similar to that of *Archaeopteryx*. The metacarpal and digits are fused, and the claws disappear. The femur, longer than the humerus, and the pygostyle, longer than the cervical vertebrae provide the only example in early birds. Its small sternum with only the posterior process is just slightly more derived than *Archaeopteryx*. Coexistence of conservative and derived features on *Liaoxiornis* may improve our understanding of the evolution of avian flight, and provide new information for study of skeletal transformation during the early stage of avian evolution. According to characters of unfixed skull bones and the presence of teeth, with the sauriurae like shoulder girdle and pelvis, *Liaoxiornis delicatus* should be referred to the Sauriurae.

In early birds, acquisition of flight capability composes an important respect of avian evolution. Thus, the forelimbs and girdle shoulder evolved faster, compared with the hindlimbs and pelvic girdle. In contrast to the earliest bird, *Archaeopteryx*, the femur of *Liaoxiornis* is longer than the humerus; this is a characteristic of their reptile ancestor.

Both humerus and sternum of *Liaoxiornis* are different from either enantiornithine or *Confuciusornis*. *Liaoxiornis* is similar to *Confuciusornis* in having broad cervical vertebrae, whereas its shoulder girdle is similar to that of enantiornithine. *Cathayornis*[2] and other enantiornithines have a high dorsal process on the ischium and a pubic foot on the pubis, which are missing on *Liaoxiornis*.

The sternum and muscular system attached on it are a source of energy in the flight of birds. Thus the changes in sternum have aroused attention in study of early birds. The morphology of the sternum of modern birds is an important characteristic for classification. The sternum of *Liaoxiornis* is very simple, but a lower keel was present at its center, and it has a short posterior process. It differs from *Confuciusornis*[5], because the sternum of the latter has lateral processes, but no keel and post process. From morphology, *Liaoxiornis* is closely related to the enantiornithes[5], and represents an evolution link between *Archaeopteryx* and the enantiornithes.

Whether the tail of early birds is long or short is another important sign of flight ability. It is still disputable whether *Archaeopteryx* has flight ability, because it has a long tail. The pygostyle of *Liaoxiornis* is longer than that of all other Mesozoic birds except *Archaeopteryx*. The pygostyle of modern birds are short and dorsiventrally flat, the caudal feathers on which are in charge of flight direction. In early birds, the pygostyle is in the stage of formation, so its main function is to reduce the burden of flight, but not for flight direction. The flight ability of *Liaoxiornis* with advanced forelimbs, very small sternum, and long pygostyle, is still worth discussing.

The function of hindlimbs is an important factor that affected flight. Differing from other vertebrates, the hindlimbs of birds have a series of ligament and tendon system from femur to digits. In primitive and early birds this system is not present or not well-developed. *Liaoxiornis* has primitive hindlimbs. Unlike the femur, the tibiotarsus is simple and not strong. The hindlimbs of *Liaoxiornis* represent morphologically a very primitive status according to either the arboreal hypothesis or the cursorial hypothesis of the origin of avian flight[6,7].

Like *Liaoxiornis*, phalange 3 (with claw) of *Liaoxiornis* is longer than the tarsometatarsus, and the claws are not strongly curved. These may result from the same environment they lived in.

Liaoxiornis represents a new morphological type, and provides a further understanding of avian evolution. The early adaptive radiation of birds is more complicated than previously thought[6—8].

Acknowledgement We thank Profs. Rong Jiayu and Qiu Zhuding, Dr. Wang Yuanqing, Deng Tao and Wang Yuan for reading the manuscript and provide valuable suggestions. This work was supported by the National Natural Science Foundation of China (Grant No. 49832020) and the Chinese Academy of Sciences (Grant No. K2951-131-410).

References

1 Hou, L. H., *Mesozoic Birds of China*, Nantou County: Feng-Huang-Ku Bird Park of Taiwan Provincial Government, 1997, 1—228.
2 Martin, L. D., Stewart, J. D., Teeth in Ichthyornis (Class: Aves), *Science*, 1977, 195: 1331.
3 Zhou Z. H., The discovery of early Cretaceous birds in China, *Courer Forschungsinstitus Senckenberg*, 1995, 181: 9.
4 Hou L. H., Martin, L., Zhou Z. H. *et al*. Early adaptive radiation of birds: evidence from fossils from northeastern China, *Science*, 1996, 274: 1164.
5 Hou, L. H., Martin, L., Zhou, Z. H. *et al*., *Archaeopteryx* to opposite birds-missing link from the Mesozoic of China, *Vert. PalAsiat*., 1999.
6 Feduccia, A., *The Origin and Evolution of Birds*, New Haven: Yale University Press, 1996.
7 Ostrom, J. H., On the origin of birds and avian flight, *Major Features of Vertebrate Evolution*, Paleontological Society, Short Courses in Paleontology, 1994(7): 160.
8 Padian, K., Chiappe, L. M., The origin and early evolution of birds, *Biol. Rev*., 1998, 73: 1.

(*Received February* 10, 1999)