

Large anseriform (Aves: Anatidae: Romainvilliinae?) fossils from the Late Eocene of Xinjiang, China

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Abstract Two new avian fossils from the Late Eocene of Xinjiang in western China appear to document the possible first occurrence of the extinct anseriform group Romainvilliinae (Anatidae) within China and Asia. The tarsometatarsus has several anseriform and anatid characters, and a combination of traits only reported from the romainvilliines among waterfowl. The absence of a medial flange on the second trochlea, its large size similar to extant swans, and asymmetrical proximal end of the plantar side of the third trochlea indicate that this specimen represents a new unnamed taxon. The equally large femur specimen exhibits morphology consistent with the anatid, and possible romainvilliine, *Cygnopterus affinis* from the Early Oligocene of Belgium. If these unnamed fossils represent Asian romainvilliines, they support a geographic range extension of the group, the occurrence of large body-sized romainvilliines in the Eocene, and an avifaunal biogeographic link between Europe and Asia during the Eocene prior to the end of the Turgai Strait as a dispersal barrier to most mammals.

Key words Xinjiang, Eocene, Anseriformes, Anatidae, Romainvilliinae

1 Introduction

The fossil record of birds from the Paleogene of China is relatively poorly known compared to equivalent aged sediments in Europe and North America and the much publicized Chinese Cretaceous avifaunas. The work on avian Paleogene fossils from China has uncovered less than a dozen named species, and those taxa include specimens of questionable phylogenetic affinities, as well as varying levels of diagnosability in some cases (Hou et al., 2003; Mayr, 2009; Wang et al., 2012). However, the work of documenting the fossil record of Chinese and Asian Paleogene birds in general continues (Hwang et al., 2010; Kurochkin and Dyke, 2010, 2011; Wang et al., 2012). Adding to that short list of known Chinese Paleogene avian taxa are recently collected anseriform bones including a partial distal tarsometatarsus and a distal femur from the Paleocene-Eocene Irtys River Formation in Xinjiang, western China.

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As noted by Mayr (2008, 2009) and Mayr and de Pietri (2013), the fossil record of anseriforms in the Paleogene of the Northern Hemisphere is somewhat limited in terms of its overall diversity, but does include members of all major anseriform lineages. Much of that early Cenozoic record is of the extinct Presbyornithidae, known from the Middle Paleocene through the Middle Eocene (Kurochkin and Dyke, 2010; Mayr, 2009). The Asian anseriform record in the Paleogene is quite sparse with presbyornithids reported from the Paleocene and Eocene of Mongolia (Kurochkin and Dyke, 2010) and Oligocene specimens of dubious phylogenetic placement (see Mayr, 2009 and Mayr and de Pietri, 2013 for a further discussion of those taxa). Currently, the oldest published anseriform fossils from China are *Sinanas* from the Middle Miocene, and *Aythya shihuibas* and an indeterminate species of *Anas* in the Late Miocene (Yeh, 1980; Hou et al., 2003) indicating a long gap in the known history of anseriforms in China.

Part of the biodiversity of Paleogene anseriforms in the Northern Hemisphere is the recently recognized clade Romainvilliinae. At present, that extinct monophyletic group is known from the Late Eocene *Romainvillia stehlini* from France, the Late Oligocene *Saintandrea chenoides* from France, *Paracygnopterus scotti* from the Early Oligocene of England, and an unnamed taxon from the Early Oligocene of Belgium (Lebedinsky, 1927; Mayr, 2008, 2009; Mayr and de Pietri, 2013). Those species are thought to form the sister group to crown Anatidae to the exclusion of Presbyornithidae, and have been placed taxonomically in the Anatidae (Mayr, 2008, 2009; Mayr and de Pietri, 2013). Furthermore, Mayr and de Pietri (2013) discuss other larger body-sized Oligocene and Miocene anseriform material from Europe and Asia that may belong to this clade. Even without those other fossils, the known romainvilliines range in size from that of a dabbling duck to a goose indicating a similar amount of body size variation with that in presbyornithids and crown anatids (Mayr, 2008; Mayr and de Pietri, 2013). Extending the fossil record of anseriforms into the Eocene in China is a distal tarsometatarsus that appears consistent in its morphology with the Romainvilliinae and a distal femur that shares much of its morphology with *Cygnopterus affinis*, an anatid and potential romainvilliine (see Mayr and de Pietri, 2013 for a discussion of that species).

The Xiaerhete locality (IVPP locality XJ201009) in Xinjiang has produced several fossil amiid fish remains, two taxa of turtles (a trionychid and a testudinoid), one species of crocodilian, and tooth and bone fragments of mammals. Both of the anseriform specimens described below were collected at that locality and represent the only avian material from that fossil locality. The inferred depositional paleoenvironment at Xiaerhete is clearly associated with an open body of water, and the addition of an anseriform to the Xiaerhete faunal list is entirely consistent with that habitat interpretation. The fossils were discovered from a locality near Xiaerhete Village, about 6 km northwest of Jeminay City (Fig. 1), and very close to the border between China and Kazakhstan. Geographically, the Xiaerhete fossil locality lies in the Jeminay-Kaba-Burqin Basin, which is generally regarded as the eastern part of the Zaysan

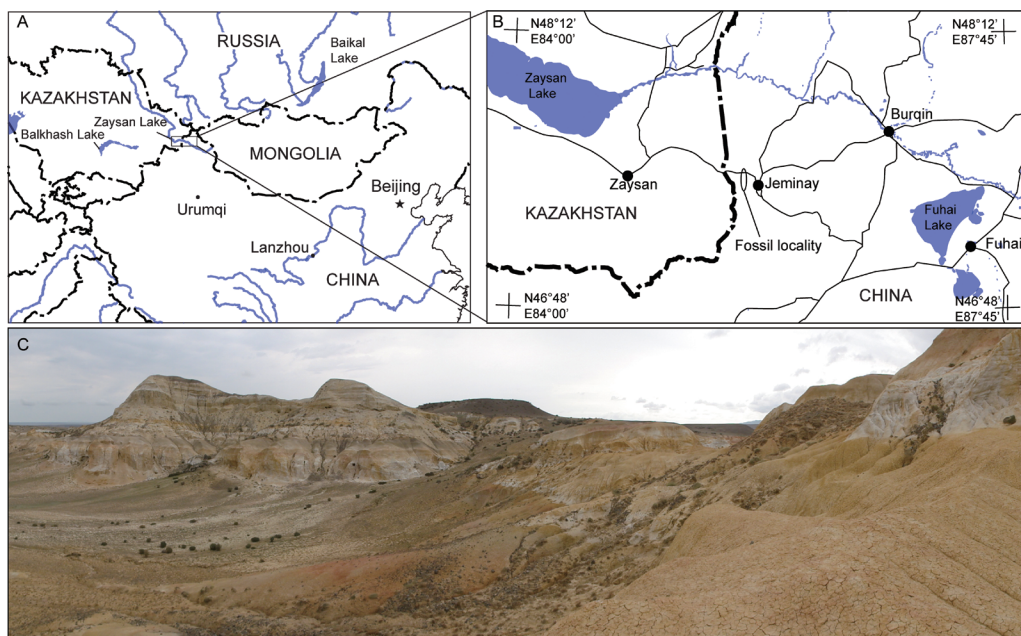


Fig. 1 Xiaerhete fossil locality and the Irtysh River Formation in the Jeminay region

A. Map showing the location of the Xiaerhete fossil locality in the Jeminay region within China adjacent to several other countries; B. Detailed map showing the border region between Xinjiang and Kazakhstan and the location of the Xiaerhete fossil locality; C. Panoramic view of the fossiliferous hills of the Irtysh River Formation that produced the anseriform fossils

Basin.

The Cenozoic deposits in the Jeminay region consist of two rock units. The overlaying Suosuoquan Formation is a set of eolian reddish brown muddy siltstones. It usually exhibits a massive structure, with no bedding, and the sediments commonly contain small carbonate nodules and clay-coated grains, similar to the red clay on the Loess Plateau. The Suosuoquan Formation crops out in a very large area of the northern Junggar Basin, and numerous mammalian fossils have been discovered in this formation. Paleomagnetic research has suggested that the Suosuoquan Formation was deposited as early as 24 Ma (Sun et al., 2010, Ye et al., 2012). The usually bright-colored fluviolacustrine sediments in the Jeminay region that underlay the Suosuoquan Formation previously were misinterpreted as the Ulunguhe Formation (Jin, 2000; Ye et al., 2005). Our investigations during the past a few years in this region have revealed that these fluviolacustrine sediments instead should belong to the Irtysh River Formation. At its type section about 80 km northeast of the Xiaerhete locality, the Irtysh River Formation is characterized by pale gray, greyish yellow, and light brown mudstone, siltstone, and sandstone beds that are interbedded with reddish and purplish variegated crack layers and dark brown ferruginous layers. At the Xiaerhete locality, the sediments have similar crack layers and ferruginous layers, but the color is slightly less variegated. No fossil has ever been discovered at the type section of Irtysh River Formation, but the sediments at the

Xiaerhete locality are quite fossiliferous. Numerous fish and crocodilian fossils are known from the upper part of the Irtysh River Formation at the Xiaerhete locality. However, mammalian and avian fossils are rare. An unidentified anthracotheriid fossil and a few brontotheriid dental and postcranial fossils discovered at the Xiaerhete locality suggest an early Late Eocene age. A few perissodactyls (*Triplopus* sp., *Triplopus? jeminaiensis*, and *Lophialetes* sp.), and an unidentified hyaenodontid were found in the same formation about 20 km southeast of the Xiaerhete locality. These fossils suggest an older age within the Middle Eocene Irindmanhan Land Mammal Age. However, their stratigraphic correlation with the Xiaerhete locality fossils is unclear.

The only other Paleogene birds so far reported from Xinjiang are the Middle Eocene *Eociconia sangequanensis* from the Three-Spring area in Yixibaili Formation in the Junggar Basin, that is approximately 250 km from the Jeminay/Xiaerhete locality (Hou, 1989; Wang et al., 2012) and a tarsometatarsus fragment from the Early Oligocene Usu locality in the southern part of the Junggar Basin that was identified as anseriform (Chow et al., 1982). *Eociconia* is phylogenetically indeterminate. However, the holotype specimen lacks the deeply recessed plantar distal foramen of the Anatidae, and is much too small to be the same species as this new anseriform tarsometatarsus. The location of the Usu locality fossil is currently unknown, is not within the IVPP collection's database, and cannot be examined. If indeed, these new Xinjiang specimens are from a romainvilline, it would appear that not only did this derived anseriform clade attain large body size earlier than presently thought (before the Late Oligocene; e.g., Mayr and de Pietri, 2013), but that romainvillines also were more widespread in Eurasia (in both Europe and central Asia). Additionally, the presence of stem anatids in the Late Eocene after the youngest known records of the presbyornithids in the Middle Eocene suggests the potential succession of one anseriform clade for another (Romainvilliinae + crown Anatidae) during the Eocene.

Osteological terminology follows Baumel and Witmer (1993) with English equivalents of the Latin terms.

Institutional abbreviations and collections used IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Science, Beijing, China. Fossil specimens are denoted with a 'V' prior to the specimen number and modern skeletons in the IVPP collections do not have the 'V' prefix.

Comparisons were made with modern avian skeletons available in the IVPP and the Museum of Vertebrate Zoology at the University of California in Berkeley, USA. Specimens of *Palaelodus* and *Presbyornis* in the University of California Museum of Paleontology in Berkeley, USA also were examined during this research. Dr. Thierry Smith provided unpublished photographs of the femur of the only specimen of *Cygnopterus affinis* that is housed in the Royal Belgian Institute of Natural Sciences in Brussels for comparative purposes only.

2 Systematic paleontology

Aves Linnaeus, 1758

Anseriformes (Wagler, 1831)

Anatidae Leach, 1820

cf. Romainvilliinae (Lambrecht, 1933)

unnamed sp. nov.

Specimen IVPP V 18901, a partial distal right tarsometatarsus (Fig. 2).

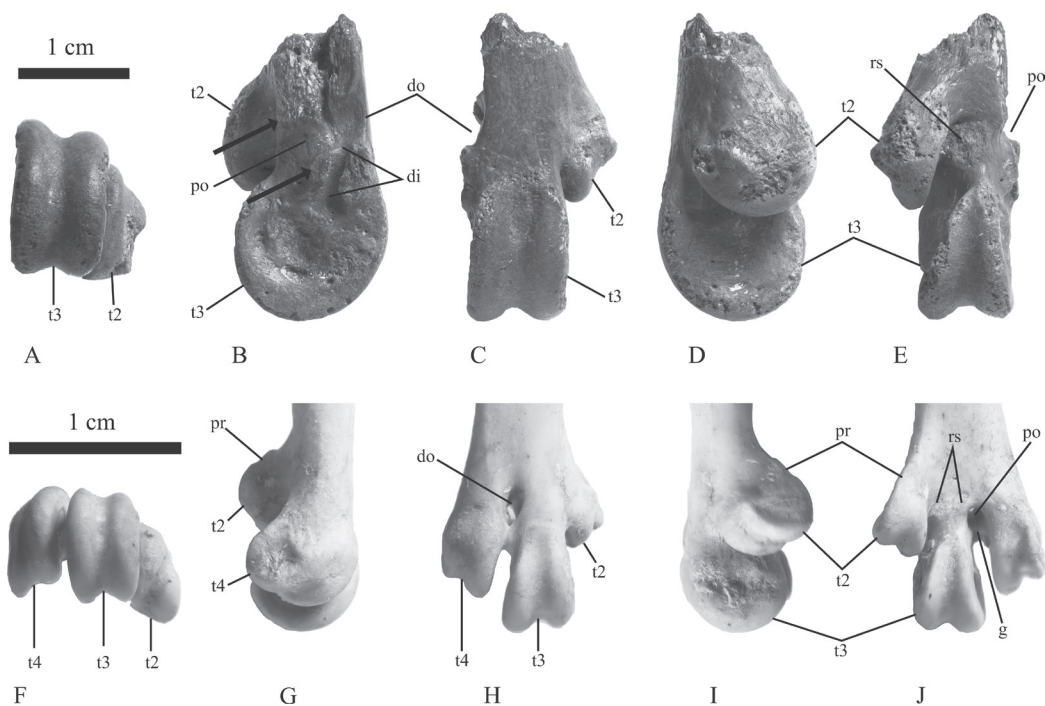


Fig. 2 The Xinjiang anseriform tarsometatarsus IVPP V 18901 in distal (A), lateral (B), dorsal (C), medial (D) and plantar (E) views, and the right tarsometatarsus of *Anas fabalis* IVPP 1747 in distal (F), lateral (G), dorsal (H), medial (I) and plantar (J) views

Abbreviations: di. distal interosseus canal; do. dorsal opening of the distal vascular foramen; g. groove on the plantar side distal to the distal vascular foramen; po. plantar opening of the distal vascular foramen; pr. ridge on the proximal plantar base of trochlea II; rs. rugose scar; t2. trochlea II; t3. trochlea III; t4. trochlea IV. The arrows indicate the plantar edges of the plantar opening of the distal vascular foramen highlighting the dorsoplantar offset between the proximal and distal sides of the foramen

Locality IVPP locality XJ201009 near Xiaerhete Village in Jeminay region in the early Late Eocene bed of the Irtys River Formation in Xinjiang, China (see above; Fig. 1).

Description The specimen preserves trochleae II and III of the tarsometatarsus, and it is dark brown in color. Trochlea IV and the lateral edge of the bone are broken off through

the distal foramen. The specimen only preserves a small amount of bone proximal to the distal foramen. The fragment's maximum length is 28.5 mm, the mediolateral width of trochlea III is 8.9 mm, the dorsoplantar depth of trochlea III is 14.0 mm, the mediolateral width of trochlea II is 5.7 mm, and the dorsoplantar depth of trochlea II is 11.1 mm.

Trochlea III projects very far distal to trochlea II, it has a relatively wide and deep trochlear furrow, and its trochlear rims have equal proximal extent. The dorsal face proximal to trochlea III is nearly flat to slightly convex. The dorsal opening of the distal foramen is located level with the proximal end of trochlea III, and is at the same proximodistal level as the medial angle of trochlea II. The medial intertrochlear incision extends more proximal than the lateral intertrochlear incision. Dorsally, trochlea II lacks a distinct trochlear furrow, but it is broadly and shallowly concave. Additionally, the dorsal proximal edge of the trochlea II articulation is damaged. Most of the medial side of trochlea III is visible in medial view, and it lacks a distinct ligamental pit. The medial side of trochlea II is damaged with some bone missing from the articular surface. Trochlea II projects only slightly plantar of trochlea III, and the medial side of trochlea II is shallowly concave.

The lateral face of trochlea III is distinctly pitted and concave. The plantar opening of the distal foramen is distal to the dorsal opening. The distal interosseus canal, preserved partially in cross section, angles somewhat plantarly entering the lateral intertrochlear incision just dorsal of mid-depth of the shaft. The plantar border of the distal interosseus canal is dorsal to the plantar edge of the bone indicating that a recess was present distal to the distal foramen and proximal to the lateral intertrochlear incision. There is an additional foramen that opens into the distal foramen from its proximal end within the shaft of the bone.

Trochlea III is slightly asymmetrical in plantar view, with its medial edge shorter and more angled relative to the proximodistal axis than the lateral rim. The plantar side of the trochlea comes to a point proximally, and at least part of the trochlear furrow extends to the proximal end. The plantar side of trochlea II is nearly flat and shows no evidence of a trochlear furrow. Lateral to trochlea II and proximal to trochlea III on the plantar surface is a rugose scar that is near the level of the proximodistal midpoint of the trochlea II. There is no evidence of a metatarsal I scar on the preserved end of the bone, and there is no plantar ridge extending proximally on the plantar-medial edge of the base of trochlea II. That area is rounded instead.

Comparisons Mayr (2008) lists diagnostic characters for Romainvilliinae in the tarsometatarsus as including the absence of metatarsal I scar, trochlea II being mediolaterally narrow and lacking a plantar trochlear furrow, and trochlea II also lacking a medioplantar crest extending proximally. However, the romainvilline *Saintandrea* has a shallow metatarsal I scar unlike *Romainvillia* and crown Anatidae, and it exhibits a shallow groove between the plantar opening of the distal foramen and the lateral intertrochlear incision (Mayr and de Pietri, 2013). If Mayr and de Pietri's allocation of *Saintandrea* to Romainvilliinae is correct, then there is clearly homoplasy among the characters of the tarsometatarsus in that group. The Xinjiang specimen exhibits all of those original Romainvilliinae (i.e. *Romainvillia*) tarsometatarsus

traits, except that the presence or absence of a metatarsal I scar cannot be determined because the part of the tarsometatarsus where the metatarsal I scar occurs in *Saintandrea* is not preserved in IVPP V 18901. Furthermore, the plantar distal foramen opening is connected to the intertrochlear incisure by a groove or recess in crown anatids, *Romainvillia*, and in *Saintandrea* to a lesser extent, but that the character is absent in anseranatids (Mayr, 2008; Mayr and de Pietri, 2013) and *Presbyornis pervetus*. In the Xinjiang tarsometatarsus, there was a groove or recess between the plantar opening of the distal foramen and the intertrochlear incision as seen in Fig. 2B, but it may not have been as deeply incised as in crown anatids and perhaps similar to the reported state in *Saintandrea* (Mayr and de Pietri, 2013). Mayr and de Pietri (2013) also say that the shallower state in *Saintandrea* could be the result of allometric differences in that large anseriform. Presumably a similar difference in scaling may be present in this large Xinjiang specimen as well. However, V 18901 clearly exhibits an angled distal foramen (with dorsal opening proximal to plantar opening) that also is deeply recessed in its plantar opening (a synapomorphy of Romainvilliinae + crown Anatidae; Livezey, 1997: character 92; Mayr, 2008).

The Xinjiang specimen shares with *Saintandrea* (but not *Romainvillia*) the asymmetrical plantar side of trochlea III where the medial plantar trochlear rim of trochlea III is shorter (proximodistally) than the lateral rim (Mayr, 2008; Mayr and de Pietri, 2013). In V 18901, there is a thin low ridge on the medial edge of the trochlea III furrow at its most proximal end, but that is an extension of the trochlear furrow and not the medial trochlear rim. However, the Xinjiang specimen lacks *Saintandrea's* apomorphic medial flange on trochlea II (Mayr and de Pietri, 2013). This Chinese anseriform is larger than *Romainvillia* and is similar in size to extant species of *Cygnus* (smaller than *C. cygnus* and larger than *C. melanocoryphus* and *C. atratus*). Despite its large size, the absence of the plantar ridge at the base of trochlea II in the Xinjiang tarsometatarsus is consistent with a phylogenetic position outside of crown Anatidae (and its large-bodied goose and swan clades) (Mayr, 2008; Mayr and de Pietri, 2013). Additionally, the absence of that ridge makes trochlea II relatively short proximodistally and a bit more rounded in the fossil compared to crown anatids who have the ridge. Furthermore, the very reduced or absent trochlea II furrow in V 18901 is inconsistent with the state in the extant large-bodied *Anser fabalis* (IVPP 1747) and *Cygnus cygnus* (IVPP 1030), who exhibit a more substantial concave notch or groove than the very subtly shallow area on the distal face in V 18901. Given the combination of its size, absence of the medial flange on trochlea II, asymmetric plantar side of trochlea III, and trochlea II lacking a medioplantar crest extending proximally, this fossil tarsometatarsus from Xinjiang can be separated from the other currently recognized taxa of romainvilliines (and crown anatids). Despite that level of character differentiation, we refrain from naming this fragmentary specimen. However, the absence of a plantar furrow on trochlea II, a mediolaterally narrow trochlea II, absence of a ridge on the proximal medioplantar side of trochlea II, and presence of a groove (or recess) between the plantar distal foramen opening and the lateral intertrochlear incision would seem to support

some affinity of this new fossil with *Romainvillia* (Mayr, 2008; Mayr and de Pietri, 2013). As a result of the homoplasy and morphological variability in the tarsometatarsus, definitive phylogenetic allocation of this fossil within the Anatidae is prevented, but the specimen's characters are highly suggestive of a position within or near the Romainvilliinae outside of crown Anatidae.

Although, V 18901 is very similar in its preserved size to specimens of *Eogrus*, it can be distinguished readily from the common eogruids from the Late Eocene to Miocene of Asia (Clarke et al., 2005; Kurochkin, 1976). *Eogrus* lacks the plantar groove between the distal foramen and intertrochlear incision and associated deeply recessed plantar opening of the distal foramen, has a plantar furrow or concavity on trochlea II and its plantar surface is proximodistally shorter than that in anseriforms, has a deep distinct ligamental pit on the medial side of trochlea II (absent in the Xinjiang specimen), has a symmetrical proximal plantar end of trochlea III, and has a trochlea II positioned more distally relative to trochlea III than in the Xinjiang specimen (Kurochkin, 1976; Clarke et al., 2005). Additionally, the Xinjiang anatid has a narrower medial intertrochlear incision, and lacks the distinct pits on the medial and lateral sides of the plantar proximal end of trochlea III (Clarke et al., 2005).

aff. *Cygnopterus* Lambrecht, 1931

sp. indet.

Specimen IVPP V 18902, a distal right femur (Fig. 3).

Locality IVPP locality XJ201009 near Xiaerhete Village in Jeminay region in the early Late Eocene bed of Irtysh River Formation in Xinjiang, China (see above; Fig. 1). This is the same locality as the tarsometatarsus described above.

Description The bone is light gray in color, relatively thick for its diameter, is worn in places and has some flakes missing from its surface. The maximum preserved length is 42.5 mm, distal mediolateral width is 24.1 mm, and distal craniocaudal depth is 17.3 mm.

A large rugose ridge, presumably the tuberculum m. gastrocnemialis lateralis, extends proximally along the lateral face from the proximal end of the lateral condyle. The lateral rim of the patellar groove extends proximal to the medial rim, but the medial rim is distinctly taller than the rounder and lower lateral rim. The distal end of the tuberculum m. gastrocnemialis lateralis is near the same proximodistal level as the proximal end of the lateral patellar groove rim. The medial patellar groove rim has a distinct proximal end (it does not just blend into the shaft, but has a distinct concave proximal end where it meets the shaft, best seen in medial view). The distal margin of the bone is concave in cranial view.

The medial face is slightly convex proximally, but nearly flat just proximal to the condyle. A thin medial supracondylar ridge extends proximally from the medial ligament pit adjacent to the condyle proximally to near the midpoint of the length of the preserved specimen. The caudal margin of the medial condyle is damaged, but the condyle is a semicircle in outline (medially) with the proximal end of the medial patellar groove rim approximately

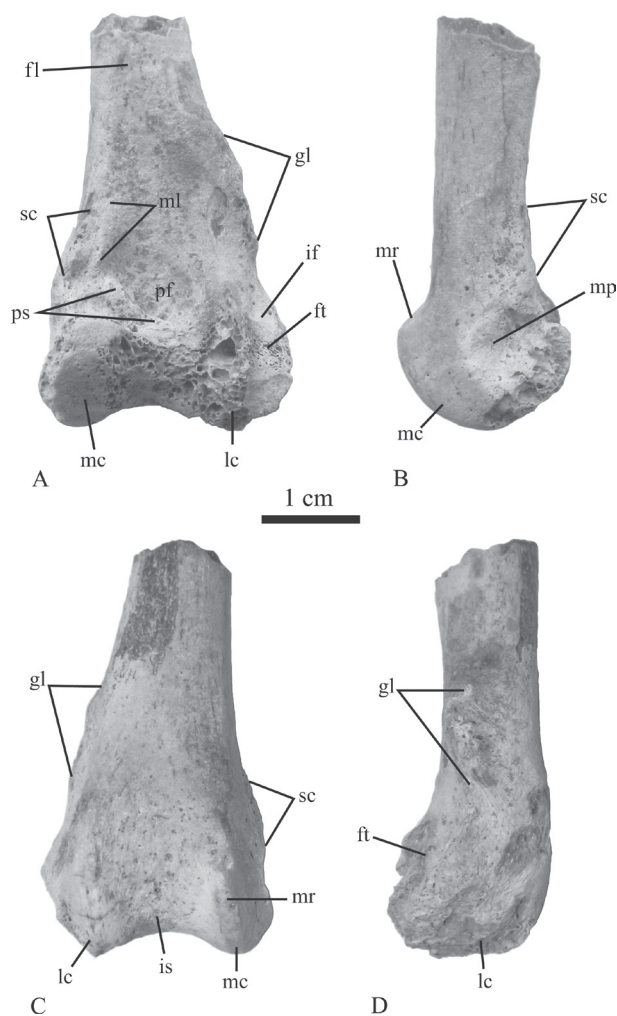


Fig. 3 The Xinjiang anseriform distal femur IVPP V 18902 in caudal (A), medial (B), cranial (C), and lateral (D) views. Abbreviations: fl. femoral ligamental attachment of Worthy and Lee (2008); ft. fibular trochlea; gl. presumed elongate tubercle for the origination of the gastrocnemialis lateralis; if. impression of the ansae iliofibularis; is. intercondylar sulcus; lc. lateral condyle; mc. medial condyle; ml. ligament attachment (scar) on the medial side of the popliteal fossa; mp. medial pit; mr. medial rim of the intercondylar sulcus; pf. popliteal fossa; ps. popliteal fossa muscle scar; sc. medial supracondylar crest and adjacent fossa

equal in its proximodistal position to that of the caudal tip of the medial condyle (Fig. 3B). The medial condyle has a centrally placed ligamental pit on a raised area (relative to the flat cranial portion of the condylar region).

The tuberculum m. gastrocnemialis lateralis is proximal to the lateral condyle. The shaft area cranial to the tuberculum is nearly flat, and the apex of the tuberculum is near the proximodistal length midpoint of the specimen. The lateral side of the lateral condyle is damaged. As preserved (since its damaged), the caudal edge of the femur is concave giving the distal end an overall dumbbell outline in distal view.

There is a concave notch in the lateral edge of the femur (cranial and caudal view) at the distal end of the tuberculum m. gastrocnemialis lateralis. Near the lateral edge and just distal to that notch is a shallow pit at the proximal end of the fibular trochlea that may be the impression of the ansae m. iliofibularis. The preserved fibular trochlea is mediolaterally wider than the pit. The long axis of the deepest part of the popliteal fossa is oriented oblique to the shaft with its proximal end medial to its distal end, and it shallows proximally and medially. The popliteal fossa is deepest at its distal end and houses several

small foramina in its distal face. Extending from the distal face around to the medial side of the popliteal fossa is a raised scar ('ps' in Fig. 3A). That popliteal scar is arcuate in its shape with a concave distal end and a convex proximal end. The medial end of the scar is proximal to the proximal end of the medial condyle, and the lateral end is near the mediolateral midpoint of the

intercondylar notch (adjacent to the distal tip of the popliteal fossa). Proximal to the proximal end of that popliteal fossa muscle scar is another raised muscle scar that bounds (partly) the medial edge of the popliteal fossa ('ml' in Fig. 3A). That muscle scar extends proximally to near the proximal end of the medial supracondylar ridge. Near the proximodistal midpoint of the medial supracondylar ridge is a thickening on its caudal side that is medial to the distal end of what is labeled 'mr' in Fig. 3A. The area proximal to the proximal end of the medial condyle is concave. Near the proximal end of the caudal face of the specimen is a tubercle that may be equivalent to what Worthy and Lee (2008) term the femoral ligamental attachment that lies at the distal end of the caudal intermuscular line (line not preserved in this specimen).

Comparisons Many anseriform femora lack the combination of the greatly enlarged tuberculum m. gastrocnemialis lateralis and the raised elongate attachment scar(s) within the popliteal fossa. The combination of characters in the Xinjiang femur also is absent in flamingoes (including *Palaelodus*), pelecانiforms, and other groups of birds (i.e. other groups with stocky thick-walled femora with enlarged muscular origination and insertion sites). The morphology in the Xinjiang femur closely resembles that of the femur of *Cygnopterus affinis* from the early Oligocene of Belgium (Lambrecht, 1931: pl. 1). *C. affinis* originally was described as a sulid before its recognition as an anatid (i.e. specifically as a species of swan, Lambrecht, 1931), but Mayr and de Pietri (2013) have called that identification as a swan into question. They suggest that *C. affinis* could be a romainvilline, but skeletal elements with diagnostic characters (the carpometacarpus and tarsometatarsus) are absent from the only known skeleton of that species (Mayr and de Pietri, 2013). See Mayr and de Pietri (2013) for a further discussion of material allocated to other species of *Cygnopterus*.

The Xinjiang femur is much larger than that of *C. affinis*. The femur of *C. affinis* and the Xinjiang femur appear to share the elongate raised scars around the distal and medial sides of the popliteal fossa that border the medial supracondylar ridge laterally. *C. affinis* and the Xinjiang femur also share the related fossa on the caudal side of the medial supracondylar ridge. Additionally, the 'ml' (Fig. 3A) of the Xinjiang femur seems to be present in *C. affinis* as a raised ridge and extends proximal to the medial supracondylar crest in both femora. However, it appears that what is designated as separate scars 'ml' and 'ps' in the Xinjiang femur (Fig. 3A) form a continuous elongate scar in *C. affinis*. Both specimens have a very similar morphology of the medial supracondylar ridge. The medial condyle of *C. affinis* extends medial to the medial supracondylar ridge, but that area is damaged in the Xinjiang femur, and it is not possible to know how far medially the condyle may have extended. The subequal proximodistal position of the proximal end of the medial patellar groove rim and the caudal tip of the medial condyle are similar in IVPP V 18902 and *C. affinis* (though the rim is damaged in the Belgian fossil, Lambrecht, 1931: pl. 1). In contrast, *Cygnus cygnus* (IVPP 1030), *Anser fabalis* (IVPP 1747), and *Anas penelope* (IVPP 1749) all exhibit a medial rim of the patellar sulcus that extends much further proximally relative to the caudal tip of the condyle. The relative (enlarged) size and position of the tuberculum m. gastrocnemialis

lateralis is very similar between the two taxa as well. Despite their size differences and subtleties of the shape and depth of the popliteal fossa, these femora appear to be from very closely related taxa. The femur is not known in *Cygnopterus lambrechtii* (Kurochkin, 1969), but the Xinjiang femur could be from a related older species, if *Cygnopterus lambrechtii* is not a flamingo as Mayr and de Pietri (2013) postulate.

3 Discussion

The Xinjiang femur has a different preservation from that of the tarsometatarsus (different color and surface texture), and the two specimens were collected years apart during different field expeditions. It does not seem likely that the femur and the tarsometatarsus derive from the same individual, but could represent two individuals of the same species given their derivation from similar sized birds at the same place. At the same time, we cannot conclude that these two specimens stem from the same species given their phylogenetic uncertainty and the occurrence of many sympatric anatid species today and in the fossil record. The tarsometatarsus fragment exhibits characters that place it within Anatidae, but outside of the crown group in the same region of the phylogenetic tree as the Romainvilliinae. The Xinjiang femur exhibits many morphological similarities with *Cygnopterus affinis* (above). Mayr and de Pietri (2013) already considered that *C. affinis* may be another large-bodied Romainvilliinae, and the occurrence of a strikingly similar femur in the Late Eocene at a locality with a possible romainvilliine tarsometatarsus provides further, though, tentative support for the allocation of *C. affinis* to the Romainvilliinae. However, as no femur has been reported for any certain member of Romainvilliinae, the allocation of this isolated femur from Xinjiang to that clade must be treated as unsettled. Together, these specimens may represent a new member of the Romainvilliinae (and/or *Cygnopterus*), or possibly even a currently unrecognized Asian lineage in the anatid stem.

Kurochkin (1969) named a species of *Cygnopterus* (*C. lambrechtii*) and a species of *Cygnavus* (*C. formosus*) from the Oligocene of Kazakhstan based on a large distal humerus and a large distal tibiotarsus, respectively. Given that those species share no common skeletal elements with the material from Xinjiang, no direct comparisons can be made. However, if fossils allocated to *Cygnopterus* (and *Cygnavus*) are close relatives or even members of Romainvilliinae, then these new Chinese fossils may be closely related, or even equivalent, with one or more of those younger species level taxa from geographically close Kazakhstan. However, until more substantial skeletal elements are located in Asia (including the carpometacarpus), the phylogenetic placement of those anatid specimens will remain uncertain.

The known mammalian faunas of the Late Eocene of Europe and Asia differ significantly, but that biogeographic division broke down during near the Eocene-Oligocene boundary leading to the mammalian ‘Grande Coupure’ in Europe with the invasion of Europe by Asian mammalian clades (Hooker et al., 2004). During most of the Paleogene, Europe, Western Asia

and Northeastern Asia were separated from each other by the Turgai Strait and Danish-Polish Trough (Meulenkamp and Sissingh, 2003; Popov et al., 2004; Akhmetiev and Beniamovski, 2009). These two seaways, that joined the Tethys Sea and Arctic Ocean (along with climatic or environmental factors), formed a dispersal barrier to faunal exchange between Europe and Northeastern Asia. Abrupt global cooling and continental aridification during the Eocene-Oligocene transition period co-occurred with the regression of the Paratethys and likely helped to drive the faunal interchange between Europe, Western Asia, and Northeastern Asia (Rögl, 1998; Akhmetiev and Beniamovski, 2009). However, research on some small Paleogene mammals has demonstrated examples of mammalian dispersal to Europe from Asia before the Eocene-Oligocene transition (Baciu and Hartenberger, 2001; Maridet and Ni, 2013) indicating that the barrier(s) to dispersal started to break down during the Late Eocene. Additionally, Mayr (2011) hypothesizes that the mammalian ‘Grande Coupure’ resulted in the extinction of several flightless avian clades in Europe through the introduction of new predators.

Previously very little work has been done on the correlation of Paleogene avian faunas between Asia and Europe, and thus discussion of the timing and direction of any intercontinental dispersal among birds can only occur in general terms at present. In contrast to that of the better known contemporaneous mammalian faunas, the Turgai Strait and related waterways likely would not have been a significant dispersal barrier to volant birds, and the occurrence of the presumably flight capable Romainvilliinae in both the Late Eocene of France and possibly China may be a demonstration of that presumed geographic interconnectedness. As a result, the contemporaneous occurrence of Romainvilliinae and some small mammals in both Europe and Asia in the Late Eocene would seem to support at least a filter on dispersal or geographic movement of tetrapods rather than a complete ban on immigration before the en-masse movement of mammals (and presumably other taxa) between Europe and Asia at the beginning of the Oligocene (the Grande Coupure) that is associated with significant climatic (global cooling) and environmental change (Liu et al., 2009).

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新疆晚始新世的大型雁形目化石(鸟纲: 鸭科: Romainvilliinae?)

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摘要: 报道了发现于新疆晚始新世地层中的两件鸟类化石, 这两件化石可能代表了雁形目一个绝灭亚科Romainvilliinae在中国乃至亚洲的首次发现。其中一件跗跖骨片段保存了多个雁形目鸭科鸟类的特征, 同时保存了水禽中仅见于Romainvilliinae鸟类的特征组合。该跗跖骨属于一个个体很大的鸟类, 与现生天鹅相当, 其第二滑车内侧不存在突缘, 第三滑车足底面的近中侧不对称, 这些特征表明这件标本属于一个新属种。另一件股骨片段属于一个与跗跖骨标本个体同样大小的鸟类, 其特征与在比利时发现的早渐新世可能属于鸭科Romainvilliinae的*Cygnopterus affinis*相一致。如果新发现的这两件标本确属亚洲的Romainvilliinae鸟类, 则说明Romainvilliinae的地理分布范围也包括亚洲, 大体型的Romainvilliinae鸟类在始新世时即已存在, 并且也说明在阻断绝大多数哺乳动物扩散的图尔盖海峡干涸之前, 欧亚之间的鸟类地理区系一直存在联系。

关键词: 新疆, 始新世, 雁形目, 鸭科, Romainvilliinae

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