

A carinate bird from the Upper Jurassic of western Liaoning, China

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AFTER the publication of the fossil bird *Confuciusorins*^[1, 2], additional skeletons of fossil birds have been found by Hou Lianhai, Hu Yaoming, Wang Ping, Gu Yucai and Sun Yutie in the Yixian Formation of Beipiao, Liaoning Province. The new locality is about 3 km southwest of that of *Confuciusorins*. Among those specimens were two of *Confuciusorins* and two new birds. A well-developed carina was found on the smallest specimen, a feature not found in the Jurassic birds, such as *Archaeopteryx* and *Confuciusorins*. The new Jurassic fossil bird is described in the present note.

1 Description

Class Aves Linnaeus, 1758

Subclass Ornithurae Haeckel, 1866

Order Liaoningornithiformes ord. nov.

Family Liaoningornithidae fam. nov. (figure 1)

Genus *Liaoningornis* gen. nov.

Diagnosis: Sternum with a developed carina; presternum present; ribs robust. External condyle on distal end of humerus large. Head of femur very developed and distal condyle large. Tarsometatarsus short, 1/2 length of tibiotarsus. Phalange 3 longer than the tarsometatarsus.

Etymology: "Liaoning" is Chinese phonetic alphabet after Liaoning Province.

Liaoningornis longidigitris sp. nov. (figure 1)

Specific diagnosis: As for genus. Sternum cotyloid; distal end of coracoid broad; ulna robust; humeral articulation in proximal end of radius well developed. Tarsometatarsus short and broad. Claws as long as the penultimate phalanx. Distal phalanx with a groove on its lateral side.

Type specimen: An incomplete skeleton with the sternum *in situ* (V11303. 1-2).

Locality, horizon and age: Beipiao City, Liaoning Province; Bottom of Yixian Formation; Tithonian, Late Jurassic.

Etymology: Longi in Latin means long; digit in Latin means digit.

Sternum. The sternum is different from that of all other birds, gobletlike in ventral view. The proximal end is expanded on both lateral sides, and is similar to that of *Hesperornis*. It narrows distally, and expands again near the distal end, and then sharply narrows to an angle. The carina is developed, and the distal end is similar to that of *Phalacrocorax*.

The specimen of *Liaoningornis* exhibits some cracks on the slab. However, it is possible that the fossil is different from other birds in development of rhombic presternum on its proximal end of the sternum. At the proximal end of the sternum (or presternum), there is a broad and deep coracoidal sulcus, and the anterior sternum articulates with coracoid.

Two ribs are preserved; the ribs are robust and gastralia are present.

Forelimbs. Only the shaft and the distal end of the humerus are preserved. The shaft is slightly hollow. The distal external condyle is developed. On the surface of the external condyle, there is an olecranal fossa. The ectepicondylar process is prominent and an ectepicondyle is present.

Only the shaft and the proximal end of the ulna are preserved. The shaft is slightly bowed and very strong, but it has no anconal and inner papillae of secondary. The external cotyla is deep and round. The internal cotyla is slightly elevated. The radius is straight and its shaft is slightly narrower than the ulna. The humeral cotyla and bicipital tubercle are developed in the proximal end of the radius.

Pectoral girdle. Part of the coracoid, scapula and furcula are present. The distal end of coracoid is very wide and round. The shaft of the scapula is triangular. There is a long process, similar to the furcular process of furcula, between the anterior border and the sternum. Because the furcular process is not so long, this process is possibly an interclavicle which is articulated with sternum. Both ends of scapula is missing. The shaft is wide and triangular.

Hindlimbs. The structure of the hind limb is more advanced than that of *Confuciusornis*. The femur is relatively long and slightly curved. The head of femur is developed. An attach-

ment for the round ligament is present on the head. At the distal end of the femur, the rotular groove is developed, and the internal condyle is large with a ligamental attachment. The rotular groove is very shallow. The tibiotarsus is longer than the femur. Both proximal and distal ends are expanded. There is a small bone at the proximal end of tibiotarsus, similar to that of the inner and outer cnemial crests.

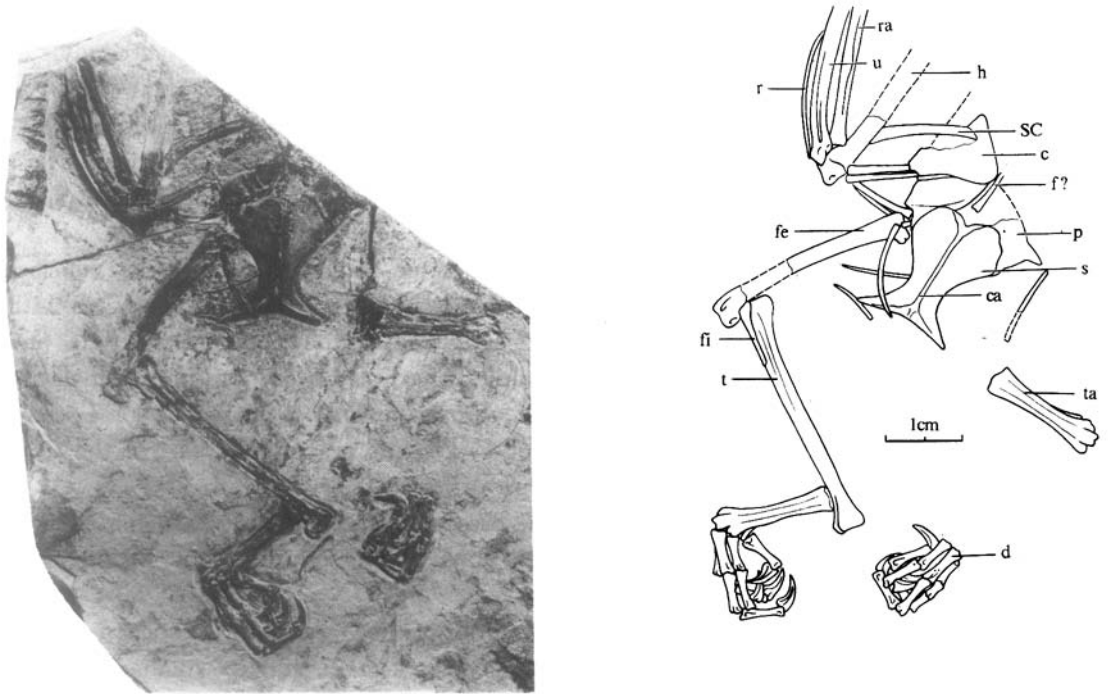


Fig. 1. *Liaoningornis longiditris* Gen. et sp. nov. c, coracoid; ca, carina; f, furcula; fe, femur; fi, fibula; h, humerus; d, digit; p, presternum; r, rib; s, sternum; ra, radius; t, tibiotarsus; ta, tarsometatarsus.

The external condyle is more developed at the distal end than in inside. The anterior intercondylar fossa is narrow. The tendinal groove of tibia at the distal end is long, and without an supratendinal bridge. The fibula is short.

The tarsometatarsus is short and strong. It is fused only at its proximal end. Metatarsus 3 is the longest. The 2nd metatarsus is more prominent in length than other metatarsals. In lateral view, there is a groove on the last digit. The claws are large and sharp, but not strongly curved. The length of claw is equal to that of the last digit, and the lateral groove is developed.

2 Discussion

Liaoningornis is the only bird that has a keeled sternum among Jurassic birds: 1) It contacts the sternum only with a medial seam, as in modern carinates; 2) The anterior sternum is articulated with the coracoid plate with a broad and deep groove lying on its anterior margin to a broad and round distal end of the latter; 3) It is possible that the new bone is a presternum that is articulated with the coracoid. There is not any other bone contacting the anterior sternum.

Liaoningornis shares the following advanced features with flying birds: 1) Sternum has a well-developed carina; 2) Internal and external cotyla of ulna are developed; 3) Head of femur is developed, with attachment of round ligament.

Liaoningornis has the following primitive features: 1) Sternum does not appear to have lateral process and its bone plate is thick; 2) Tibiotarsus does not appear to have a supratendinal bridge; 3) The distal end of tarsometatarsus is fused incompletely; 4) Radius is very straight; 5) Presternum is possibly present.

Liaoningornis shares the following features with the other birds: 1) External condyle of humerus is large and developed transcurently; 2) Ratio of the cross section of shaft of ulna to that of radius is low; 3) Form of sternum is special and presternum is possibly present; 4) Femur is shorter than the tibiotarsus; 5) Tarsometatarsus is very short, and its length is less than 1/2 of that of the tibia; 6) Last digits have groove on the lateral side; 7) Claws are curved, but not excessively.

According to the above features, it is difficult to refer *Liaoningornis* to the Subclass Sauriurae^[3] or to the Subclass Ornithurae, but it shares a number of advanced features with ornithurine birds. A presternum is found only in the early stages of development of reptiles and mammals and it ossifies as the manubrium on the anterior part of the sternum in mammals. It is said that the presternum is present in *Sphenodon*, lizards and *Crocodylus*, but some scientists argue that the presternum and xiphisternum of *Crocodylus* are actually part of the sternum. This disagreement results mainly from the lack of fossils.

If *Crocodylus* has the presternum, it would be present in the ancestral Eosuchia. Thus, the presternum possibly discovered in *Liaoningornis* could play a significant role in the study of the origin of the birds.

If the new bone between the presternum and anterior of the sternum in the specimens discovered in Liaoning Province proves to be an interclavicle, *Liaoningornis* will have a more complicated structure and be more significant for the origin of birds.

Liaoningornis and *Confuciusornis* were found in the same area and both have a developed sternum, although in the former there is no keel. They differ in many morphological features but they are both more advanced than *Archaeopteryx*^[4]. For example, they have developed external condyles at the distal end of the humerus and internal and external cotylae at the proximal end of the ulna. According to the features, *Liaoningornis* is different from *Confuciusornis* both in the level of evolution and in the direction of divergence. *Liaoningornis* is possibly the ancestral branch of ornithurines from which birds like *Hesperornis* and *Ichthyornis* are descended. They have a similar sternum and a similar ratio of tarsometatarsus to tibiotarsus. Their ecological habits are also nearly the same. It is likely that *Liaoningornis* lived in trees near water or shore. The relationship between *Liaoningornis* and modern birds is shown in figure 2.

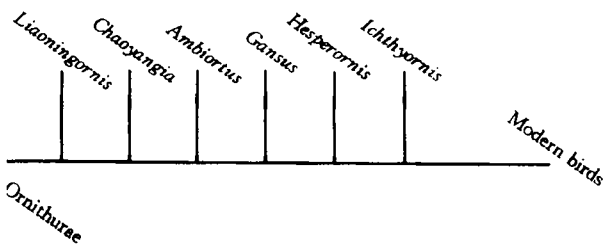


Fig. 2. Proposed possible phylogeny of Ornithurae.

The age of the Yixian Formation was generally thought to be Late Jurassic before 1980s. There was much disputation after that time. Some people argued that it is Early Cretaceous. Recently, more and more people support the Late Jurassic age because of the discovery of

many fossil animals' and plants' characteristics of that period^[5]. Jin^[6] considered that the demarcation line of continental Jurassic and Cretaceous should be put in middle to lower part of Yixian Formation. Zhao (1985) dated the volcanic deposits at 146—147 Ma by K-Ar method. Li *et al.*^[7] argued that the Yixian Formation corresponds to the Tithonian Stage based on the study of the new specimens of the symmetrodont which were found in the same locality and same layer with *Confuciusorins*. Zhang^[8] believed that Laiyang Formation (Late Jurassic) corresponds to the Yixian Formation. According to the complicated structure and the level of evolution of *Liaoningornis*, the author regards Tithonian as a more reasonable age of Yixian Formation.

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