

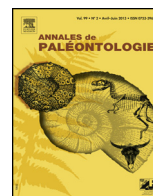


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Original article

Turtle remains from the Middle Jurassic Xintiangou Formation of Yunyang, Sichuan Basin, China

Restes de tortues de la Formation Xintiangou (Jurassique moyen) de Yunyang, bassin du Sichuan, Chine

Xufeng Hu^a, Lu Li^b, Hui Dai^a, Ping Wang^a, Eric Buffetaut^{c,d}, Guangbiao Wei^e, Can Xiong^a, Haiyan Tong^{c,d,*}

^a Chongqing Laboratory of Geoheritage Protection and Research, No. 208 Hydrogeological and Engineering Geological Team, Chongqing Bureau of Geological and Mineral Resource Exploration and Development, 400700 Chongqing, China

^b Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Science, 100044 Beijing, China

^c CNRS (UMR 8538), Laboratoire de Géologie de l'École Normale Supérieure, PSL Research University, 24, rue Lhomond, 75231 Paris Cedex 05, France

^d Palaeontological Research and Education Centre, Mahasarakham University, Kantarawichai, 44150 Maha Sarakham, Thailand

^e Chongqing Institute of Geological Survey, 401122 Chongqing, China



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ABSTRACT

Three turtle shells from the Middle Jurassic Xintiangou Formation of Yunyang (Chongqing, China) are described and assigned to Xinjiangchelyidae (Testudines: Eucryptodira). This is the first report of turtle remains from the Xintiangou Formation, Sichuan Basin and represents the oldest known Xinjiangchelyidae. The assemblage includes two taxa, *Protoxinjiangchelys* sp. and Xinjiangchelyidae indet. This discovery extends the stratigraphical distribution of Xinjiangchelyidae and improves our knowledge about the early evolution of that family. It demonstrates that by the Middle Jurassic, at the time of deposition of the Xintiangou Formation, the group was already diversified in the Sichuan Basin.

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R É S U M É

Trois carapaces de tortues provenant de la Formation Xintiangou (Chongqing, Chine), datée du Jurassique moyen, sont décrites et attribuées aux Xinjiangchelyidae (Testudines : Eucryptodira). C'est la première mention de restes de tortues dans cette formation du bassin du Sichuan, correspondant aux plus anciennes Xinjiangchelyidés connues. L'assemblage se compose de deux taxons, *Protoxinjiangchelys* sp. et Xinjiangchelyidae indet. Cette découverte étend la répartition stratigraphique de la famille des Xinjiangchelyidae et améliore notre connaissance de l'évolution précoce de la famille. Elle démontre que dès le Jurassique moyen, lors du dépôt de la Formation Xintiangou, le groupe était déjà diversifié.

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1. Introduction

The Sichuan Basin, China is an important place for the study of the early evolution and diversification of turtles during the Jurassic.

In 1953, Young and Chow reported turtle remains from the Jurassic beds along the Chengyu Railway and the suburbs of Chongqing city (Young and Chow, 1953). This was the first study of Jurassic turtles from China (Tong, 2017). Since then abundant turtle remains have been discovered from the Middle Jurassic Xiashaximiao Formation and the Upper Jurassic Shangshaximiao Formation and numerous taxa have been erected (Ye, 1990a, 1990b; Ye, 1983, 1982; Ye and Fang, 1982; Ye and Pi, 1997). According to recent reviews

* Corresponding author.

E-mail address: htong09@yahoo.fr (H. Tong).

(Tong et al., 2012a, 2012b), turtles from the Sichuan Basin consist of Sichuanchelyidae and Bashuchelyidae from the Xiashaximiao Formation and Xinjiangchelyidae from both the Xiashaximiao and Shangshaximiao formations. The Shangshaximiao Formation has also yielded the basalmost Trionychoidea *Sinaspideretes wimani* Young and Chow, 1953 which is also the most ancient representative of the crown group of turtles (Danilov and Parham, 2006; Tong et al., 2014; Young and Chow, 1953).

All Middle Jurassic turtles from the Sichuan Basin hitherto came from the Xiashaximiao Formation of Dashanpu, Sichuan Province. In this paper we report on the first turtle remains from the Middle Jurassic Xintiangou Formation of Yunyang, Chongqing Municipality. This is the oldest turtle record from the Sichuan Basin since the Xintiangou Formation underlies the Xiashaximiao Formation. The material, consisting of three shells of Xinjiangchelyidae, is housed in Chongqing Laboratory of Geoheritage Protection and Research, No. 208 Hydrogeological and Engineering Geological Team, Chongqing Bureau of Geological and Mineral Resource Exploration and Development, Chongqing, China.

Xinjiangchelyidae is a basal eucryptodiran turtle family mostly known from the Jurassic of Asia. Originating in the Middle Jurassic, this group underwent a quick radiation and became dominant turtles in the Late Jurassic freshwater ecosystems in Asia. Xinjiangchelyids are medium-sized turtles with a carapace length not exceeding 400 mm. The skull is primitive with an incompletely floored internal carotid canal and often a remnant of an interpterygoid vacuity (Brinkman et al., 2013; Rabi et al., 2014; Tong et al., 2019). The shell is low-domed and characterized notably by anterior peripherals with prominent guttered edges; seventh to eleventh peripherals transversely expanded; fourth to seventh marginals extending onto second through fourth costals; entoplastron and epiplastron similar in size; a large entoplastron usually longer than wide; mesoplastron absent; femoroanal sulcus usually omega-shaped, reaching or extending onto the hypoplastron and three or four pairs of inframarginals (Tong et al., 2012b). Our knowledge of the evolution, as well as the stratigraphical and geographical distribution of xinjiangchelyids has greatly improved during the last decade. The group is now known to be widely distributed across Central Asia, Mongolia, northern and southern China and also SE Asia (Sukhanov, 2000; Tong, 2017; Tong et al., 2019). The monophyly of the Xinjiangchelyidae has not been demonstrated, the majority of the characters that are used to diagnose the group are considered as symplesiomorphies (Rabi et al., 2010). According to the recent reviews and discoveries, Xinjiangchelyidae contains *Protoxinjiangchelys salis*, *Chengyuchelys* spp., *Tienfuchelys* spp. and *Yanduchelys delicatus* from the Sichuan Basin, China; *Xinjiangchelys* spp. and *Annemys* spp. from Central Asia, Mongolia and China and *Phunoichelys thirakhupti* and *Kalasinemys prasarttongosothi* from Thailand (Averianov et al., 2016; Brinkman et al., 2013; Rabi et al., 2014, 2010; Sukhanov, 2000; Sukhanov and Narmandakh, 2006; Tong et al., 2019, 2015b, 2015a, 2012b, 2012a; Wings et al., 2012). *Brodiechelys* spp. from the Early Cretaceous of Europe has also been referred to Xinjiangchelyidae (Hirayama et al., 2000; Pérez-García et al., 2014). As early representatives of xinjiangchelyids, the turtle remains from Yunyang described in the present paper provide new insights on the early evolution of the group.

2. Geological setting

The turtle remains reported in this paper have been recovered from the Middle Jurassic Xintiangou Formation at the locality of Laojun village, Pu'an Town, Yunyang County, Chongqing Municipality, in the NE part of the Sichuan Basin (Fig. 1). The Jurassic beds in the Sichuan Basin consist of, from bottom to top, the Lower

Jurassic Zhenzhuchong and Ziliujing formations, the Middle Jurassic Xintiangou and Xiashaximiao formations, and the Upper Jurassic Shangshaximiao, Suining and Penglaizhen formations. The Xintiangou Formation is widely distributed in the Sichuan Basin and well-developed east of the Jiangyou-Nanchong-Chongqing line, but eroded or not deposited west of the line. It is composed of inter-bedded purplish red argillites and yellowish grey siltstones of primarily lacustrine origin, and conformably contacts the underlying Ziliujing Formation and the overlying Xiashaximiao Formation. Based on the sporopollen and conchostracan assemblages, the Xintiangou Formation is regarded as early Middle Jurassic in age (Wang et al., 2010). A preliminary U-Pb dating provided an age range between 180 and 170 Ma, corresponding to the Toarcian-Aalenian stages (late Early to early Middle Jurassic) (Li et al., 2019).

Since 2015, abundant vertebrate remains have been collected from the Xintiangou Formation at Laojun site. In addition to turtles, the associated vertebrate fauna includes freshwater sharks, bony fishes, lungfishes, temnospondyl amphibians, sauropterygians, crocodiles, sauropod (Tan et al., 2019), theropod (Dai et al., 2020) and ornithomimid dinosaurs (Li et al., 2019), and tritylodont mammal-like reptiles. The turtle remains described in the present paper have been unearthed from the same layer as the ornithomimid *Sanxiasaurus modaosiensis* and theropod *Yunyangdosaurus puanensis* (Li et al., 2019; Fig. 2).

3. Systematic palaeontology

Testudines Linnaeus, 1758
Cryptodira Cope 1868
Xinjiangchelyidae Nessov in Kaznyshkin et al., 1990

3.1. *Protoxinjiangchelys* Tong, Danilov, Ye, Ouyang & Peng, 2012

Protoxinjiangchelys sp.

(Fig. 2)

Referred specimen: 19YP-2006.1, a nearly complete shell with articulated carapace and plastron, lacking the posterolateral end of the carapace and the xiphiplastron.

3.1.1. Description

Carapace: 19YP-2006.1 is an almost complete shell without deformation. As preserved, it measures 175 mm. in length (with an estimated length of 180 mm), 150 mm. in width and 35 mm. in height. The shell is low. The carapace has an oval outline, being longer than wide, with a smooth margin. There is a relatively small cervical notch, apparently delimited by the peripheral 1. The anterior border of the carapace from the marginals 1–2 up to the marginal 5 is slightly upturned forming a shallow gutter. The carapace surface is covered by tiny irregular and vermiculated furrows that give it a rough aspect. In addition, light ridges are present on the region of vertebrals 2–4, extending forward in a radiating manner from a central point close to the posterior border of each vertebral scute. Such radiating ridges are also present in *Chengyuchelys radiuplicatus* (Young and Chow, 1953) and *Xinjiangchelys radiuplicatoides* Brinkman, Eberth, Xu, Clark and Wu, 2013, but they are more prominent and present also in the pleural region in the latter (Brinkman et al., 2013; Tong et al., 2012b; Ye, 1986a). 19YP-2006.1 is an adult individual, most plates of the carapace are fused, the sutures are not discernible.

The scute sulci are well imprinted. The cervical scute is complete; it is wide and short, with its width about four times its length. The series of five vertebrals is completely preserved, they are all very wide. The vertebral 1 is roughly quadrangular in shape with the lateral sulci nearly parallel to one another; its front margin is slightly convex forward and its width is about twice its length. The vertebrals 2 to 4 are hexagonal. The vertebral 2 is wider than the



Fig. 1. Map showing the location of Yuniyang in the Sichuan Basin, China.
Carte montrant la localisation de Yuniyang dans le bassin du Sichuan, Chine.

vertebral 1, its anterior portion is narrower than its posterior part. The vertebral 3 is the widest vertebral, followed by the vertebral 2 then the vertebral 4. The vertebral 4 has its posterior portion narrower than the anterior part. The vertebral 5 is trapezoidal and smaller than the vertebral 1. The intervertebral sulci are mostly straight, except that between the vertebrae 1 and 2, which has an anteriorly pointed spur in the middle. There are four narrow pleural scutes, their width is less than half of the vertebral width. There are twelve marginal scutes. The marginal 1–4 and 6 are mesiolaterally narrow, whereas the marginals 5 and 7 are wider than the surrounding marginals, with a clear medial protrusion visible on both sides. The marginals 8 and 9 are expanded mesiolaterally and roughly square in shape. As the sutures are not visible, the relationship between the marginal scutes and the peripheral/costal plates is unclear.

Plastron: The plastron is sutured to the carapace. Although the anterior end of the plastron is damaged, when reconstructed, the anterior margin of the plastron would reach the anterior margin of the carapace. The anterior lobe is relatively long with the lateral borders slightly convergent anteriorly. The bridge is long, likely longer than the anterior lobe. The posterior lobe is as wide as the anterior lobe at the base. The axillary buttresses are long, extending anteriorly almost up to the level of the epi/hyoplastral suture. The inguinal notch is wider than the axillary notch. The epiplastra are not preserved while the entoplastron is complete and the epi/entoplastral and epi/hyoplastral sutures are intact. The epi/hyoplastral suture is slightly directed posterolaterally. The entoplastron is leaf-shaped. The hyo/hyoplastral suture is not discernible, it is unclear whether mesoplastra are present. The plastron is broken off along the hypo/xiphoplastral suture, the xiphoplastra are missing.

The midline sulcus is slightly sinuous. The intergulars cover the anterior end of the entoplastron. The humeropectoral sulcus is convex posteriorly and located far anterior to the base of the anterior lobe. The pectoral scute is longer than the abdominal scute.

The anal scute, of which only the anterior end is preserved, is omega-shaped and invades the hypoplastra at the midline as in most *Xinjiangchelyids*. There is a row of four narrow inframarginals, which separates completely the plastral scutes from the marginal scutes; the last one being the largest.

3.1.2. Comparisons

Three turtle families have been recorded from the Middle Jurassic Xiashaximiao Formation of Sichuan Basin, namely *Sichuanchelyidae*, *Bashuchelyidae* and *Xinjiangchelyidae* (Tong et al., 2012a). *Sichuanchelyidae* are represented by a single species in the Sichuan Basin, *Sichuanchelys chowi* Ye and Pi, 1997. Originally considered as close to *Chengyuchelys* (Ye and Pi, 1997), the phylogenetic analysis in the recent revision placed this species in a more basal position, next to *Kayentachelys* from the Early Jurassic of North America (Gaffney et al., 1987; Tong et al., 2012a). The recent discovery of a new species of *Sichuanchelys*, *S. palatodentata* Joyce, Rabi, Clark and Xu, 2016 from the early Late Jurassic Shishugou Formation of the Junggar Basin, Xinjiang, China confirmed the primitive nature of *Sichuanchelys*, with notably the presence of palatal teeth (Joyce et al., 2016). 19YP-2006.1 is distinct from *Sichuanchelyids* in having a small cervical emargination that is delimited by the peripherals 1, narrower vertebrae with the width about twice the length, the vertebral 1 with anteriorly convex front margin and transverse posterior border, and an omega-shaped femoroanal sulcus extending onto the hypoplastra. In *Sichuanchelys* spp. the cervical emargination is huge, delimited by the peripheral 2; the vertebrae are extremely wide, with their width more than three times their length; the vertebral 1 has a straight anterior margin and strongly posteriorly convex posterior border and the anal scutes are restricted to the xiphoplastra (Joyce et al., 2016; Tong et al., 2012a). 19YP-2006.1 is more derived than *Sichuanchelyids*, but close to *Bashuchelyidae* and *Xinjiangchelyidae*.

Bashuchelyidae and *Xinjiangchelyidae* are closely related to one another (Tong et al., 2012b). 19YP-2006.1 shares with them

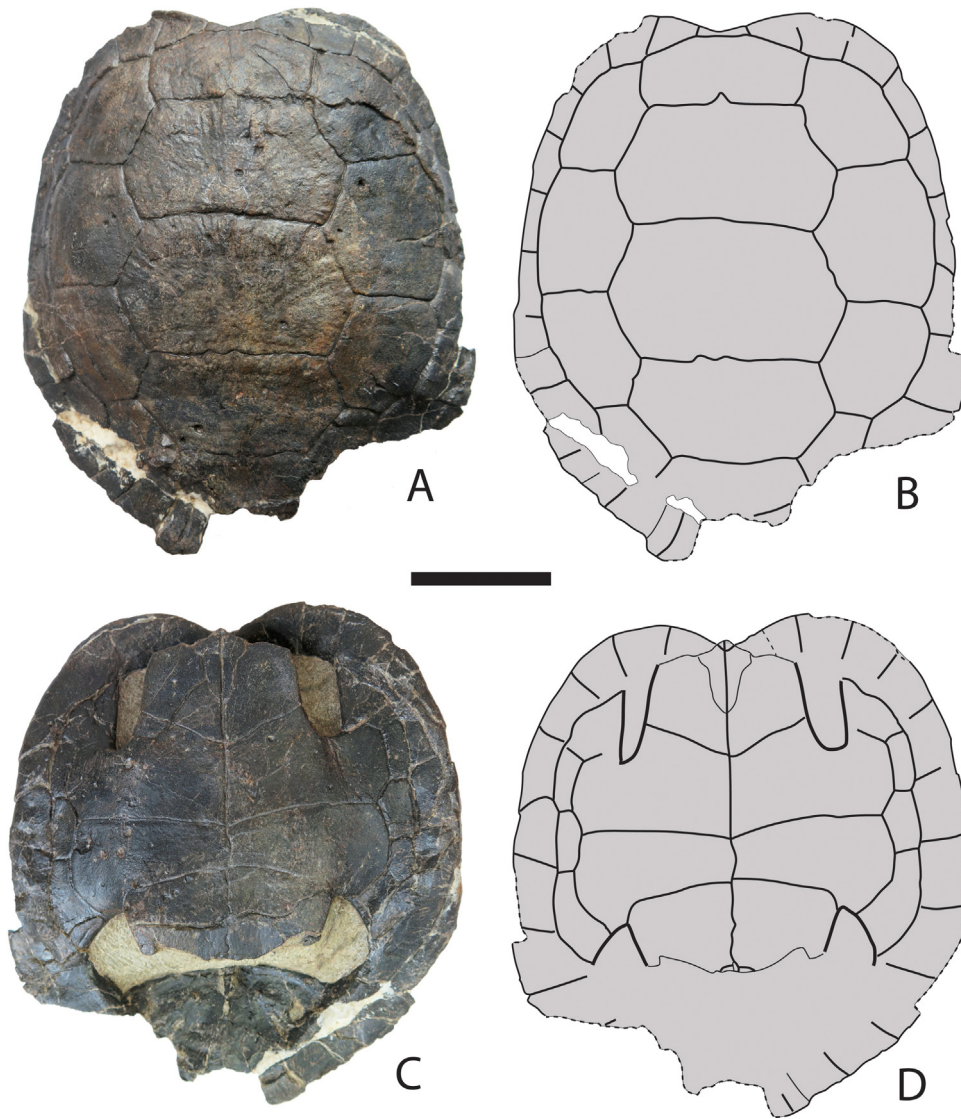


Fig. 2. *Protoxinjiangchelys* sp. (19YP-2006.1) from the Middle Jurassic Xintiangou Formation, Yunyang, Chongqing. Shell in dorsal (A and B) and ventral (C and D) views. Scale bar = 5 cm.

Protoxinjiangchelys sp. (19YP-2006.1) provenant de la Formation Xintiangou (Jurassique moyen), Yunyang, Chongqing. Carapace en vues dorsale (A et B) et ventrale (C et D). Barre d'échelle = 5 cm.

the omega-shaped femoroanal sulcus invading the hypoplastra, a synapomorphic character of the group. Although most features of the bony plates are not observable, 19YP-2006.1 is distinguished from *Bashuchelys* spp. in the rounded outline of the carapace and the wide vertebral scutes 2–4. In *Bashuchelys* spp., the shell is more elongate and the vertebrals 2–3 are narrow while the vertebral 4 is clearly wider. The wide vertebrals 2–4, a long pectoral scute and the position of the humeropectoral sulcus distant from the level of axillary notches seen in 19YP-2006.1 are reminiscent of *Chuannanchelys dashanpuensis* and *Protoxinjiangchelys salis* from the Middle Jurassic Xiashaximiao Formation of Dashanpu. However, *C. dashanpuensis* differs from 19YP-2006.1 in having a longer carapace, a diamond-shaped entoplastron and wider anterior and posterior lobes at the base (Fang, 1987; Tong et al., 2012a). 19YP-2006.1 is more similar to *P. salis* in the rounded carapace outline, leaf-shaped entoplastron and the anterior and posterior lobes that have a relatively narrow base (Tong et al., 2012a). These similarities support attribution of the new specimen to *Protoxinjiangchelys*. However, some differences between them can be noticed: in *P. salis*, the radiating ridges on the carapace surface are absent and the

epi/hyoplastral suture is transversal. Considering these differences and the lack of most characters of the bony plates, we assign 19YP-2006.1 to *Protoxinjiangchelys* sp.

19YP-2006.1 presents primitive features among Xinjiangchelyidae. These include the wide vertebrals, the relatively narrow lateral marginals, the more anterior position of the humeropectoral sulcus and the pectoral longer than the abdominal scute. Wide vertebral scutes are present in the Early-Middle Jurassic primitive turtles, such as *Heckerochelys romani* Shukhanov, 2006 from the Middle Jurassic of Russia, *Eleanchelys waldmani* Anquetin, Barrett, Jones, Moore-Fay and Evans, 2009 from the Middle Jurassic Kilmaluag Formation of Scotland and *Condorchelys antiqua* Sterli, 2008 from the Middle Jurassic Cañadon Asfalto Formation, Argentina. In these stem testudines the vertebral scutes are even wider (Anquetin, 2010; Sterli et al., 2018; Sterli and De La Fuente, 2010; Sukhanov, 2006). In more advanced xinjiangchelyids, including *Chengyuchelys* spp. *Tienfuchelys* spp., *Annemys* spp., and most *Xinjiangchelys* species (except *X. chowi* (Matzke et al., 2005)) the vertebral scutes are narrower (Rabi et al., 2014, 2013; Tong et al., 2015a, 2012b). The narrow lateral marginals, the humeropectoral sulcus located

anteriorly, and the pectoral longer than the abdominal are present in phylogenetically more primitive bashuchelyids and some basal xinjiangchelyids such as *Protoxinjiangchelys*, whereas in more advanced xinjiangchelyids, the lateral marginals are mesiolaterally expanded, extending onto the costal plates; the humeropectoral sulcus is located at the base of the anterior lobe and the pectoral has roughly the same length as the abdominal.

3.2. *Xinjiangchelyidae* indet

(Figs. 3 and 4)

Referred material: 17YP3513-S1, a damaged and dorsoventrally crushed shell with articulated carapace and plastron and appendicular elements; 17YP1609-S6, a partial carapace.

3.2.1. Description

3.2.1.1. Specimen 17YP3513-S1. The shell is incomplete, the distal portion of the left costals 1 to 7, damaged right and left costals 8, the complete suprapygal, pygal, left peripherals 2–3 and both right and left peripherals 8 to 11 are preserved. As preserved, the carapace measures 170 mm in length (with an estimated length of 180 mm) and 158 mm in width. The shell is low and slightly deformed, the carapace is pushed leftwards relative to the plastron by crushing. The nuchal and neural series are not preserved. There is a large single diamond-shaped suprapygal. The pygal is almost complete, it is twice wider than long. The costal 1 is short as in other primitive turtles. Anterior to the suprapygal, at least the costals 8 meet along the midline. The free margin of the peripherals 2–3 are thickened and slightly upturned, forming a light gutter. The peripherals 8 to 11, nearly complete on the right side, are mesiolaterally expanded.

The vertebrae 2–4 are partly preserved. The vertebral 2 and 3 are similar in width whereas the vertebral 4 is wider. The vertebral 5 is slightly narrower than the vertebral 4, roughly as wide as the vertebral 3, and covers the anteromedial corner of the peripheral 10. The intervertebral sulcus between the vertebrae 4 and 5 is located on the costal 8, posterior to the reduced neural series and anterior to the suprapygal. The marginals 9–11 are restricted onto the corresponding peripherals, whereas the marginals 12 are longer than the pygal.

The plastron is incomplete, lacking the epiplastron, entoplastron, and left hyoplastron. The plastron is loosely attached to the carapace. A peg-like structure is present on the anterior and posterior ends of the bridge. The bridge, almost complete on the left side, is long. The posterior lobe is complete. It is relatively short, being shorter than the bridge, with the lateral margins strongly convergent posteriorly. An anal notch is absent. The mesoplastra are absent. The hypo/xiphiplastral suture is convex posteriorly.

The pectoroabdominal sulcus is straight. The abdominofemoral sulcus is convex anteriorly. The femoroanal sulcus is omega-shaped, extending onto the hypoplastra.

Scapula: Both scapulae are preserved, the right one is more complete. The acromion process of the right scapula is complete whereas the scapular process is broken. The acromion process measures 20 mm in length, it forms a wide angle of about 120° with the scapular process. A glenoid neck is visible.

Humerus: The right humerus is complete, presented in lateral view, whereas the left one is damaged. The humerus measures 38 mm in length. The shaft is almost straight, only slightly convex dorsally. The head bends dorsally. The distal portion is enlarged. The ectepicondylar foramen is closed.

3.2.1.2. Specimen 17YP1609-S6. 17YP1609-S6 is a partly disarticulated partial carapace, with neurals 2–7, left costals 3–6, right costals 2–6 and the right peripherals 4–9 preserved. It is smaller than 17YP3513-S1 with an estimated shell length of 150 mm.

The series of neurals 2–7 is continuous, they are relatively wide. The neurals 2 and 3 are damaged. The neurals 4–6 are slightly longer than wide, their intact left margin shows that these plates have short anterolateral sides. The neural 7 is reduced, with a narrowed posterior end, indicating that the neural series is reduced and the neural 7 is the last neural. The dorsal surface of the neurals bears a continuous marked midline ridge. The costals have parallel anterior and posterior margins. All costals bear a prominent rib swelling on the inner surface that is narrower medially and expanded and becomes lower laterally. The rib head is strong. The right peripherals are shifted downwards by crushing, the carapacial fontanelle is apparently absent.

The vertebrae 2–4 are preserved, the vertebral 3 is the most complete. The vertebrae 2 and 3 are similar in width. The vertebral 3 is wider than long, extending from the costal 3 to the costal 6. The vertebral 4 is apparently wider than the vertebral 3. The intervertebral sulcus between the vertebrae 3 and 4 is located on the anterior part of the neural 6.

3.2.2. Comparisons

17YP3513-S1 and 17YP1609-S6 likely belong to the same taxon. These two shells share the similar shape of the vertebrae 2–4 with the vertebrae 2–3 similar in width and the vertebral 4 being clearly wider than the vertebral 3; and a reduced neural series, with the posterior costals meeting along the midline. This vertebral configuration differs from 19YP-2006.1 in which the vertebrae 2–4 have a similar width. In addition, 17YP1609-S6 differs from 19YP-2006.1 in the presence of a midline keel on the carapace.

17YP3513-S1 and 17YP1609-S6 are assigned to *Xinjiangchelyidae* on the basis of the low shell, the thickened free margin of peripherals 2–3 forming a gutter, the mesiolaterally expanded peripherals 8–11, the omega-shaped femoroanal sulcus extending onto the hypoplastra and the absence of mesoplastra. The omega-shaped femoroanal sulcus extending onto the hypoplastra is distinct from *Sinemydidae*/*Macrobaenidae*. They are distinguished from all other xinjiangchelyids in having the vertebral 4 wider than the vertebrae 2–3 and in the presence of a midline keel on the carapace. The reduced neural series, with the posterior costals meeting along the midline seen in 17YP3513-S1 and 17YP1609-S6 differs from the Late Jurassic xinjiangchelyids from the Shangshaximiao Formation of the Sichuan Basin (*Chengyuchelys* spp. and *Tienfuchelys* spp.) which have a complete neural series; but this condition occurs commonly in *Xinjiangchelys* as intraspecific variation, for instance *X. junggarensis* from the Late Jurassic of the Junggar Basin, *X. oshanensis* from the Middle Jurassic of Yunnan and *X. wusu* from the Middle Jurassic of the Turpan Basin, (Peng and Brinkman, 1993; Rabi et al., 2013; Tong et al., 2015a, 2012b). In 17YP3513-S1, there is one large single diamond-shaped suprapygal, instead of two suprapygals in most xinjiangchelyids except the holotype of *X. junggarensis* Ye, 1986 which has a single large suprapygal (Tong, 2017; Ye, 1986b).

The vertebral 4 clearly wider than vertebrae 2–3, as seen in 17YP3513-S1 and 17YP1609-S6, is reminiscent of *Bashuchelys* spp. and differs from other xinjiangchelyids in which these scutes have a similar width. However in these two specimens from Yunyang the vertebrae 2–3 are wider than long whereas they are roughly as long as wide in *Bashuchelys* spp. The intervertebral 3/4 sulcus located on the neural 6 as seen in 17YP1609-S6 is reminiscent of bashuchelyids and some primitive xinjiangchelyids (e.g. *Protoxinjiangchelys salis*, *Chengyuchelys baenoides*). It may also occur in some *Xinjiangchelys* as intraspecific variation (e.g. *X. junggarensis* from Pingfengshan, Junggar Basin (IVPPV 9537-6), and *Annemys latiens* from Shar Teg, Mongolia) (Peng and Brinkman, 1993; Rabi et al., 2014), whereas in most xinjiangchelyids, this sulcus is located on the neural 5 (e.g. *Chengyuchelys latimarginalis*, *C. radiplicatoides*, *Annemys levensis*, *Xinjiangchelys oshanensis*) (Brinkman et al., 2013;

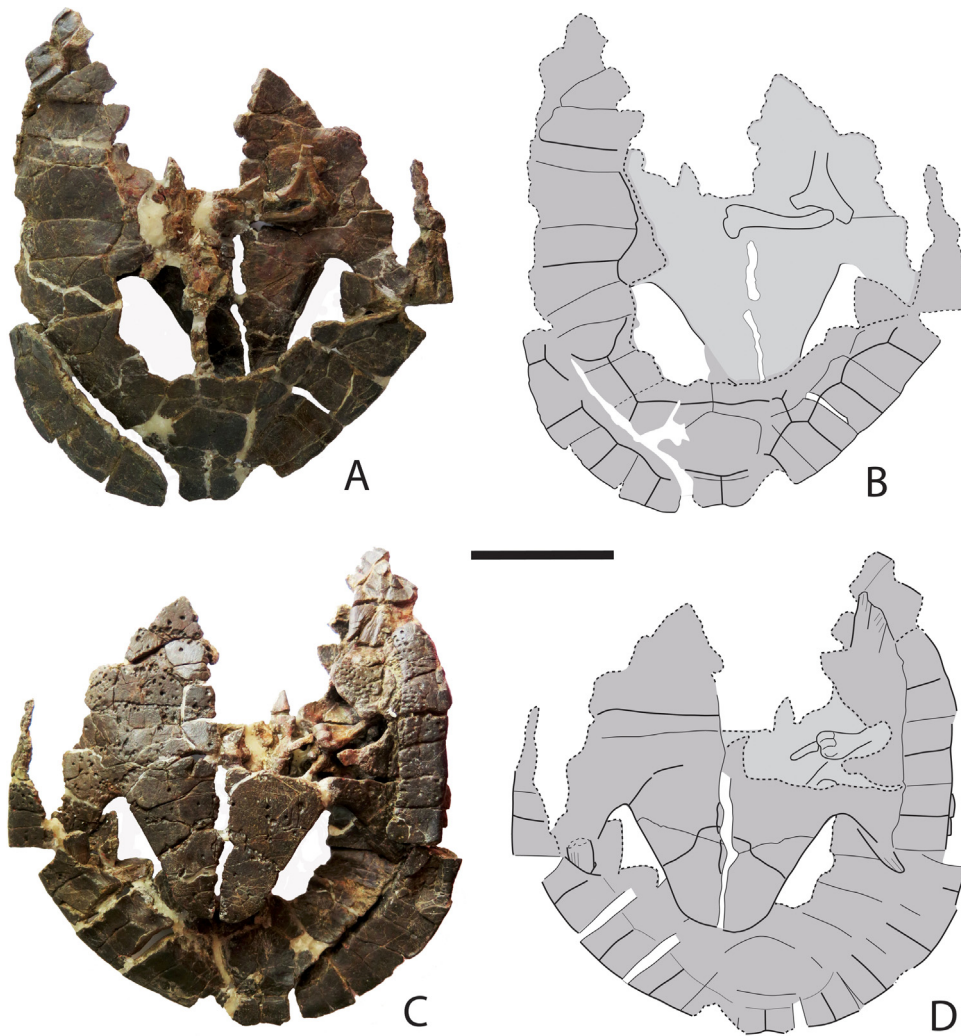


Fig. 3. Xinjiangchelyidae indet. from the Middle Jurassic Xintiangou Formation, Yunyang, Chongqing. Shell (17YP3513-S1) in dorsal (A and B) and ventral (C and D) views. Scale bar = 5 cm.

Xinjiangchelyidae indet. provenant de la Formation Xintiangou (Jurassique moyen), Yunyang, Chongqing. Carapace (17YP3513-S1) en vues dorsale (A et B) et ventrale (C et D). Barre d'échelle = 5 cm.

Rabi et al., 2014; Tong et al., 2015a, 2012b). In 17YP3513-S1, the vertebral 5 extends to the peripheral 10 as in *Bashuchelys* spp. and *Chengyuchelys* spp., but differs from *Xinjiangchelys* spp. and *Annemys* spp. in which the vertebral 5 contacts the peripheral 11. 17YP3513-S1 and 17YP1609-S6 have a loose plastron/carapace attachment as in *Xinjiangchelys* spp. and *Annemys* spp., whereas *Protoxinjiangchelys salis*, *Chengyuchelys* spp. and *Tienfuchelys* spp. have the plastron sutured to the carapace. To sum up, 17YP3513-S1 and 17YP1609-S6 appear to present a particular character combination among Xinjiangchelyidae, but because of the incomplete nature of the specimens, we refrain from erecting a new taxon pending the discovery of more complete material.

4. Discussion

4.1. Yunyang turtle assemblage

Turtle remains from the Middle Jurassic Xintiangou Formation of Yunyang described above are assigned to Xinjiangchelyidae and include two taxa, *Protoxinjiangchelys* sp. and Xinjiangchelyidae indet. Compared with the turtle fauna from the overlying Xiashaximiao Formation, the notable difference is the absence of the basal Testudines sichuanchelyids in the Xintiangou Formation,

but the sample is too small to be significant. The turtles from Yunyang present some primitive features among Xinjiangchelyidae (e.g. wide vertebrals, narrow lateral marginals, humeropectoral sulcus located anteriorly, and pectoral longer than abdominal in 19YP-2006.1; and a vertebral 4 wider than vertebrals 2. 3 and the intervertebral 3. 4 sulcus located on the neural 6 in 17YP3513-S1 and 17YP1609-S6).

The vertebrate fauna from the Xintiangou Formation consists of predominantly freshwater dwellers (fishes, temnospondyl amphibians, sauropterygians and crocodiles), with a few land animals (dinosaurs and tritylodont mammal-like reptiles). The depositional environment of the vertebrate-bearing beds at Yunyang is considered as predominantly lacustrine (Li et al., 2019). As indicated by the morphology of their shell, the xinjiangchelyids from Yunyang were freshwater turtles like other members of the family.

4.2. Stratigraphical distribution of Xinjiangchelyidae

Known since the Middle Jurassic, Xinjiangchelyidae reached their peak diversification during the Late Jurassic when they were dominant in the turtle faunas from Asia. During that period, xinjiangchelyids were widespread in this region, being reported from

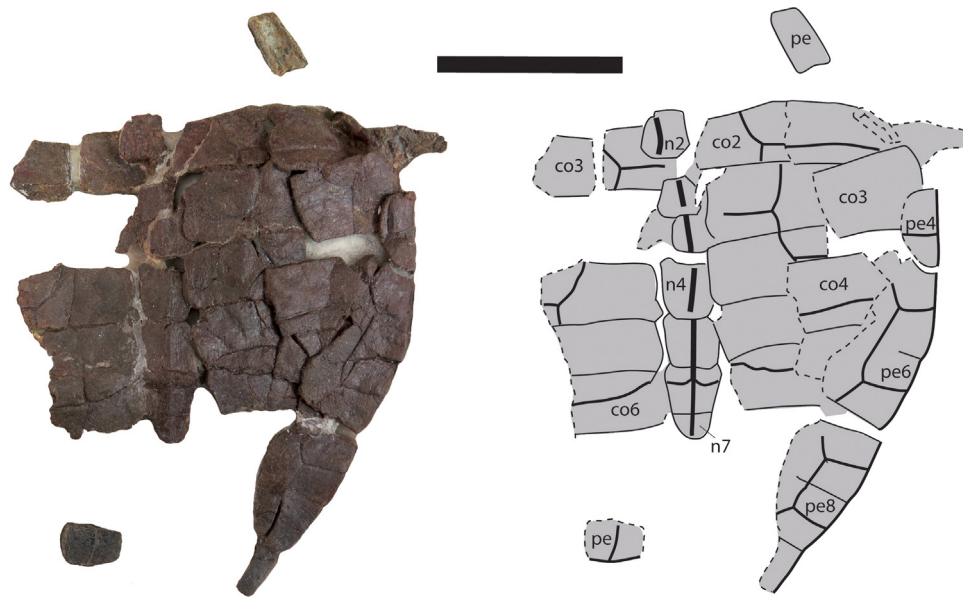


Fig. 4. Xinjiangchelyidae indet. from the Middle Jurassic Xintiangou Formation, Yunyang, Chongqing. Partial carapace (17YP1609-S6) in dorsal view. Scale bar = 5 cm. co: costal plate; n: neural plate; pe: peripheral plate.
Xinjiangchelyidae indet. provenant de la Formation Xintiangou (Jurassique moyen), Yunyang, Chongqing. Carapace partielle (17YP1609-S6) en vue dorsale. Barre d'échelle = 5 cm. co : plaque costale ; n : plaque neurale ; pe : plaque périphérique.

Central Asia, North and South China and also from SE Asia (Rabi et al., 2010; Sukhanov, 2000; Tong, 2017; Tong et al., 2019, 2015b). In mainland Asia, by the Early Cretaceous, xinjiangchelyids appear to have been replaced by Sinemydidae/Macrobaenidae in the freshwater ecosystems. The only record of the family from the Early Cretaceous is a single shell of *Xinjiangchelys* sp. from the Tugulu Group, Junggar Basin, Xinjiang (Danilov and Parham, 2007). Most Middle Jurassic xinjiangchelyids are from the latest Middle Jurassic (Callovian) except *Annemys* sp. from the Bathonian Itat Formation of Berezovsk coal mine in western Siberia (Averianov et al., 2016), for instance *X. qiguensis* from the Qigu Formation, *X. chowi* from the Toutunhe Formation, Junggar Basin, Xinjiang, China, and *X. tianshanensis* and *Annemys* sp. from the Balabansai Formation, Fergana, Kirgizstan (Averianov et al., 2016; Matzke et al., 2005; Nessov, 1995; Nessov and Kaznyshkin, 1985; Tong, 2017). Based on the dinosaur fauna, the Middle Jurassic Chuanjie Formation in Yunnan that yielded *X. oshanensis* is considered as coeval with the Xiashaximiao Formation (Li et al., 2011; Tong et al., 2015a). The age of the Xiashaximiao Formation that yielded *Protoxinjiangchelys salis* is debated, although a recent detrital zircon U-Pb dating provided 159 ± 2 Ma for the Xiashaximiao Formation, corresponding to basal Late Jurassic (Oxfordian), however, most biostratigraphical indicators, such as bivalves, estherias, ostracods, sporopollen and plants; support a Middle Jurassic age for that formation (Peng et al., 2005; Wang et al., 2018). As the Xintiangou Formation underlies the Xiashaximiao Formation, the turtles from Yunyang are likely the most ancient xinjiangchelyids hitherto recorded.

5. Conclusions

The shells from Yunyang described in the present paper are the first report of turtle remains from the Middle Jurassic Xintiangou Formation, Sichuan Basin. They are referred to Xinjiangchelyidae and include two taxa (*Protoxinjiangchelys* sp. and *Xinjiangchelyidae* indet.). Corresponding to the oldest known Xinjiangchelyidae, the Yunyang turtle assemblage is marked by some primitive features of that family, such as the wide vertebral scutes or the vertebral 4 wider than vertebrals 2–3, and narrow lateral marginals. The discovery of the Yunyang turtle fauna extends the stratigraphical

distribution of Xinjiangchelyidae and improves our knowledge of the early evolution of that family. It demonstrates that by the Middle Jurassic, at the time of the deposition of the Xintiangou Formation, the group was already diversified in the Sichuan Basin. Further field work for the discovery of additional material is expected for a better understanding of the origin and evolutionary history of eucryptodiran turtles.

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