

First Turtle Remains from the Middle-Late Jurassic Yanliao Biota, NE China

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Abstract - The Middle-Late Jurassic Yanliao Biota, preceding the Early Cretaceous Jehol Biota in NE China has yielded a rich collection of plant, invertebrate and vertebrate fossils. But contrary to the Jehol Biota which is rich in freshwater vertebrates, in the Yanliao Biota the aquatic reptiles are absent, and turtles have not been reported so far. In this paper, we report on the first turtle remains from the Yanliao Biota. The material consists of a partial skeleton from the Upper Jurassic Tiaojishan Formation of Bawangou site (Qinglong, Hebei Province, China). Characterized by a broad skull with a pair of sulci carotici and a remnant of an interpterygoid vacuity, a well-developed anterior lobe of the plastron with mesiolaterally elongated epiplastra and a relatively large oval entoplastron; it is assigned to *Annemys* sp. (Xinjiangchelyidae). This discovery adds a new element to the poorly known freshwater vertebrate fauna of the Yanliao Biota and extends the geographical distribution of *Annemys* to NE China.

Keywords: Testudines, Xinjiangchelyidae, Yanliao Biota, NE China, Tiaojishan formation, late jurassic

1. Introduction

The Middle-Late Jurassic non-marine deposits in northeastern China (Western Liaoning, northern Hebei and southeastern Inner Mongolia) have yielded a rich collection of fossil assemblages, termed Yanliao Biota. Like the famous Early Cretaceous Jehol Biota that covers the same area, remains of plants, invertebrates and vertebrates of the Yanliao Biota are mainly preserved in lacustrine sediments rich in volcanic ash. Vertebrates include fishes, amphibians, pterosaurs, dinosaurs and mammaliaforms

(see Xu *et al.*, 2016 for a thorough review). But contrary to the Jehol Biota that is rich in freshwater animals, in the Yanliao Biota the freshwater reptiles are absent; and turtles and crocodiles have hitherto not been reported (Xu *et al.*, 2016, 2019 ; Zhou & Wang, 2017). In this paper we report on the first turtle remains from the Yanliao Biota. The material consists of a partial skeleton of xinjiangchelyid turtle from the Upper Jurassic Tiaojishan Formation of Bawanggou, Qinglong, Hebei Province, China.

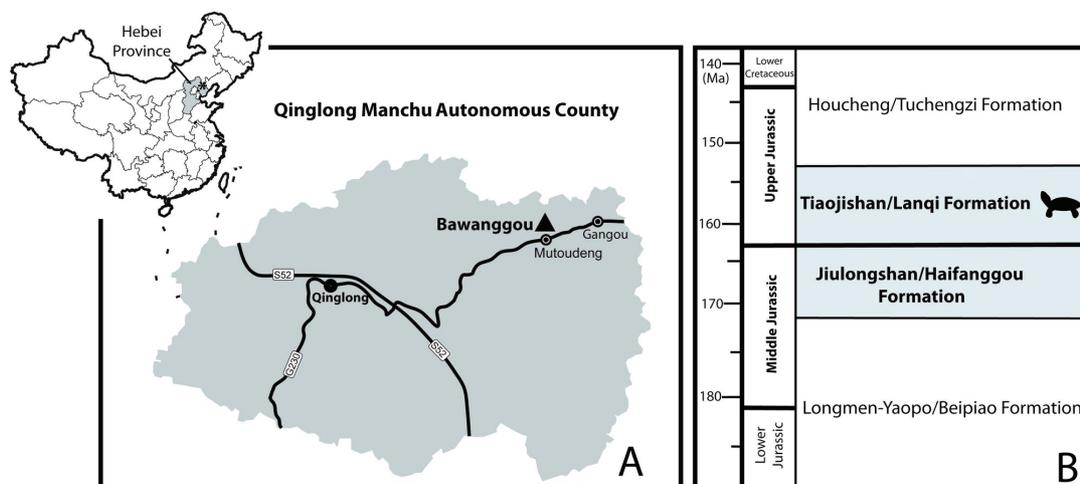


Figure 1A. Map showing the location of Bawanggou site, Qinglong Manchu Autonomous County, Hebei Province, China. **B.** Stratigraphical distribution of the Middle-Late Jurassic Yanliao Biota (shading).

2. Geological setting

The Bawanggou site (also called Mutoudeng site) is located north of Mutoudeng Town, Qinglong Manchu Autonomous County, in the northern part of Hebei Province (Figure 1). It has yielded some important vertebrates of the Yanliao Biota, such as

the salamander *Chunerpeton tianyiensis* (Sullivan *et al.*, 2014), the pterosaur *Qinglongopterus guoi* and *Dendrorhynchoides mutoudengensis* (Jiang *et al.*, 2015 ; Lü *et al.*, 2012), the dinosaur Yi qi (Xu *et al.*, 2015) and the mammal *Arboroharamiya jenkinsi* (Zheng *et al.*, 2013).

The Yanliao Biota straddled the Middle and Late Jurassic for about 10 million years. It is divided in two phases: the Bathonian-Callovian Daohugou phase (early Yanliao Biota, Jiulongshan/Haifengshan formations, about 168-164 million years ago) and the Oxfordian Linglongta phase (late Yanliao Biota, Tiaojishan/Lanqi formations, 164-159 million years ago). The fossil-bearing beds of Bawangou site pertain to the Tiaojishan Formation, which is regarded as Middle Jurassic (Daohugou Phase) (Sullivan *et al.*, 2014) or Late Jurassic in age (Linglongta Phase) (Liao & Huang, 2014) based on palaeontological and biostratigraphic studies. A recent study on SIMS zircon U-Pb yielded an age of 159.0-159.8 Ma, which places the Tiaojishan Formation of Bawangou site in the Oxfordian (Upper Jurassic) (Yu *et al.*, 2020), providing a direct isotopic age to support the opinion of Liao et Huang (2014).

3. Material and method

The specimen studied in the present work (IVPP V16730, anterior portion of a skeleton) is housed in the Institute of Vertebrate Palaeontology and Palaeoanthropology (IVPP), Chinese Academy of Sciences, China. Preserved on a slab, the ventral surface of the specimen is prepared mechanically. To reveal the hidden features, the X-ray scanning technology is used. The scanning is carried out using a micro-computed

laminography system (160-Micro-CL) at the Key Laboratory of Vertebrate Evolution and Human Origin of Chinese Academy of Sciences, IVPP, Beijing.

4. Systematic palaeontology

Testudines Linnaeus (1758)

Cryptodira Cope (1868)

Xinjiangchelyidae Nessov in Kaznyshkin *et al.* (1990)

Annemys Sukhanov and Narmandakh. (2006)

Annemys sp.

(Figure 2-3)

Referred material: IVPP V16730, a partial skeleton presented in ventral view, including skull with attached lower jaw; disarticulated cervicals, complete right and left humeri, right forearm, right and left scapula, anterior portion of the carapace and anterior lobe of the plastron with both right and left axillary buttresses, as well as other shell fragments. The specimen is preserved on a slab and further included in plaster. It is dorsoventrally crushed.

Locality and horizon: Bawangou site, Xinglongtaizi Village, Mutoudeng Township, Qinglong Manchu Autonomous County, Qinhuangdao City, Hebei Province, China. Upper Jurassic (Oxfordian) Tiaojishan Formation.

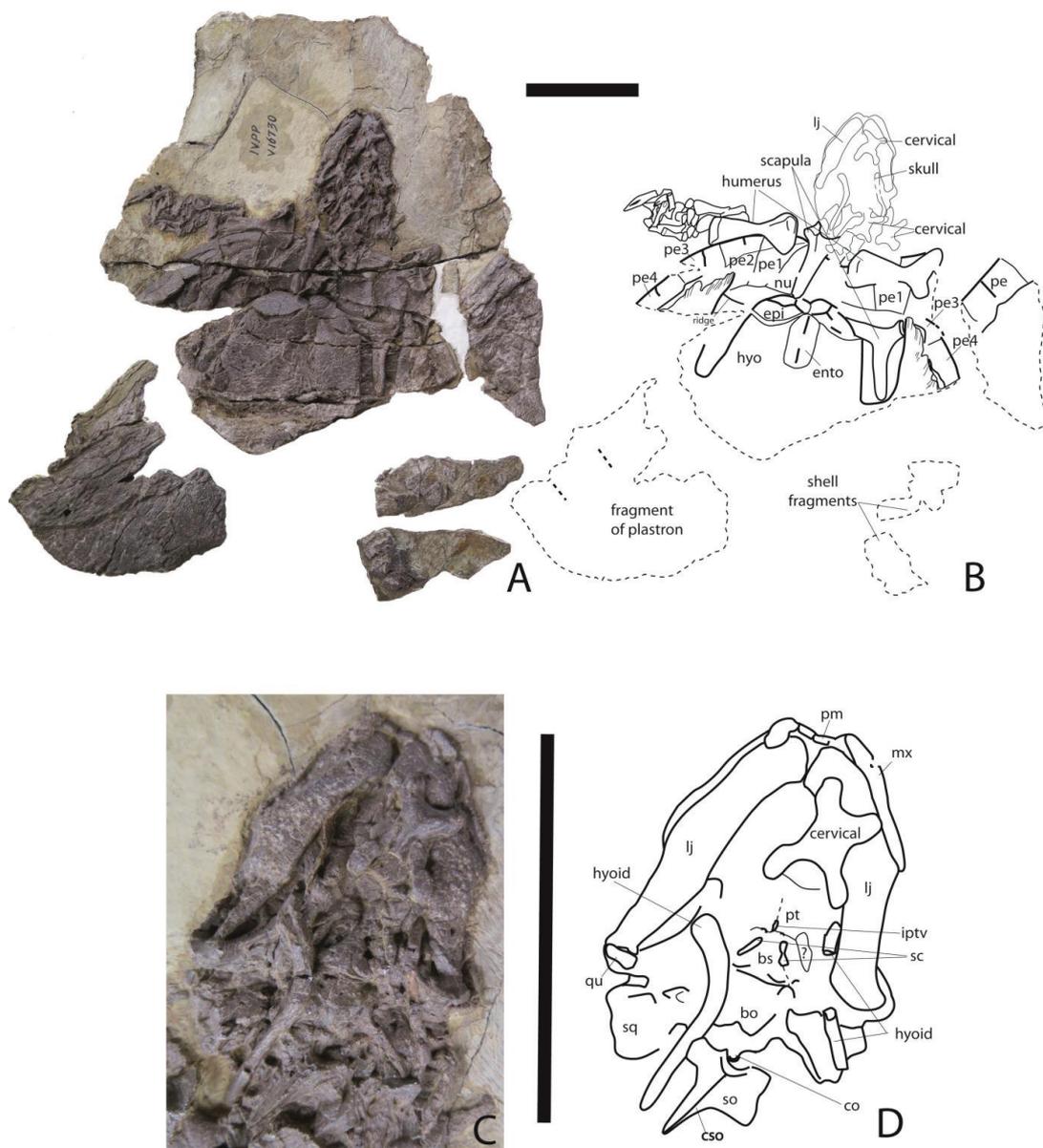


Figure 2. *Annemys* sp. (Xinjiangchelyidae) from the Upper Jurassic Tiaojishan Formation of Bawangou, Qinglong Manchu Autonomous County, Hebei Province, China. A-B, partial skeleton (IVPP V16730) in ventral view; C-D, detail of skull. Scale bar = 5 cm. Abbreviations: bo, basioccipital; bs, basisphenoid; co, costal; coc, condylus occipitalis; cso, crista supraoccipitalis; ento, entoplastron; epi, epiplastron; hyo, hyoplastron; ipv, interpterygoid vacuity; lj, lower jaw; mx, maxilla; n, neural; nu, nuchal; pe, peripheral; pm, premaxilla; pt, pterygoid; qu, quadrate; sc, sulcus caroticus; so, supraoccipital; sq, squamosal.

5. Description

Skull *The skull*, measuring 47 mm. from the snout to the posterior end of the squamosal and 38 mm. at the level of the quadrates, is elongate, with almost parallel lateral borders and a blunt snout. The ventral surface of the skull is somewhat crushed and moreover covered by the lower jaw, the hyoid apparatus, a cervical vertebra and other bone fragments, so that many structures and sutures are not clearly visible. The triturating surface, as partly exposed on the left side, appears to be narrow with a sharp labial ridge. The pterygoids are partly exposed; the processus pterygoideus externus is mostly hidden by the lower jaw. Anterior to the basisphenoid and between the pterygoids, there is a short slit extending anteroposteriorly along the midline, which we interpret as a remnant of the interpterygoid vacuity (Figure 2C-D and Figure 3B). The foramen posterius canalis carotici interni, located at the posterior end of the pterygoid, is visible on the left side. The basisphenoid is slightly shorter than the main body of the basioccipital. Anteriorly, the basisphenoid contacts the pterygoid with a transverse suture on which a pair of foramina posterius canalis carotici palatinum is located. The basisphenoid extends laterally to form the basipterygoid processes, but as the lateral portion of the basisphenoid is not completely exposed, the shape and size of the processes are not determinable. A pair of grooves, the sulcus caroticus, extends anteromedially within the basisphenoid. A pair of swellings, delimited by a furrow posteriorly, is present posterior to the sulcus caroticus. The basisphenoid contacts the basioccipital posteriorly with a straight suture. The basioccipital is robust, the main body of its

ventral exposure is roughly as long as wide, with the lateral borders slightly convergent posteriorly. The tubercula basioccipitale are reduced and set close one to another. A strong occipital condyle is preserved. The supraoccipital bears a relatively long crista supraoccipitalis. The lower jaw is somewhat disarticulated, allowing the right condylus mandibularis to be exposed. The articular surface is concave and wider than long.

Lower jaw The lower jaw is robust, with a rough outer surface similar to that of the shell. The left ramus is separated from the right one by crushing, it is not clear whether they are united by suture or fused.

Hyoid bone The right cornus branchiale I is complete whereas the left one is damaged. It is rod-like and curved, with a narrow posterior end.

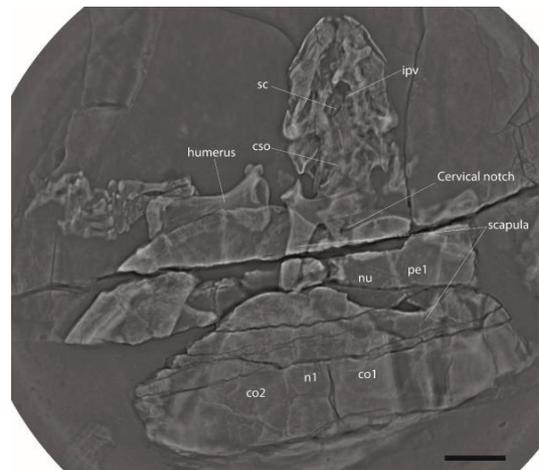


Figure 3. Micro-computed scanning slice of *Annemys* sp. (IVPP V16730) from the Upper Jurassic Tiaojishan Formation of Bawangou. Scale bar = 2 cm. Abbreviations: see Figure 2.

Shell The carapace, presented in ventral view, has a smooth and likely upturned anterolateral margin. The cervical notch is relatively deep and delimited by the peripherals 1 (Figure 2A and Figure 3). The nuchal is trapezoidal, with the anteriorly convergent lateral margins. The neural 1 appears to be six-sided with short posterolateral sides (Figure 3). The peripheral 1 is narrow; the sutural contact with the costal 1 is short. The peripheral 2 is roughly as long as wide and slightly narrowed posteriorly. The peripherals 3-4 are wider than long. The costal 1 bears a sharp ridge on its ventral surface.

The preserved part of the plastron consists of a complete anterior lobe, but the epiplastra are slightly disarticulated. The anterior lobe, of 47 mm. long and 67 mm. wide at the base, is relatively long and narrow, with a rounded and slightly scalloped anterior border. The lateral margins are gently curved and convergent anteriorly. The length/width ratio of the anterior lobe is about 70%, comparable to that of *Annemys wusu* (Rabi *et al.*, 2013). The plastron is loosely attached to the carapace, a series of pegs with striations on the surface is visible on the lateral border of the axillary buttresses. The axillary buttresses are long, extending anteromedially to reach the peripheral 2. The epiplastron has a similar size as the entoplastron. The left and right epiplastra meet along the midline with a long suture, preventing the entoplastron to be exposed on the front margin of the plastron. The entoplastron is an oval plate and much longer than wide as in other xinjiangchelyids.

The intergular reaches the anterior end of the entoplastron. The gularohumeral sulcus is located at about midlength of the

epiplastron. The humeropectoral sulcus is not discernible. Some scute sulci on the detached fragment of the plastron likely indicate the presence of inframarginals (Figure 2).

Axial and appendicular elements

At least three cervical vertebrae are preserved, all disarticulated and presented in dorsal view. They are relatively short and wide, with divergent pre- and postzygapophyses that form an X in dorsal view.

Both coracoids are preserved, but none of them are completely exposed. The scapular process and acromion process form a wide angle of about 100°.

Both humeri are presented in ventral view. The humerus, of 39 mm. long, has an enlarged proximal end. The medial process and the lateral process have roughly the same length. The shaft is straight. The distal end is enlarged, but the trochlea and capitellum are not distinct.

The right forearm is preserved. The radius and ulna have roughly the same length. The metacarpals and phalanges are somewhat mixed. The claws are long and slender.

6. Comparisons and discussion:

Based on the skull and shell morphology, IVPP V16730 is assigned to Xinjiangchelyidae. In IVPP V16730, the internal carotid canal is incompletely floored and a remnant of the interpterygoid vacuity is present. This configuration is comparable to that of xinjiangchelyids such as *Annemys* spp. from the Late Jurassic of Shar Teg, Mongolia, *A.* sp. from the Shishugou Formation of the Junggar Basin and Qigu Formation

of the Turpan Basin, and *Kalasinemys prasarttongosothi* from the Phu Kradung Formation of Thailand (Brinkman *et al.*, 2013 ; Rabi *et al.*, 2014 ; Tong *et al.*, 2019 ; Wings *et al.*, 2012). The morphology of the plastron of IVPP V16730 matches well that of xinjiangchelyids in having a well-developed anterior lobe with a rounded front margin, mesiolaterally elongated epiplastra, and an oval, longer than wide entoplastron (Tong *et al.*, 2012b). The lack of obvious ornamentation on the shell surface and a longer than wide entoplastron distinguishes IVPP V16730 from the basal trionychoid *Sineaspideretes wimani* from the Late Jurassic Shangshaximiao Formation of the Sichuan Basin (Danilov & Parham, 2006 ; Tong *et al.*, 2014 ; Young & Chow, 1953).

Xinjiangchelyidae is the dominant turtle group in the freshwater ecosystems during the Middle-Late Jurassic in Asia. According to the recent reviews, the family Xinjiangchelyidae consists of eight genera in mainland Asia, namely *Protoxinjiangchelys* from the Middle Jurassic Xiashaximiao Formation and Xintiangou Formation, *Chengyuchelys*, *Tienfuchelys* and *Yanduchelys* from the Late Jurassic Shangshaximiao Formation of the Sichuan Basin ; *Xinjiangchelys* from the Middle-Late Jurassic of Lufeng, Turpan and Junggar basins, *Annemys* from the Middle-Late Jurassic of China, Mongolia, Kirgizstan and Siberia ; and *Phunoichelys* and *Kalasinemys* from the Late Jurassic Phu Kradung Formation of NE Thailand (Averianov *et al.*, 2016 ; Rabi *et al.*, 2014, 2013, 2010 ; Sukhanov, 2000 ; Tong, 2017 ; Tong *et al.*, 2019, 2015a, 2015b).

IVPP V16730 is distinguished from xinjiangchelyids from the Sichuan Basin

(*Protoxinjiangchelys*, *Chengyuchelys*, *Tienfuchelys* and *Yanduchelys*) in having a loose plastron/carapace attachment (Hu *et al.*, 2020 ; Tong *et al.*, 2012b, 2012a). In this respect, it is closer to *Xinjiangchelys* and *Annemys* (Matzke *et al.*, 2005, 2004 ; Nessov, 1995 ; Rabi *et al.*, 2014, 2013 ; Tong *et al.*, 2015a ; Ye, 1986).

The skull morphology of IVPP V16730 is similar to that of *Annemys*. The skull of IVPP V16730 is relatively broad with roughly parallel lateral borders as in *Annemys*, different from a more triangular skull of *Xinjiangchelys*. In IVPP V16730, the interpterygoid vacuity is not completely closed, but remains open as a slit. This primitive feature is also present in *Annemys* (*A. levensis* and *A. sp.* from the Junggar and Turpan Basins) and *K. prasarttongosothi* (Brinkman *et al.*, 2013 ; Rabi *et al.*, 2014 ; Tong *et al.*, 2019 ; Wings *et al.*, 2012). In *A. wusu* (Rabi *et al.*, 2013) from the Qigu Formation, Turpan Basin, the interpterygoid vacuity is an oval-shaped opening. The skull of *Xinjiangchelys* is more derived, e.g. in *X. radiplicatoides* from the Shishugou Formation, Junggar Basin, the interpterygoid vacuity is completely closed. In addition, the main body of the basioccipital in IVPP V16730 is roughly square, with the lateral borders slightly convergent posteriorly, with reduced and close-set tubercula basioccipitale as in *Annemys* whereas in *Xinjiangchelys*, the basioccipital is wider than long, with nearly parallel lateral borders and more developed tubercula basioccipitale which are more distant from one another. The crista supraoccipitalis in IVPP V16730 is relatively long as in *Annemys*, in contrast to a short crista in *Xinjiangchelys*. *Kalasinemys* differs from IVPP V16730 in having a very long basisphenoid and a reduced basioccipital

(Tong *et al.*, 2019). On the basis of these skull characters, IVPP V16730 is assigned to *Annemys*.

During the Middle-Late Jurassic, the genus *Annemys* was widespread in northern China and Central Asia. The genus contains originally two species: *A. levensis* and *A. latiens*, both from the Late Jurassic of Shar Teg, Transaltai Gobi, Mongolia (Rabi *et al.*, 2014 ; Sukhanov, 2000 ; Sukhanov and Narmandakh, 2006). Originally assigned to *Xinjiangchelys*, *A. wusu* from the late Middle Jurassic Qigu Formation of the Turpan Basin, China has been referred later to *Annemys* (Averianov *et al.*, 2016 ; Rabi *et al.*, 2013), the assignment being supported by the remnant of interpterygoid vacuity, the narrow vertebral scutes 2-4 and the vertebral 1 wider than the vertebrae 2-4. *A. sp.* from the Bathonian Itat Formation of Berezovsk coal mine in western Siberia represents the oldest record of the genus (Averianov *et al.*, 2016). The Qigu Formation of the Turpan Basin has yielded a large number of *Annemys sp.* skeletons (Wings *et al.*, 2012). Additional material of *A. sp.* has been reported from the Middle-Late Jurassic Shishugou Formation (Callovian or Oxfordian) of the Junggar Basin and the Balabansai Formation, Fergana, Kirgizstan. (Brinkman *et al.*, 2013 ; Nesson & Kaznyshkin, 1985). Although *Annemys* contains the best material among Xinjiangchelyidae, the study of many of the specimens is still outstanding. Because of the preservation of our specimen, we assign IVPP V16730 to *Annemys sp.* *Annemys sp.* from Qinglong is the first xinjiangchelyid turtle reported from NE China and also represents the easternmost distribution of the genus *Annemys*.

7. Conclusions

The partial skeleton (IVPP V16730) from the Upper Jurassic Tiaojiashan Formation of Qinglong, Hebei Province, China, described in the present paper is the first turtle specimen reported from the Yanliao Biota. It is assigned to *Annemys sp.* (Xinjiangchelyidae). This discovery adds a new element to the poorly known freshwater vertebrate fauna of the Yanliao Biota and extends the geographical distribution of *Annemys* to northeastern China. Further discoveries of more complete turtle material from the Yanliao Biota are expected for a better understanding of the Yanliao fauna and the evolutionary history of xinjiangchelyid turtles.

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