A femur of the giant bird *Gargantuavis* from the Late Cretaceous of Var (south-eastern France)

Eric Buffetaut[1,2], Delphine Angst[3], Patrick Mechin[4], Annie Mechin-Salessy[4]

Abstract

An incomplete femur from the Bastide-Neuve site (Fox-Amphux, Var) is referred to the giant bird *Gargantuavis philoinos*, various remains of which have already been reported from that locality. It shows close similarities with a more complete *Gargantuavis* femur previously described from the Montplo-Nord locality (Cruzy, Hérault). An estimate based on the minimum circumference of the femur from Bastide-Neuve indicates a mass of 75 kg, between the weights of the living cassowary and ostrich.

Keywords: *Gargantuavis*, femur, Late Cretaceous, southern France, body mass.

Résumé

Un fémur de l'oiseau géant *Gargantuavis* du Crétacé supérieur du Var (sud-est de la France)

Un fémur incomplet provenant du site Crétacé supérieur de Bastide-Neuve (Fox-Amphoux, Var) est attribué à l'oiseau géant *Gargantuavis philoinos*, dont divers restes ont déjà été signalés dans ce gisement. Il montre des ressemblances étroites avec un fémur plus complet de *Gargantuavis* précédemment décrit du gisement de Montplo-Nord (Cruzy, Hérault). Une estimation réalisée à partir de la circonférence minimum du fémur de Bastide-Neuve indique une masse de 75 kg, entre les poids du casoar et de l'autruche actuels.

Mots-clés : *Gargantuavis*, fémur, Crétacé supérieur, Sud de la France, masse corporelle.

Introduction

The giant bird *Gargantuavis philoinos* is known from a few Late Cretaceous localities in France and Spain (Buffetaut & Angst 2016a, b; Angst & Buffetaut 2017); in addition, a pelvis resembling that of *Gargantuavis* has recently been described from the Late Cretaceous of Romania (Mayr *et al.* in press). Its osteology is still incompletely known, as only elements of the pelvis [synsacrum and incomplete ilia (Angst *et al.* 2017; Buffetaut *et al.* 1995; Buffetaut & Le Loeuff 1998; Buffetaut *et al.* 2015; Buffetaut & Angst 2016b), a cervical vertebra (Buffetaut & Angst 2013) and two femora (Buffetaut & Le Loeuff 1998; Buffetaut & Angst 2019)] had hitherto been reported. Therefore, any new discovery of *Gargantuavis* bones is worth reporting. We describe here an incomplete femur from the Bastide-Neuve locality at Fox-Amphoux (Var, south-eastern France). That locality had already yielded the first element referrable to *Gargantuavis* [a synsacrum fragment (Buffetaut *et al.* 1995)], as well as two incomplete pelves consisting of the synsacrum and incomplete ilia (Buffetaut *et al.* 2015).

1. CNRS (UMR), Laboratoire de Géologie, École Normale Supérieure, PSL Research University, 24 rue Lhomond, 75231 Paris Cedex 05, France. eric.buffetaut@sfr.fr
2. Palaeontological Research and Education Centre, Maha Sarakham University, Maha Sarakham, Thailand
3. University of Bristol, School of Earth Sciences, Life Sciences Building, 24 Tyndall Avenue, Bristol BS8 1TQ, United Kingdom. angst.delphine@gmail.com
4. 13127 Vitrolles, France.

Geographical and geological setting

The Bastide-Neuve locality is located in the northern part of department Var, in Provence (south-eastern France), near the village of Fox-Amphoux. Geologically, it belongs to the Montmeyan/Fox-Amphoux syncline. According to Tortosa (2014), the deposits at the Bastide-Neuve site correspond to the Lower Rognacian facies, of late Campanian age. In view of uncertainties regarding the exact ages of the non-marine formations in Provence, an early Maastrichtian age probably cannot be excluded. On the basis of magnetostratigraphy, *Gargantuavis* remains from Laño (Spain) are of late Campanian age, whereas those from Campagne-sur-Aude (France) are early Maastrichtian (Buffetaut & Angst 2016a and references therein).

At Bastide-Neuve, the fossiliferous siltstones and sandstones have been excavated for many years by two of us (P.M. and A.M.S.) and have yielded a large number of vertebrate fossils, including fishes, turtles, crocodiles, pterosaurs and dinosaurs (see Buffetaut *et al.* 2015 and references therein). As mentioned above, the site had already yielded several pelvic elements belonging to *Gargantuavis philoinos.*

Systematic description

Class Aves Linnaeus, 1758
Subclass Ornithurae Haeckel, 1866
Family Gargantuaviidae Buffetaut & Angst, 2019
Genus *Gargantuavis* Buffetaut & Le Loeuff, 1998

Species ***Gargantuavis philoinos***
Buffetaut & Le Loeuff, 1998

The specimen (Mechin collection, n° 711) is a left femur lacking both articular ends (**Fig. 1**). It has been compared (**Fig. 2**) with a nearly complete right femur of *Gargantuavis philoinos* (Musée de Cruzy, n° MC-MN 1335) from the Montplo-Nord locality at Cruzy (Hérault) described by Buffetaut and Angst (2019). The specimen from Fox-Amphoux has undergone relatively heavy crushing and distortion. The caudal face, in particular, is much fractured. Proximally, the articular head that fitted into the *acetabulum* is missing, only the oblique mediodistal part of the "neck" (*collum femoris*) is visible. Where the widened proximal end of the specimen is broken, the internal bony structure is visible, showing cancellous bone of the kind usually seen in this position in birds. The shaft is robust, its medial margin is markedly concave, whereas the lateral margin is straight along most of its length, as in the femur from Cruzy. In lateral and medial views, it shows a distinct sigmoid curvature. On the cranial face of the shaft, there is a well-marked *crista intermuscularis cranialis* which is somewhat displaced laterally by crushing.

As in the femur from Cruzy, and unlike the condition in the enigmatic bird-like taxon *Elopteryx nopcsai* from the Late Cretaceous of Romania (Lambrecht 1929, 1933), there is no indication of a vestigial fourth trochanter on the medial margin of the shaft. Distally the shaft becomes wider and flatter. Where it is broken distally, the bone is hollow, with thin bony walls, 2.3 to 4 mm in thickness. The poorly preserved caudal face shows a well-marked *crista intermuscularis caudalis*. Its proximal part is not preserved, so that the prominent muscle scar visible on the specimen from Cruzy cannot be seen. In the distal part of the bone a low ridge located in a more or less median position arises medially to the *crista intermucularis caudalis*; a similar ridge is present on the femur from Cruzy. This ridge forms the lateral rim of the well defined *fossa poplitea*. The distal condyles are completely missing.

Measurements, size and mass estimates

Measurement description	Measurement (mm)
Maximum length, as preserved	177
Maximum width proximally, as preserved	75
Maximum width distally, as preserved	60.5
Minimum width of shaft	36.7
Minimum circumference of shaft	112

Table 1 - Principal measurements of specimen number 711.

Because the specimen n°711 is not complete, the measurements can only be taken "as preserved" (**Tabl. 1**), and the initial length of the bone can only be estimated by comparison with the better preserved femur from Cruzy, which is 235 mm in length (Buffetaut & Angst 2019). The femur from Bastide-Neuve was apparently slightly longer than that from Cruzy. It appears somewhat more robust, as shown by the greater minimum circumference

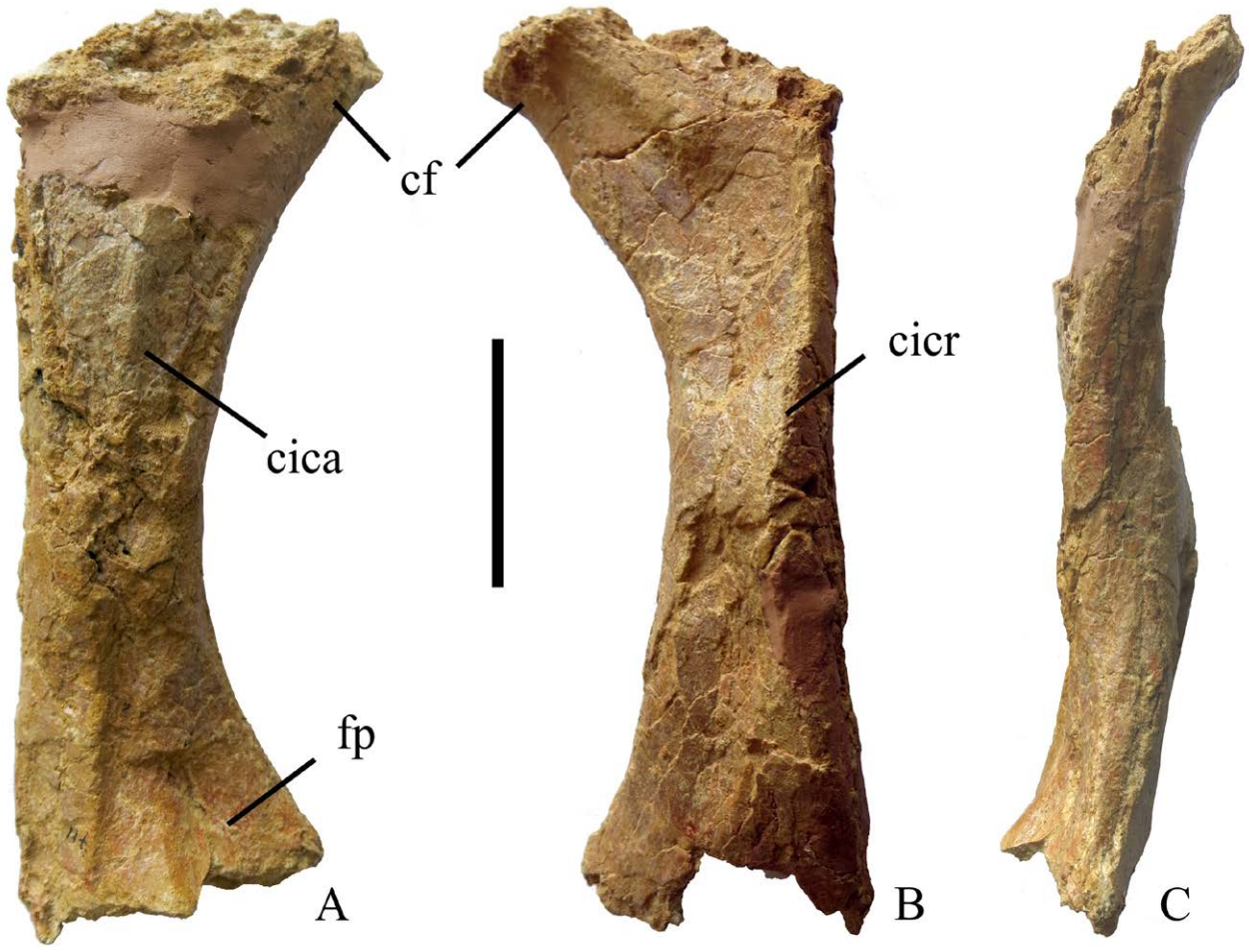

Fig. 1 – Left femur of *Gargantuavis philoinos* from the Bastide-Neuve locality (Fox Amphoux, Var, southern France), Mechin collection n° 711, in caudal (**A**), cranial (**B**) and medial (**C**) views. Abbreviations: cf: *collum femoris; cica: crista intermuscularis caudalis; cicr: crista intermuscularis cranialis; fr: fossa poplitea*. Scale bar: 50 mm.

but this may be slightly exaggerated by crushing. In terms of length, the femur from Bastide-Neuve, like that from Cruzy (Buffetaut & Angst 2019), is intermediate in size between the femur of an emu and that of a one-wattled cassowary (Dickison 2007), thus being comparable with some of the largest living ratites. The specimen from Bastide-Neuve is smaller than the incomplete and poorly preserved femur from Villespassans (Hérault) that was referred to *Gargantuavis philoinos* by Buffetaut and Le Loeuff (1998) but may possibly belong to a distinct, related taxon of the Gargantuaviidae (Buffetaut & Angst 2019) (**Tabl. 2**).

The mass of an extinct bird can be estimated on the basis of the minimum circumference of its femur, using the equation proposed by Campbell and Marcus (1992) (equation 1) – see also Angst & Buffetaut (2017).

Equation 1: Body Mass = $(10^{2.411 \times \log10(\text{Minimum circumference of the femur})-0.065})/1000$

Using this equation, the body mass estimated for specimen n° 711 is 75 kg, a mass which falls between those of the living cassowary and ostrich (Dunning 2008). This mass estimate is 1.3 times higher than the body mass estimated for specimen MC-MN 1335 from Montplo-Nord (Cruzy) (Buffetaut & Angst 2019). This difference might be explained either by individual variation or by a possible limited sexual dimorphism. Without more specimens, it is so far difficult to conclude. On the other hand, this new femur indicates a mass more than 1.8 times smaller than that estimated for the first femur attributed to *Gargantuavis*, from

Specimens	Length (mm) (of the preserved part)	Minimum circumference of the femur (mm)	Estimated body mass (kg)
MDE-A08	237	148	141 (1) or 147 (2)
MC-MN 1335	235	100	57 (2)
Mechin collection, n° 711	177	112	75 (2)

Table 2: Summary of the measurements of the femora attributed to *Gargantuavis* and the body masses estimated from them, using the equations proposed by (1) Anderson *et al.* (1985) or (2) Campbell & Marcus (1992)

Villespassans, Hérault (MDE-A08). This may be linked to the poor preservation of femur MDE-A08, which may have led to calculate an erroneous and overestimated body mass, or to an important sexual dimorphism in *Gargantuavis*, or might reflect the possibility that the specimen from Villespassans (Buffetaut & Le Loeuff 1998) belongs to a distinct, related taxon of the Gargantuaviidae (Buffetaut & Angst 2019). More material is necessary to propose a more robust conclusion.

Conclusions

Both in its morphology and its dimensions, the femur from Bastide-Neuve closely resembles that from the Montplo-Nord locality at Cruzy (Hérault). As noted by Buffetaut and Angst (2019), the femur from Montplo-Nord was found in the same stratum and a short distance away from pelvic remains that are very similar to the type specimen of *Gargantuavis philoinos* from Campagne-sur-Aude (Buffetaut & Le Loeuff 1998). At Bastide-Neuve, the femur also comes from a locality that has yielded sacral and pelvic elements clearly referrable to *Gargantuavis philoinos* (Buffetaut *et al.* 2015). Both at Montplo-Nord and at Bastide-Neuve, large avian femora occur together with pelvic remains that clearly belong to *Gargantuavis philoinos*. Although the various elements have not been found in articulation, the co-occurrence at two distinct localities of pelvic remains and femora of large size all showing clear avian characters is most parsimoniously explained by the hypothesis that they all belong to the same taxon. We therefore refer the Bastide-Neuve femur number 711 to *Gargantuavis philoinos*.

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Fig. 2 – Comparison between the *Gargantuavis philoinos* femur from Montplo-Nord, MC-MN 1335 (**A**) and that from Bastide-Neuve, Mechin collection n° 711 (**B**), in cranial view. Scale bar: 50 mm.

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