A palaeogravity calculation based on *Mantellisaurus atherfieldensis*

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Abstract

One fundamental technique to quantify palaeogravity is to compute weight against mass estimates of ancient animals. This technique is applied to a specimen of *Mantellisaurus atherfieldensis*. The results indicate that palaeogravity about 126 million years ago was approximately 0.59g based on the *Mantellisaurus atherfieldensis* holotype specimen BMUK R5764.

Key words: *Mantellisaurus*, palaeogravity

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1. Introduction to *Mantellisaurus atherfieldensis* holotype (BMUK R5764)

In 1914 the fossil collector Reginald Walter Hooley discovered a very fine fossil from fragments of a rock fall at the bottom of a cliff near Atherfield, Isle of Wight, UK. He was only able to search for other portions during low tides but soon realised that he had a nearly complete skeleton, only missing part of the foot of the talus, the bone that makes up the lower part of the ankle. That fragment had probably been carried away by the heavy seas that had pummelled the rocks for several days. The disarticulated bones of the skull were lying scattered among the bones of the body and limbs in many blocks of the matrix. The rocks have been dated as between the Barremian and early Aptian ages of the Early Cretaceous, between about 128 to 124 million years ago.

Hooley briefly announced his discovery in 1917. After removal of the fossil from the rock Hooley (1925) described the fossil in more detail a few years later. The unfused condition of the elements of the skull proved the skeleton was a young individual. Before the specimen was completely prepared it seemed that it was an *Iguanodon bernissartensis*, but after the bones had been completely removed from the matrix it was clear this specimen was neither *Iguanodon bernissartensis* nor the closely related *Iguanodon mantelli*. It was the smaller, more lightly built new species of dinosaur *Iguanodon atherfieldensis*. The estimated length of the skeleton was about 6.3 metres (about 21·6 feet).

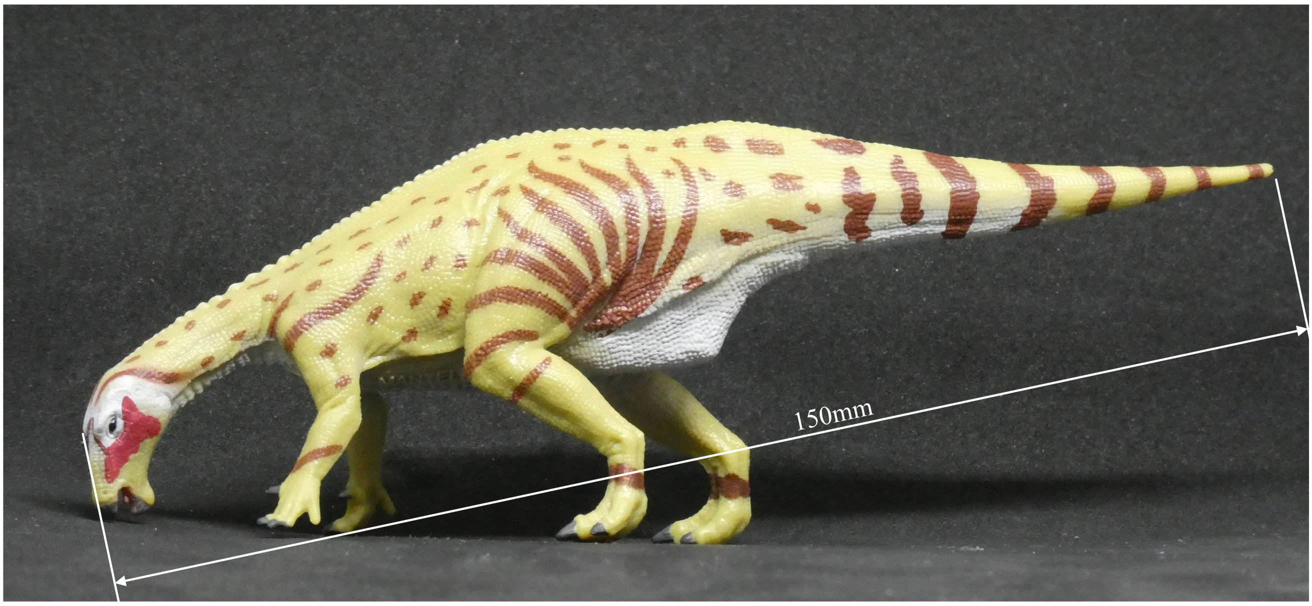
The specimen was more lightly built than other *Iguanodon* species but was still similar in general form. They all possessed large thumb spikes, which are thought to have been used as the dinosaur's primary defence against predators, while their teeth revealed they ate plants. The new specimen had short front limbs and it probably spent more of its

Figure 1. The *Mantellisaurus atherfieldensis* holotype specimen on display in the dinosaur gallery at the Natural History Museum of London in 2009. At this time it was labelled as a small species of *Iguanodon*. After further study it has now been renamed and remounted in one of the side galleries of Hintze Hall.

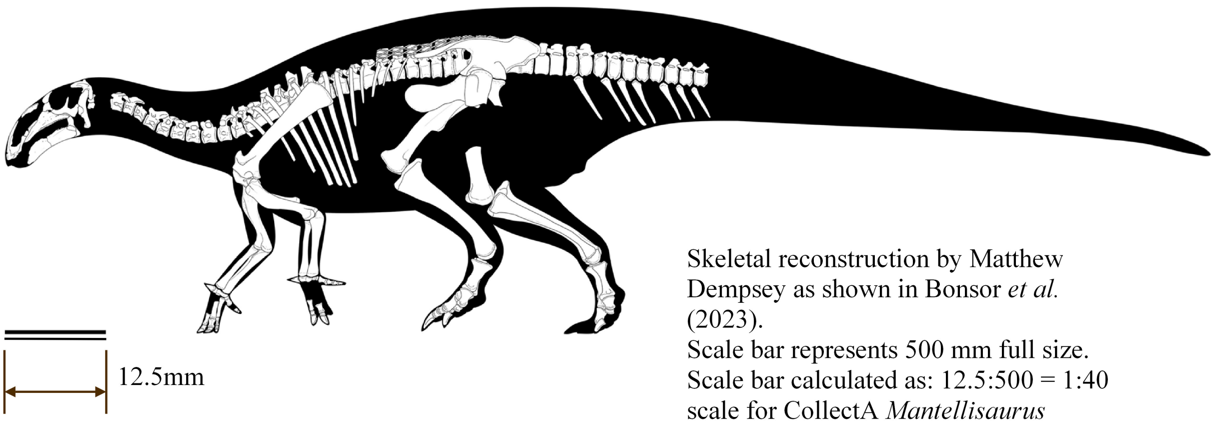
time in a bipedal stance than the larger *Iguanodon bernissartensis*. The skin impressions associated with the specimen show that the dinosaur was covered in small, irregular scales.

Norman (1986) completely reviewed another specimen of *Iguanodon atherfieldensis* (IRSNB R57 = [1551 "T"]) from the coeval site of Bernissart, Belgium, supplemented with additional information from the holotype specimen. Norman described how the differences between *Mantellisaurus atherfieldensis* and other types of *Iguanodon* were sufficiently clear to enable them to be distinguished as separate species. This fossil specimen was excavated between 1878 and 1881 along with a number of other similar species, causing a general confusion about the *Iguanodon* genus. It was suggested that the smaller specimens were smaller members of the general *Iguanodon* genus. The smaller fossil was found as an almost complete skeleton in virtually perfect articulation and was later displayed in the Royal Belgian Institute of Natural Sciences, Brussels. This specimen was estimated to be between 6 to 7 metres in length. The status of this Belgium specimen is debated with Paul (2008) reclassifying it as a new genus and species, *Dollodon bampingi*, but Norman (2010) and McDonald (2011) have disputed this. Bonsor *et al.* (2023) have strongly suggested that much further work is required to resolve this relationship.

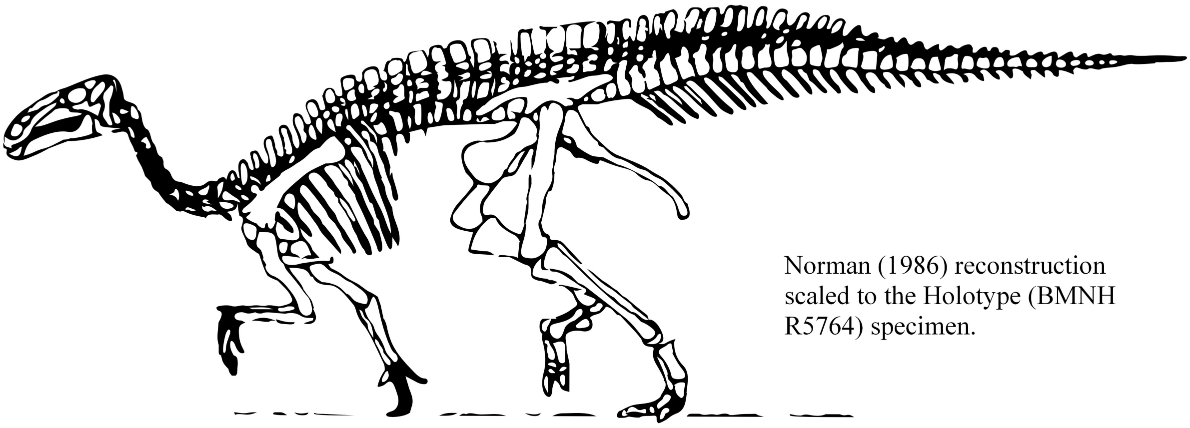
The *Iguanodon atherfieldensis* (BMNH R5764) specimen spent 80 years known as a species of *Iguanodon* but that view has changed. Paul & Carpenter (2006) proposed the new genus *Mantellisaurus* because of the considerable difference between the two taxa. Naish & Martill (2007) agreed this was a problem, describing how *Iguanodon*, along with the British dinosaur genera *Cetiosaurus* and *Megalosaurus*, were often viewed as "taxonomic dumping grounds" for species that did not fit seamlessly into any other group. The Hooley



CollectA *Mantellisaurus* model.



Skeletal reconstruction by Matthew Dempsey as shown in Bonsor *et al.* (2023).
Scale bar represents 500 mm full size.
Scale bar calculated as: 12.5:500 = 1:40 scale for CollectA *Mantellisaurus* model.



Norman (1986) reconstruction scaled to the Holotype (BMNH R5764) specimen.

Figure 2. The CollectA *Mantellisaurus* model used for calculating the mass by the volume method. The CollectA *Mantellisaurus* model is estimated as 1:40 scale of the holotype R5764 specimen. Based on this model the mass of the R5764 specimen would be 1,670 kg. See text for further discussion.

Mass and weight estimates in kg for *Mantellisaurus atherfieldensis* (Holotype BMNH R5764)				
Mass from models kg				
Reference	Mass	Notes	Density tonne/cu.m	Volume cu.m
Paul (2008)	750	See fig. 1C		
Paul (2010)	NA	"Adult size not certain"		
This paper	1670	CollectA scale model (1:40)	0.97	1.72
Best estimate	1670			
Weight from leg stress kg(f)				
Reference	Weight	Notes		
Bone dimensions	926	Using the Anderson *et al.* bipedal formula		
Bone dimensions	1377	Using Campione *et al.* bipedal formula		
Bone dimensions	979	Using Hurrell bipedal formula (unpublished)		
Best estimate	979			

Palaeogravity	**0.59**
Average Age	**126**

Table 1. Mass and weight estimates for the *Mantellisaurus atherfieldensis* holotype (BMNH 5764) specimen. See text for further discussion.

specimen was renamed *Mantellisaurus atherfieldensis* (BMNH R5764) and designated as the holotype as part of the revision of the *Iguanodon* genus.

The fossilised bones of the Hooley specimen *Mantellisaurus atherfieldensis* (BMNH R5764) were displayed hanging from the ceiling in the dinosaur gallery at the Natural History Museum of London for many years, as shown in Figure 1. However, in 2019 the fossil was dismantled, deep cleaned and scanned in high resolution 3D, before being remounted in one of the side galleries of the Hintze Hall. The Hooley *Mantellisaurus* skeleton was found to be made up of 80% to 90% real bone in generally good condition, making it one of the most complete dinosaur skeletons ever found in the British Isles. Several other fossils of deformed dorsal vertebrae have also been found close to the holotype specimen of the large theropod *Neovenator*, so it would seem likely that *Mantellisaurus* was regularly hunted and eaten by *Neovenator*.

The *Mantellisaurus atherfieldensis* (BMNH R5764) specimen was redescribed by Bonsor *et al.* (2023) based exclusively on the holotype specimen. They determined that it was a valid taxon distinct from the genus *Iguanodon*. It is among the best descriptions of a dinosaur specimen and should provide accurate weight and mass estimates.

2. Weight estimates

The body weight of the specimen can be estimated from bone dimensions. There are two estimates possible since the animals could have been either bipedal or quadrupedal. Lauters *et al.* (2012) describe how it was historically suggested that adult Iguanodons were mainly quadrupedal by Norman (1985) but more recent descriptions consider the gait for *Iguanodon* and *Mantellisaurus* to have been bipedal for much of the time. A bipedal gait for even part of the time means the rear leg bones must have been strong enough to carry the full weight of the animal and the bipedal formula for weight estimates must be used.

The British specimen BMNH R5764 was measured and scanned in 2019. The 3D models were later made available by Bonsor (2021) to enable further study. Bonsor (2022) measured the minimum circumference of both left and right femur as 300 mm. This would indicate a weight of 926 kg for the specimen using the Anderson *et al* (1985) formula or 1377 kg using the Campione *et al.* (2012) formula.

Both Anderson *et al.* (1985) and Campione *et al.* (2012) based their predictive formulas on results obtained from extant quadrupedal animals. Comparisons with extant bipedal animals would indicate that the Anderson *et al.* (1985) predictive formula gives a more reasonable result. Clearly more work is required in this area but a new formula for bipedal animals has been used in the interim.[1] This predicts weight as 979 kg(f).

3. Mass estimates

Most mass estimates based on the volume method seem to be based on relatively old restorations. Galton (2012) for example gives mass estimate 750 kg for the R5764 specimen, taken from Paul (1997, 2008), although Paul (2010) states "Adult size not certain" in a later publication. Paul is well-known for preferring "shrink-wrapped" restorations of dinosaurs so we might expect these early mass estimates to be low.

Fortunately there is a fine scale model of *Mantellisaurus* produced by CollectA. Checking this model against the skeletal reconstructions shown in Bonsor *et al.* (2023) and Norman (1986) indicates that this model can be taken as proportionally correct and scales to 1:40, as shown in Figure 2. The volume of the model was measured at 26.9 ml, indicating that the mass of the R5764 specimen would be 1,670 kg with a tissue density of 0.97 tonne/cu.m.

4. Palaeogravity estimates

The palaeogravity estimate for the holotype *Mantellisaurus atherfieldensis* (BMNH R5764) specimen is calculated as 979/1670 = 0.59g at approximately 126 million years ago.

5. Discussion

Determining the correct gait for *Mantellisaurus* is one source of potential major error for these palaeogravity calculations. If it was bipedal for most or some of the time then its hind legs would have to be strong enough to carry its whole weight. If it was quadrupedal then the hind legs would have a reduced weight distribution and the use of the bipedal weight calculation would give a lower weight estimate than reality. In practice the palaeogravity calculation is in general agreement with other published calculations [see Hurrell (2020)] indicating that *Mantellisaurus* did use a bipedal gait.

[1] Unpublished at this time but currently in preparation.

6. Suggested Citing Format

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