PALEONTOLOGY OF MADAGASCAR

IV. - DINOSAURS

by
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The presence of dinosaur remains in the Mesozoic rocks of Madagascar has been noted on several occasions since 1895. Bones from the Jurassic were attributed by Mr. Lydekker to a sauropod known by the name *Bothriospondylus madagascariensis* (1), among those from the Cretaceous, bones of one belong to a theropod (*Megalosaurus crenatissimus* Depéret) (2), and others to a genus with poorly known affinities (*Titanosaurus madagascariensis* Depéret).

The officers or explorers of our African colony have, since 1896, sent many vertebrae and limb bones of these gigantic reptiles to the Museum. There appear to be very rich localities in Madagascar where one could perhaps find whole skeletons comparable to those which decorate the museums of North America; but while waiting for such discoveries, it might be useful to publish the studies already completed. Mr. Boule, who had made known one of the more important samples in 1896 (3), quite deliberately charged me with continuing this study.

The many bones that I have examined belong neither to a new genus nor to an undescribed species. My goal in making them known is only to determine, as much as possible from the new material, the relationships of the species described by Messrs. Lydekker, Boule and Depéret to the dinosaurs or Europe or America, which are continuously the object of important memoirs (4).

I also hope that this work can be useful to explorers of Madagascar, in giving them some anatomical knowledge of these reptiles, of which their gigantic size arouses much curiosity, but on which a thorough study cannot be made from the complete bones and the carefully collected portions of the skeleton.

Localities. - The principal samples of dinosaur bones made by the Museum from 1896 to 1905 were those of Messrs. Bastard, Captain Colcanap, Dr. Decorse, Frager, Moriceau, and

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(1) LYDEKKER (R.), On bones of a Sauropodous Dinosaur from madagascar, *Quart. Journ. Geol. Soc. of London*, vol. LI, p. 329, 1895.

(2) DEPÉRET, Note sur les Dinosauriens Sauropodes et Théropodes du Crétacé supérieur de Madagascar. *Bull. de la Soc. géol. de France*, 3e sér., Vol. XXIV, p. 176, 1896 and *C. R. Ac. Sc.*, vol. CXXII, p. 483, 1896.

(3) BOULE (M.), Note préliminaire sur les débris de Dinosauriens envoyés au Museum par M. Bastard. *Bull. du Museum d'Histoire naturelle*, 1896, p. 317.

(4) Many damaged fragments have been collected in Europe and attributed incorrectly to names of genera and species from minimal portions of the skeletons and isolated vertebrae; the result is that no group of fossil reptiles has a nomenclature so confused as that of dinosaurs, and that it is nearly impossible to outline the phylogeny of these animals. The collection of good complete skeletons from America has demanded very much care and was the object of special scientific expeditions.

Perrier de la Bathie. They found the localities situated in the northwest of the island, along a length of more than 400 kilometers.

According to Mr. Paul Lemoine (1), who had visited a few of these localities, in the Analalava region the dinosaur beds were interbedded with the *Corbula pectinata* and *Corbula grandidieri* beds that Mr. Barin, and the geologists who have studied Madagascar after him, attribute to the Bathonian (2). In general, we can say that many dinosaurs lived in Madagascar during the Middle Jurassic. Captain Colcanap made important discoveries of Jurassic bones near Befotaka and Andranosamonta, at Ankinganivalaka on the edge of the Maivarano, and at Marojano on the left bank of the Doroa. The environs of Antsohihy were explored in 1896 and in 1903 by Mr. Bastard and Mr. Colcanap (3). Later, Mr. Moriceau collected portions of a skeleton near Port-Bergé (4). The Captain of Bouvié, I am told, found a femoral fragment some distance from Ambato; finally Mr. Perrier de la Bathie discovered some bones on the right bank of the Mahavavy between Anaboringa and Issialana, not far from Lake Kinkony.

These localities are probably all Jurassic.

The dinosaur bones found in the Cretaceous are all, or nearly all, from a single locality situated about 40 kilometers south of Majunga in the Bas-Boeny territory, on the right bank of the Betsiboka near the village of Maevarano. The main samples sent to the Museum, found at this site, were made by Messrs. Bastard and Decorse. The bones are found in whitish or varicolored sandstones forming some hills that the indigenous people call "the radiant hills" according to Mr. Decorse. These sandstones are overlain by Senonian marls where the Doctor has collected *Gryphaea vesicularis* and *Alectryonia ungulata*, after the other explorers. One can thus say generally that dinosaurs were living in the Malagasy region since the beginning of the Upper Cretaceous (1).

Mr. Decorse collected some bones further south, for which it is impossible to fix an age, but which have the same white sandstone matrix as the bones from the Cretaceous of Maevarano. Their locality is situated between the Kamori and the Betsiboka, between the villages of Amballazanakomby and Ampanihiniampango.

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(1) LEMOINE (P.), Études geeologiques dans le Nord de Madagascar, p. 130-135, fig. 33. Paris, 1906. The locality named Ankinganivalaka by Mr. Colcanap is called Ankingavala by Mr. Lemoine.

(2) These beds would thus be older than the Atlantosaurus beds of the Rocky Mountains that Marsh attributed to the Upper Jurassic. It is nevertheless possible that the deposition of these American dinosaur beds had begun during the Middle Jurassic; it is difficult to establish a synchrony with the marine deposits (HATCHER, An attempt to correlate the marine with the non-marine formation of the Middle West. *Amer. philos. Society*, Vol. XLIII, 1904, p. 341).

(3) The bones collected by Mr. Last, sent to the British Museum and described by Mr. Lydekker, were probably found in the area of Antsohihy "20 miles to the east of Narinda Bay."

(4) At the Colonial Exposition in Marseilles in 1906, they illustrated some fragments of a sauropod dinosaur of fairly thin form; they bore the assignment: Ampanihikely, Port-Bergé district.

(1) Mr. DEPÉRET, who had indicated the superposition of the beds in this locality in 1896, considers these dinosaur beds as a fluviolacustrine facies of the Turonian.

At the present, dinosaur localities are not known south of Cape Saint-André.

JURASSIC DINOSAUR

BOTHRIOSPONDYLUS MADAGASCARIENSIS, Lydekker (2).

The dinosaur bones found in the Jurassic of Madagascar all belong to animals from the suborder Sauropoda, which are understood to be the largest quadrupeds known (3). These herbivorous reptiles were probably half-aquatic, half-terrestrial, their skin was naked, and their brain very small in spite of their great size; they had very slow movements, at least on dry land.

The bones collected from the richest localities at Ankinganivalaka and the area of Antsohihy certainly belonged to several individuals of distinctly different sizes; but in spite of this size inequality, it is not possible to distinguish several genera and species since it is known that growth continues nearly throughout life in these reptiles, and so size is not a specific character (4). I think that all the Jurassic bones collected up to the present must be described under the name *Bothriospondylus madagascariensis,* except perhaps those from Port-Bergé; but these latter are too incomplete for a precise study.

We will examine the different parts of the skeleton successively: following this we will compare this animal with other sauropods.

Skull. - The cranium is totally unknown and it is very desirable that the explorers of Madagascar might carefully collect a complete skull or the essentially important portion of the cranium (1).

Mr. Colcanap has collected a tooth from Ankinganivalaka (pl. I, fig. 1, 2, 3, 4). The root is broken at the neck, the surface is fractured, and the anterior and posterior edges are a little worn from mastication.

All the cetiosaurids have teeth similar in form to this. The most similar are the teeth of *Morosaurus* (2), it is impossible to establish a distinction based on a single incomplete tooth.

Shown below are the most important comparisons, in the form of a branching table.

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(2) The etymology of the name *Bothriospondylus* created by Owen is: βοφρυσ cavity, σπονδυλοσ vertebra.

(3) The most recent restoration of a sauropod, which was made the object of detailed publications, is that of *Diplodocus*. The height of the skeleton is 4.50 m, and the length 23 meters, about 6.50 m for the neck and 12 meters for the tail. The head is 22 centimeters in width and only 60 centimeters in length (HOLLAND, The Osteology of Diplodocus. *Memoirs of the Carnegie Museum*, vol. 2, no. 6, 1905).

(4) Some adult individuals are four times larger than one of the others in the same species of crocodiles.

(1) In living animals gigantism is nearly always associated with the persistence of epiphyseal cartilages and a hypertrophy or lesion of the pituitary; already Marsh has remarked that this part of the brain was very large in *Diplodocus*; it is also well developed in *Triceratops* according to the figure given by the same author; perhaps examination of endocranial casts could one day explain the evolution of giant reptiles.

(2) MARSH, Dinosaurs of North America, *U. S. Geol. Survey 16th Annual Report*, 1896 (pl. XXXI, fig. 1, 2).

Spatulate teeth with convex, gently concave, or gently convex cross-section:
A little elongated, slightly striated...*Brontosaurus*
Rope-shaped
Striated lengthwise...*Cardiodon* (= *Cetiosaurus*)
A little striated lengthwise, convex or
gently concave cross-section..............................*Ornithopsis, Pelorosaurus*
Not striated, fractured, slightly biconvex
cross-section..*Morosaurus, Bothriospondylus*
Elongate teeth with subcircular cross-section...*Diplodocus*

Vertebral column.(3) - The many vertebral bodies of *B. madagascariensis* in the paleontological collections of the Museum are very similar to those illustrated by Mr. Lydekker in 1895. I figure here a cervical (pl. I, fig. 5, 6), two dorsals (pl. I, fig. 3, 4), and several caudals (pl. I, fig. 5 to 9).

The *cervicals* have a very unusual form because the neck of sauropods was very long and mobile, permitting these animals to gather the plants which nourished them in a large radius around their heavy, massive, and very tall bodies. As to the food-grasping function, one can make a familiar comparison between this long neck and the trunk of the elephant. The mobility of the neck is obtained by the shape of the cervical vertebral articulation, which is strongly convex anteriorly and concave posteriorly; it was also due to the work of very numerous muscles that inserted on a system of plates surmounting the bodies of the cervical (fig. 3) and dorsal vertebrae, and made a covering over the spinous and transverse processes (1). This placement is related to maximizing resistance and minimizing weight; it is not developed in any other vertebrae.

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(3) The vertebral column of sauropods is composed of a large number of vertebrae (sometimes a hundred). The caudal vertebrae are the most solid and the most numerous; caudal vertebral bodies of *Bothriospondylus* are known from nearly the entire area of Madagascar. But there is not a single vertebra complete with its processes; it is an unfortunate gap.

The cervical and dorsal vertebrae are concave posteriorly and convex anteriorly, the caudals are in contrast gently concave anteriorly and flat or slightly flat posteriorly. This fact could be very useful for explorers in orient their work to search for the pelvis initially, which is the center of the skeleton in sauropods and which can be easily visible on the ground because of its large size.

(1) For the nomenclature of these blades see: OSBORN, A Skeleton of Diplodocus. *Mem. Am. Mus. Nat. History*, vol. 1, part V, 1899, p. 194; HATCHER, Diplodocus, its Osteology. *Mem. Carnegie Museum*, vol. 1, no. 1, 1901, p. 16.

The bodies of the cervical vertebrae are fairly long and perforated with two large lateral cavities that are only separated by a thin, complete bony partition; the vertebra figured here (pl. I, fig. 2, 2a) clearly shows this placement (fig. 4). This is one of the first cervicals (2).

The lateral cavities and the vertebral plates correspond to the insertion of long muscles analogous to those in the neck of birds (long posterior, lateral, long flexor, spino-cervical, etc.), extending from the cervical region to the anterior portion of the trunk.

The anterior dorsals (pl. I, fig. 3) still show lateral cavities forming two pockets on both sides of the vertebral body. In section (fig. 5) they are very similar to a vertebra of *Morosaurus* illustrated by Marsh (3).

The vertebra represented here is an anterior dorsal because it is still strongly convex anteriorly (4). The successive dorsals are less and less opisthocoelous and show increasingly reduced lateral cavities. In the last dorsals, which are sometimes incorrectly called the lumbars (1), these cavities are very shallow and located very high on the body (pl. I, fig. 4). In ventral view (pl. I, fig. 4a), the bodies of these last dorsals are strikingly excavated in the middle (2).

According to Mr. Lydekker, *Bothriospondylus* had four sacral vertebrae; no conclusion can be drawn after examining several portions of the poorly-preserved sacrum, sent to the Museum by Mr Bastard and Mr. Colcanap (3).

The tail of sauropods is very long, designed to serve as counterbalance to the long neck and perhaps sometimes, according to Mr. Osborn, to balance the animal when it raises itself up on its hind limbs.

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(2) By comparison with *Diplodocus* this vertebra is very anterior, because from the fifth or sixth the pleurocentral cavity is divided by a bony blade (HATCHER, *Mem. Carnegie Museum*, vol. 1, no. 1, 1901, Pl. III, IV, V); perhaps it is the same as that which immediately follows the axis (HOLLAND, *Mem. Carnegie Museum*, 1903, p. 228, fig. 1). It seems that here the sides of the cervicals were not fused to the vertebral body as in other sauropods.

(3) MARSH, The Dinosaurs of North America, *U. S. Geol. Surv.*, 1896, pl. XXXII, fig. 2a.

(4) Mr. LYDEKKER has considered some vertebrae that are strongly convex anteriorly as cervicals of *Bothriospondylus madagascariensis*, but the body is already quite thick and they are instead anterior dorsals.

The body of the vertebra illustrated above is made of dense tissue in circumference and slightly spongy in the interior, which differentiates the vertebrae of *Bothriospondylus* from those of *Diplodocus*; these latter are very spongy.

(1) There are no presacral vertebrae without ribs in sauropods.

I give here some detail on the processes of the dorsals of *Bothriospondylus*, they are known to be very long and very tall in the dinosaurs seen; unfortunately the explorers of Madagascar neglected to collect them, they sent some indeterminate portions to the Museum.

(2) This extreme narrowness in the middle of the body of the last dorsals could be characteristic of *Bothriospondylus madagascariensis*; it is never noted in sauropods, and recalls the form of certain theropod vertebrae.

(3) A sacral fragment, collected by Mr. Bastard with the presacral vertebra illustrated here (pl. I, fig. 8) and with two caudals, was figured by Mr. BOULE (Madagascar au XXe siècle, *Géologie*, Paris, 1902, p. 56, fig. 41). The vertebrae which constitute it seem less elongated than those in the genus *Morosaurus* figured by Mr. OSBORN (Manus, sacrum and fore limb of Sauropoda, *Bull. American Mus. Nat. Hist.*, vol. XX, art. 14, 1904, p. 185). But this character varies in a single genus, as one can see comparing *Diplodocus longus* (MARSH, *loc. cit.*, pl. XXVIII, fig. 1) and *Diplodocus carnegiei* (HATCHER, *loc. cit.*, p. 30, fig. 9).

The caudal vertebrae, of which there are a considerable number, continuously decrease in diameter from the sacrum to the end of the tail, and are weakly concave anteriorly and nearly flat posteriorly. Mr. Colcanap found a series of eleven consecutive caudal vertebrae in 1904 at Antsaongo, near Antsohihi, that we illustrate here (pl. I, fig. 10). These are proximal caudals because their bodies are shorter than high; in the middle region of the tail (pl. I, fig. 8) the vertebral body is nearly as long as high; finally in the distal part of the tail it is longer than high (pl. I, fig. 9). The tail probably ended in even thinner and longer vertebrae, having almost the shape of a baguette.

The tail of *Bothriospondylus*, like that of most sauropods, could have served as an organ of locomotion in the water. *Chevron bones* were articulated on the inferior part of each vertebra (pl. I, fig. 7); one can see their well-marked articular facets ventral and anterior to the body of each vertebra. The form of these chevron bones is similar to that observed in *Cetiosaurus*, a sauropod from the Jurassic of England that is closely related to *Bothriospondylus madagascariensis* (4).

The dorsals and first caudals show a mode of articulation unique to sauropods. In addition to the anterior and posterior zygapophyses which always contact between two consecutive vertebrae, there is here an improvement that Marsh called a displosphenal placement: a prominent blade or *hyposphene* dorsal to the neural canal, between the posterior zygapophyses, penetrates into a corresponding cavity of the following vertebra, named the *hypantrum* (1). One can easily see this latter cavity on a caudal vertebra figured here (pl. I, fig. 5).

Comparative examination of all the vertebrae collected from the Jurassic of Madagascar does not permit distinction of several genera of sauropods, but it shows us that there were animals of very great size, as the body of a dorsal vertebra from Ankinganivalaka has a diameter of 30 centimeters.

Ribs. - *Bothriospondylus* probably had a dozen pairs of thoracic ribs, of which we possess a number of fragments; the most complete is 80 centimeters long (2).

Pectoral girdle. - The Paleontology Laboratory has recovered a very large portion of the pectoral girdle, coracoids or scapulae, but they are in too poor a condition to be usefully figured.

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(4) PHILLIPS. *Geology of Oxford*, p. 259, fig. 84. - OWEN, Mesozoic Reptilia, Part II, *Palaeontographical Society*, 1874, p. 42, fig. 10. - WOODWARD (A. SMITH), *Proc. Zool. Soc. of London*, 1905, p. 232.

In the specimen illustrated here, the two rami of the chevron are not separated proximally. It is thus less bifid than the specimen of *Cetiosaurus oxoniensis* figured by Phillips and that of *Morosaurus* illustrated by Marsh (*loc. cit.*, pl. XXXIX, fig. 3-4); it is different from that of *Diplodocus*. The caudal vertebrae of *B. madagascariensis* are additionally distinguished from those of *Diplodocus* because they are never excavated ventrally and do not present the same placement of facets for the chevron articulations (MARSH, *loc. cit.*, pl. XXVI, fig. 5).

(1) In ophidians there is an analogous mode of articulation (*zygosphene* and *zyganthrum*), but completely inverse, since the prominent part is anterior on the vertebra and the hollow part posterior.

(2) Mr. RIGGS has figured the variations in the form of the rib heads according to their position in the thoracic cage in *Apatosaurus* (*Bull. Field Columbian Museum*, 1903).

Their general form does not show any exceptional character for comparison with the pectoral girdles of sauropods from the Jurassic of America.

Fore limb. - The limb bones of *Bothriospondylus* are complete; they sometimes show, when they are broken, the appearance of a central cavity surrounded by a very thick wall (3), but it is likely that this cavity was filled with very loose bony tissue that was not fossilized.

In the collection of the Museum there are numerous humeral fragments; one of these humeri is nearly complete (pl. II, fig. 1), its length is about 1.30 m and its weight 84 kilograms. It has the form of a relatively slender sauropod; it is very much more elongated, thinner and smaller than the humerus of *Brontosaurus* (4), thinner, especially in the middle part, than that of *Cetiosaurus* (5), moreover smaller than *C. oxoniensis* and larger than *C. leedsi*; it is more slender than *Morosaurus* and nearly as thin as *Diplodocus*. *Bothriospondylus* was thus a relatively agile sauropod; but in all these animals the ends of the limb bones are rugose and the epiphyses were cartilaginous, which suggests that they were less active.

The deltoid crest (*processus lateralis*) is very elevated; it position varies a little in the diverse sauropod genera, and it is placed here as in *Cetiosaurus*. The superior head of the humerus is rounded as in all sauropods; the distal extremity (pl. II, fig. 3) is in contrast nearly flat, and the base is a little quadrangular, gently convex on the anterior face and concave posteriorly.

Mr. Osborn remarked that in sauropods among reptiles, as in proboscideans or amblypods among mammals, the limbs were straight columns designed to support the weight of the body. The humerus resembles above all that of crocodiles and only resembles that of proboscideans in its straight form and its thickness; but the analogy of form due to an analogy of function is more striking if one examines the forearm (fig. 7, 8).

The proximal end of the ulna (pl. II, fig. 5) has a triangular section, and it is largely excavated anteriorly to accept the head of the radius, which is thus placed anteriorly to support the humerus and is not capable of any rotational movement.

The base of the ulna is rounded, rugose, and its section is still a little triangular. 10 centimeters around above the base, the ulna shows a strong elevation probably designed for the insertion of a ligament that connected to the radius. One can equally see a ligamentous insertion on the cradle of the ulna; the forearm had a great solidity to fulfill its supporting function.

I have only been able to examine a single fragment of the radius, a proximal end, that does not add anything new to the study of sauropods in general and of *Bothriospondylus* in particular.

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(3) BOULE, *Bull. du Muséum*, 1896, p. 350.

(4) OSBORN and GRANGER, Fore and hind limbs of Sauropoda from the Bone Quarry. *Bull. Am. Mus. Nat. Hist.*, vol. XIV, art. 13, p. 203, fig. 3, 1901. - HATCHER, *Mem. Carnegie Museum*, vol. 1, no. 1.

(5) PHILLIPS. *Geology of Oxford*, p. 256. - OWEN, *Mesozoic Reptilia*, Part II, p. 33, fig. 3. - WOODWARD (A. SMITH), *Proc. Zool. Soc. of London*, 1905, p. 232.

Carpus. - In general the carpal and tarsal bones were collected by the explorers. A bone found at Ankinganivalaka (fig. 11) might correspond to the fused fourth and fifth carpals (1), its rugose surface shows that the carpal bones were encased in cartilage, as were the ends of the limb bones.

Metacarpals. - In the locality situated between Andranosamonta and Befotaka, Mr. Colcanap found three right metacarpals from a single individual. The first metacarpal is complete (pl. I, fig. 10); it is entirely similar to that of *Morosaurus* (1) and basically analogous to that of *Cetiosaurus* (2). All sauropods are semi-plantigrade, and these digits were thinner than those of *Diplodocus* and particularly longer than those of *Brontosaurus*.

Pelvis. - Among the pelvic bones the most characteristic are the ischia; they permit the distinction of morosaurids from other sauropods. We have only fragments collected from Madagascar, but they show precisely the same form as in *Morosaurus*, in that the distal ends of the right and left ischia show the form of very slender blades, contacting each other laterally along the midline of the body (fig. 11, ABC).

An excellent pubis was found at Ankinganivalaka (pl. II, fig. 9). It differs from the pubis of *Diplodocus* and *Haplocanthosaurus* because it is thinner, and from *Brontosaurus* and *Apatosaurus* because the perforation is located near the ischiopubic symphysis and is in the form of a notch and not a round orifice. It very much resembles that of *Morosaurus* in its general form; as in the genus *Morosaurus* the two pubes contact each other on the lateral faces of their distal ends, but it is distinguished by the great development of the thin portion located posterior to the crest that divides the external face of the pubis into two parts (this crest ends here dorsal and anterior to the aforementioned perforation, not posterior), and in the type of muscle analogous to the pectineus muscle in mammals which has a larger insertion than in *Morosaurus lentus* figured by Marsh (3) and than in all other sauropods.

Hind limb. - All the sauropod femora are very similar; the most complete of those collected from Madagascar (pl. II, fig. 4) resembles *Morosaurus* and *Cetiosaurus* especially in its general proportions; it is less slender than that of *Diplodocus* or *Haplocanthosaurus*.

The proximal end is large, rounded, rugose, incompletely ossified and has no special detail (1). The base of the femur shows a cradle that separates the ectocondyle from the entocondyle

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(1) OSBORN, Manus, sacrum and caudals of Sauropoda. *Bull. Amer. Mus. Nat. History*, vol. XX, art. 14, 1904, p. 182, fig. 1.

(1) OSBORN, Fore and hind limbs of Carnivorous and Herbivorous Dinosaurs from the Jurassis of Wyoming. *Bull. Am. Mus. Nat Hist.*, vol. XII, art. 11, p. 161, 1899. - OSBORN and GRANGER, *loc. cit.*, 1901, p. 204. - RIGGS, Fore leg and pectoral girdle of Morosaurus. *Field Columbian Museum*, Publicat. 63, 1901, pl. XLI, p. 275.

(2) PHILLIPS, *loc. cit.*, p. 261.

(3) MARSH, *loc. cit.*, pl. XXVI, fig. 1.

(1) It is slightly disymmetrical when examined in planar view (fig. 12); the posterior side is the flatter, which serves to distinguish the right and left femora when the proximal part is lacking.

anteriorly and especially posteriorly, as in all dinosaurs; this latter bears a very prominent anterior tuberosity (fig. 13).

This prominence is more or less marked in the different dinosaur groups according to their mode of life; it is less developed in sauropods than in bipedal dinosaurs (2) like *Megalosaurus* or *Iguanodon*. The femur in sauropods is constructed to assure stability in a heavy animal.

The tibia (pl. II, fig. 7) is quite thin at its middle, which distinguishes *Bothriospondylus madagascariensis* from *Brontosaurus* and brings it closer to *Cetiosaurus*, although the comparison with the latter genus lacks precision since the tibia of *C. oxoniensis* figured by Phillips is crushed; it indicates a fairly slender animal like *Morosaurus* as figured by Messrs. Osborn and Granger (3). The superior head of the tibia is flat and wide, to give a solid support to the femur, possessing a prominent crest (fig. 14) that does not correspond to the anterior but instead to the lateral tibial crest in birds. As a result the sauropod tibia appears exceptionally flat anteriorly and very much more resembles the condition seen in crocodiles than that in birds, and differs entirely from that of mammals where an anterior tuberosity provides insertion for the round ligament.

The only complete fibula that we possess (pl. II, fig. 8) (4) is thin, and a little larger proximally than distally; its section is nearly flat on the tibial side, convex on the exterior. It shows a rugose tuberosity on the middle of the external region for the insertion of the peroneus muscle. This tuberosity, present in all dinosaurs, is also seen in crocodiles, but it is situated higher.

The inferior head of the fibula bears an excavated part on the anteroexternal side, as in all sauropods, designed to accept the most prominent part of the astragalus. The purpose of this placement is the same as that of the external malleolus of the fibula of mammals: restricting lateral movements of the tarsus.

I have not been able to examine any tarsal bones.

The metatarsals of sauropods are shorter than the metacarpals. Figured here (pl. I, fig. 12) is a well-preserved right first metatarsal sent to the Museum by Mr. Moriceau (1).

Restoration of the limb bones. - According to the indications of Mr. Boule, I have restored a forelimb and hindlimb of *Bothriospondylus madagascariensis* for the Paleontology Gallery of the Museum, entirely from the bones sent by Mr. Colcanap (fig. 15); the restored

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(2) It is known that this prominence is very marked in birds. It is visible, although very reduced, in crocodiles.

(3) OSBORN and GRANGER, *loc. cit.*, 1901, p. 206.

(4) It cannot be compared to the fibulae of *Cetiosaurus* and *Morosaurus*. The former is unknown and the latter poorly known.

(1) It is not certain that the metacarpal from Port-Bergé belongs to *Bothriospondylus*; it was found with fragments of a pubis, femur, tibia, and fibula, and the femur recalls instead that of *Haplocanthosaurus* figured by Hatcher, in spite of its poor preservation.

portions are the base of the humerus, the radius, most of the metacarpals, and the base of the tibia.

These limbs were placed near *Iguanodon* to clearly show the differences that separate ornithopods and sauropods.

As much as can be judged from these skeletal portions made from restored bones belonging to different individuals, *Bothriospondylus* of Madagascar must have been about 3.50 m in height and 15 meters in length.

Paleontologists would be surprised to see that the disproportion between the fore and hindlimbs is less pronounced here than in most American dinosaurs (*Diplodocus*, *Brontosaurus*, etc.).

The Madagascar animal had nearly the same proportions as *Cetiosaurus oxoniensis* (2). These two large reptiles have been found at the base of the Middle Jurassic, while the localities of American sauropods are attributed to the Upper Jurassic. It is thus natural to suppose that this is a general fact and that the length of the forelimbs decreased during sauropod evolution, as if these animals had passed from a completely quadrupedal posture to an occasionally bipedal one.

Conclusions. - The dinosaur bones found up to the present in Madagascar, in large number from the Middle Jurassic, belonged to sauropods.

American paleontologists have distinguished two families from among these herbivorous, quadrupedal, gigantic reptiles mainly according to the form of the caudal vertebrae, chevron bones, and teeth: the *diplodocids* (type: *Diplodocus*) and the *camarasaurids* (1) (example: *Brontosaurus*). It is to this second family that the animals of Madagascar belong.

What is their place in this family? They are all smaller than *Atlantosaurus* and less massive than *Brontosaurus*, they are similar to *Cetiosaurus* (as Messrs. Lydekker and Boule showed from the first discoveries) and *Morosaurus*. Despite quite notable variations in size (2) I think it preferable, in the present state of our knowledge, to place them all in the same species, that Mr. Lydekker named *Bothriospondylus madagascariensis* in 1895. However, it is very possible that bones collected in better condition will force modification of these conclusions. But my goal will be in part attained if this note provokes the discovery of new material to study from

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(2) According to the figures given by Owen, Messrs. Osborn and Granger, the following comparative table can be established (without accounting for the narrowness of the cartilages or the length of the feet):

Morosaurus	forelimb	1.36 m	hindlimb	1.58 m	approx. diff.	1/7
Diplodocus	-	2.00 m	-	2.50 m	-	1/5
Cetiosaurus	-	2.30 m	-	2.60 m	-	1/8
Bothriospondylus	-	1.79 m	-	2.03 m	-	1/8

It should be noted that the humerus and femur of the giant Rocky Mountain dinosaur *Brachiosaurus altithorax* are, according to Mr. Riggs, nearly the same size (RIGGS, *Am. Journ. of Science*, 4th ser., vol. XV, 1903, p. 299).

(1) The term *Camarasauridae* Cope has, it seems, priority over *Atlantosauridae* Marsh (ZITTEL translat. EASTMAN, Textbook of Paleontology, vol. II, p. 233).

(2) These variations can reach 1/4 or 1/5.

Madagascar. What are the affinities of *Bothriospondylus* (3) *madagascariensis*? If Mr. Lydekker had not already named it this, I would have named it *Morosaurus* (4), because it resembles this genus in the form of the teeth, vertebrae, pelvis, and metacarpals, but I prefer to avoid making changes in nomenclature when perfect materials are not available; in this particular case, this awaits the discovery of the important parts of the skeleton in association. With regard to the moderate size of *B. madagascariensis,* it is greater than that of *Morosaurus grandis*, less than that of *Cetiosaurus oxoniensis*, and nearly equal to that of *C. leedsi*.

B. madagascariensis, Morosaurus and *Cetiosaurus* are three representatives of the same group from Madagascar, Europe and North America; but to better understand this group will require more perfect materials from Europe and Madagascar, and it will be necessary to precisely determine the age of the species of *Morosaurus* from America.

CRETACEOUS DINOSAURS

Bones have been recovered from the Upper Cretaceous at Maevarano, on the right bank of the Betsiboka; they were mostly found and sent to the Museum by Mr. Dr. Decorse. They belong to two species described in 1896 by Mr. Depéret after fossils from the same locality, one probably the herbivorous and quadrupedal *Titanosaurus madagascariensis*; the other certainly the carnivorous, bipedal *Megalosaurus crenatissimus*. We have had few new specimens to report.

TITANOSAURUS MADAGASCARIENSIS, Depéret.

Dr. Decorse collected caudal vertebrae and fragments of long bones. These latter are too broken to be figured, but they are portions of complete bones, shafts of femora or indeterminate humeri. None of the new discoveries support the hypothesis of Mr. Depéret regarding the presence of dermal ossifications.

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(3) The genus *Bothriospondylus* Owen is heterogeneous; the type of the genus is *B. suffosus*, a name created for incomplete vertebrae; the other species, *B. robustus, B. magnus, B. elongatus* are even more poorly known. According to Mr. Lydekker, this latter species is really a cetiosaurid, but the vertebrae from Wealden named *B. magnus* may belong to an animal similar to *Titanosaurus* that we are studying further.

(4) Mr. Lydekker has already considered *Morosaurus* as an American representative of *Cetiosaurus* of Europe (*Quart. Journ. geol. Soc. of London,* vol. XLIV, p. 56).

The vertebrae of *B. madagascariensis* are of the same type as those of *Cetiosaurus leedsi* from the Upper Jurassic of England, recently figured by Mr. Smith Woodward. I do not think they are as different from those of *Morosaurus* as Mr. Lydekker thought at first, when studying the bones of Madagascar in 1905. *Ornithopsis* of England is closely allied to the preceding genera; it differs because the pleurocentral cavities of the dorsal vertebrae are more vast, and also in the thinner form of the pubis (HULKE, *Quart. Journ. geol. Soc. of London,* vol. XXXVIII, 1882, p. 372, pl. XIV).

Two very anterior caudals and a vertebra from the middle part of the tail are illustrated here (pl. I, fig. 13, 14). All these vertebrae, strongly convex posteriorly, bear a striking resemblance in aspect to the vertebrae of crocodiles; like these they have chevron facets that are more marked posteriorly than anteriorly. But they differ notably (besides their much larger size) because the neural arch is situated more anterior to the centrum (pl. I, fig. 14, 15, 16). In addition, the chevrons, of which we possess fragments, are rounder and less flattened in the median plane of the body than those of extant crocodiles.

The more anterior of the caudals figured here is probably the second (1) or third (pl. I, fig. 13), and its transverse processes are completely curved like those of the anterior caudals of crocodilians. The other (pl. I, fig. 14) is probably the fifth caudal. As to the third vertebra that we figured (pl. I, fig. 15), it belongs to the middle region of the tail based on the position of the transverse processes.

The genus *Titanosaurus* Lydekker (1) (*non* Marsh) (2) is known from vertebrae and limb bones. Mr. Lydekker considered it to be a sauropod (3). It is very much more similar to crocodilians than to all other reptiles of the same order, not only in the form of the vertebrae but also in the form of the humerus (4). It is interesting to consider such affinities, because the authors who have studied sauropods have often put forth the hypothesis that these animals could have been descended from the same stock as crocodilians. It will be necessary to better understand *Titanosaurus* to know whether the caudal vertebrae of certain dinosaurs are the product of parallel evolution with these vertebrae in crocodilians, in having been biplanar or weakly amphicoelous during the Jurassic, then procoelous at the end of the Cretaceous.

The species of the genus *Titanosaurus* are known from the Cretaceous of India (Lameta Group = Cenomanian-Turonian), and from the Upper Cretaceous of Patagonia (4). Mr. Lydekker has reported a slightly characteristic rounded, broken roll vertebrae, found in the Wealden of the Isle of Wight (5).

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(1) According to M. LYDEKKER, the first caudal is not concave anteriorly.

(1) LYDEKKER, *Records geol. Survey of India*, 1877, vol. X, p. 38. - *Palaeontologia Indica*, series 4, vol. 1, p. 20, pl. IV-V, 1879.

(2) *Titanosaurus montanus* Marsh (*American Journal of Science*, 1877, p. 87) is an atlantosaurid.

(3) Mr. LYDEKKER (*Catalogue of Fossil Reptilia*, vol. I, p. 134) places these same genera in the cetiosaurid group; it is the form of the femur, studied by him in 1877, which led him to suggest this classification, but he recognizes that it would be good to establish a distinct family for *Titanosaurus*.

(4) LYDEKKER, The Dinosaurs of Patagonia. *Annales del Museo de la Plata. Palaeontologia Argentina*, vol. II.
Mr. Gaudry remarked to me that *Dinosuchus terror* from Bas-Amazone, described by GERVAIS is probably a dinosaur from the same group. The vertebra figured by Gervais (*Journal de zoologie*, vol. VI, pl. VII) is a very opisthocoelous dorsal.

(5) LYDEKKER, On certain Dinosaurian vertebrae from the Cretaceous of India and the Isle of Wight.
Mr. Seeley has also described a dinosaur vertebra from the Upper Greensand of England (*Macrurosaurus*) that he describes as of enormous modification from the crocodilian type of dinosaurs (*Quart. Journ. geol. Soc. of London*, 1876, vol. XXXII, p. 441).

MEGALOSAURUS CRENATISSIMUS, Depéret.

Dr. Decorse has sent to the Museum a megalosaur tooth found at Maevarano. It is larger (pl. I, fig. 17) than the type figured by Depéret; but it probably belongs to the same species, because it is finely crenulated along the entire length of the anterior edge, though also on the posterior edge. Analogous teeth are known from the Cretaceous of India (1) and Austria (2). They show some similarity to the teeth of *Laelaps* (*Dryptosaurus*) from the Cretaceous of North America (3).

The same explorer collected fragments of thin hollow bones probably belonging to the same animal, but all poorly preserved. Mr. Bastard has found, in the same locality, biplanar or gently amphicoelous vertebrae with the body is strongly narrowed in the middle; these vertebrae can be attributed to the same bipedal carnivorous dinosaur as the preceding teeth (pl. I, fig. 18).

In summary, it is known that in the Upper Cretaceous of Madagascar there are sauropod and theropod dinosaurs belonging to the same genera as those which lived in India or South America during the same epoch. The facts at our disposal are too few for a precise anatomical study. As for paleogeographic considerations that might be inferred from the existence of these great reptiles in the Cretaceous of India, Madagascar, southern Africa (4), central Africa (5), central and western Europe, Patagonia, Brazil (6), North America (Colorado, Dakota, Wyoming, Maryland, New Jersey, etc.), such would be premature with these incomplete fossils, collected in localities distant from one another.

DINOSAURS OF INDETERMINATE AGE

A fragment of solid long bone and three vertebrae were collected by Mr. Decorse in a small hillock located on the Maroakato plateau (between the Betsiboka and the Kamoro) between the villages of Amballazonakomby and Ampanihinampango.

The matrix is a white sandstone, varicolored with red, similar to the matrix of the bones from Maevarano, which was placed definitely in the Upper Cretaceous.

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(1) *Pal. Indica*, ser. IV, vol. I, pl. VI, fig. 6.

(2) SEELEY, *Quart. Journ. geol. Soc. of London*, vol. XXXVII, p. 670, pl. XXVII, 1881.

(3) Mr. Smith Woodward has noted the existence of a megalosaurid in the Cretaceous of Patagonia. *Proceed. zool. Soc. of London*, 1901, p. 106.

(4) BROOM, On the occurrence of an opisthocoelian Dinosaur in the Cretaceous beds of South Africa. *Geol. Magazine*, 1904, p. 445.

(5) HAUG, Documents scientifiques de la mission saharienne Foureau-Lamy. *Paléontologie*, p. 823, 1905.

(6) WOODWARD (A. SMITH), *Report British Assoc. Advancement of Science*, 1903, p. 663.

A fairly posterior dorsal vertebra (pl. I, fig. 20) shows quite shallow lateral cavities situated high on the centrum. The anterior face of this vertebra is broken and shows that the interior was constructed of an extremely lacuneous bony tissue.

The other vertebrae (pl. I, fig. 19) are fairly thin and slightly amphicoelous posterior caudals, around 15 centimeters in length, nearly square in section, and without transverse processes or chevron facets; the neurapophysis inserts along nearly the entire length of the vertebral body.

These bones, at least the long bone and dorsal vertebra, belonged to a sauropod of very large size (1).

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(1) Perhaps the caudals belong to a very large megalosaurid. Cope has figured similar vertebrae and attributed them to this latter group.

DINOSAURS OF MADAGASCAR

Plate I

1, 1a, 1b, 1c. - BOTHRIOSPONDYLUS MADAGASCARIENSIS Lydekker. - Tooth; external face, profile, internal face and horizontal section. - Natural size. - Ankinhanivalaka.

2, 2a. - Ibid. - Cervical vertebra; right side and anterior face. - Area of Antsohihi?

3. - Ibid. - Anterior dorsal vertebra; right side. - Antsaongo.

4, 4a. - Posterior dorsal vertebra; left side and inferior face. - Area of Antsohihy.

5, 5a. - Ibid. - Anterior caudal vertebra; left side and inferior face. - Area of Antsohihy.

6, 6a. - Ibid. - Caudal vertebra; left side and anterior face. - Ankinganivalaka.

7, 7a. - Ibid. - Chevron bone found in connection with the preceding vertebra.

8. - Ibid. - Vertebra from the middle region of the tail; left side. - Marojano.

9, 9a. - Ibid. - Posterior caudal vertebra; right side and inferior face. - Ankinganivalaka.

10. - Ibid. - Series of eleven consecutive caudal vertebrae. - 1/10 natural size. - Antsaongo, near Antsohihy.

11, 11a. - Ibid. - Right first metacarpal; face and proximal portion. - Andranosamonta.

12, 12a, 12b. - Ibid. - Right first metacarpal; anterior face, proximal portion and distal portion. - Port-Bergé.

13, 13a. TITANOSAURUS MADAGASCARIENSIS Depéret. - One of the first caudal vertebrae; right side and inferior face. - Maevarano.

14, 14a, 14b. - Ibid. - Caudal vertebra; left side, anterior face and inferior face. - Same locality.

15, 16. - Ibid. - Two posterior caudal vertebrae; left side. - Same locality.

17, 17a. - MEGALOSAURUS CRENATISSIMUS Depéret. - Tooth; profile, lateral face and section. - Same locality.

18. - Ibid. - Caudal vertebra; profile. - Same locality.

19, 19a, 19b. - INDETERMINATE SAUROPOD. - Caudal vertebra; profile, inferior face and anterior face. - Plateau between the Betsiboka and the Kamori.

20. - Ibid. - Dorsal vertebra; left side. - Same locality.

All the figured specimens belong to the paleontology collections of the Museum.
All the figures except 1, 10 and 17 are 1/4 natural size.

DINOSAURS OF MADAGASCAR

Plate II

1. - BOTHRIOSPONDYLUS MADAGASCARIENSIS Lydekker. - Left humerus; anterior face. - Andranosamonta.

2, 3a. - Ibid. - Proximal portion of right humerus; anterior and posterior faces. - Marojano.

3. - Ibid. - Distal portion of left humerus; posterior face. - Andranosamonta.

4, 4a. - Ibid. - Right femur; anterior and posterior faces. - Antsohihy.

5. - Ibid. - Proximal portion of ulna; anterior face. - Ankinganivalaka.

6. - Ibid. - Left pubis; external face. - Ankinganivalaka.

7. - Ibid. - Right tibia; posterior face. The base is restored. - Ankinganivalaka.

8. - Ibid. - Right fibula; external face. - Ankinganivalaka.

All the figured specimens belong to the paleontology collections of the Museum.
All the figures are 1/10 natural size.

Fig. 1. - Map of the northwest region of Madagascar. - †, dinosaur localities. - Scale: 1/5,000,000 (1 millimeter equals 5 kilometers).

Fig. 2. - Restoration of the tooth illustrated in pl I, fig. 1.

Fig. 3. - Cervical vertebra of *Diplodocus,* after Hatcher.

Fig. 4. - Vertical section, perpendicular to the axis of the vertebra figured in pl. I, fig. 2.

Fig. 5. - Vertical section of the anterior dorsal vertebra, illustrated in pl I, fig. 3.

Fig. 6. - Base of the humerus illustrated in pl. I, fig. 3.

Fig. 7 and 8. - Left, radius and ulna of *Diplodocus,* after Hatcher; right, radius and ulna of *Dinotherium,* after Mr. Gaudry.

Fig. 9. - Top of the ulna of *B. madagascariensis*.

Fig. 10. - Carpal bone (?) of *B. madagascariensis*.

Fig. 11. - A. distal portion of the ischium of *B. madagascariensis*. - B. the same, profile view. - C. the same, in planar view. - D. position of the ichia of *Brontosaurus* in planar view. - E. position of the ichia of *Morosaurus*, after Marsh.

Fig. 12. - Proximal end of the femur of *Bothriospondylus madagascariensis*, illustrated in pl. II, fig. 4.

Fig. 13. - Distal end of another femur of *B. madagascariensis*. - *e*, endocondyle. - *e'*, ectocondyle.

Fig. 14. - Proximal end of the tibia illustrated in pl. II, fig. 7.

Fig. 15. - Restoration of the limbs of *Bothriospondylus madagascariensis.* 1/25 natural size.