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NOTE ON THE SAUROPOD AND THEROPOD DINOSAURS FROM THE UPPER CRETACEOUS OF MADAGASCAR*

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(PLATE VI).

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The bones of large dinosaurian reptiles described in this work were brought to me by my good friend, Mr. Dr. Félix Salètes, primary physician for the Madagascar expedition, from the environs of Maevarana, where he was charged with installing a provisional hospital. This locality is situated on the right bank of the eastern arm of the Betsiboka, 46 kilometers south of Majunga, on the northwest coast of the island of Madagascar. Not having the time to occupy himself with paleontological studies, Dr. Salètes charged one of his auxiliary agents, Mr. Landillon, company sergeant-major of the marines, with researching the fossils in the environs of the Maevarana post. Thanks to the zeal and activity of Mr. Landillon, who was not afraid to gravely expose his health in these researches, I have been able to receive the precious bones of terrestrial reptiles that are the object of this note, along with an important series of fossil marine shells. I eagerly seize the opportunity here to thank Mr. Landillon for his important shipment and for the very precise geological data which he communicated to me concerning the environs of Maevarana, and of which I will now give a short sketch.

1st. Geology of Maevarana and placement of the localities.

* Original reference: Depéret, C. 1896. Note sur les dinosauriens sauropodes & théropodes du Crétacé supérieur de Madagascar. *Bulletin de la Société Géologique de France*, 3e série, 24:176-194.

Dr. Salètes, in availing himself of Colonel Beylié's road map and some data collected by the postal officers and Mr. Landillon, agreed to draw the attached sketch (fig. 1), designed to give a precise idea of the location of Maevarana, and above all to indicate the placement of fossiliferous localities in view of future researches which could be undertaken on this point.

The wide plain where the post-hospital of Maevarana was established, undulating with numerous small hills, is dominated for a distance of several kilometers by horizontally-bedded cut plateaus, with an average altitude of 120 meters.

1st. The upper table of these plateaus is formed by a hard limestone foundation of a dozen meters' thickness, cut into a cornice, and whose rocky debris covers the slopes. In the most superior part, the limestone becomes weak and white and contains oxidized iron nodules. In these limestones, numerous molds of gastropods and lamellibranchs of the genera *Turritella, Natica, Nerinaea, Cypraea, Cytherea, Modiola*, *Cardium*, etc., are recovered, fairly poorly preserved and of difficult determination. In the weak limestones above, regular echinoids of the genus *Cyphosoma* and an irregular echinoid from the family Spatangidae, perhaps *Micraster*, are found further.

2nd. The upper and middle slopes of the plateaus appear to be composed of a thick series of marls or marly limestones with banks of oysters, such as *Ostrea vesicularis* L., *Alectryonia ungulata* Schlot., *Exogyra canaliculata* Sow., etc. The shells of these oysters are rolled in great quantity onto these slopes immediately below the hard limestone foundation. The marine marly limestone beds appear very thick, because one still finds weak limestones with molds of gastropods and lamellibranchs similar to those of the summits of the plateaus on the upper part of several hillocks of the plain, near the river (around 25-30 meters altitude). Together these marine beds would therefore have about a hundred meters of thickness.

3rd. The lower slopes of the plateau, in the same way as the hillocks and under-soil of the plain, are formed by a clay – or in places clayey sandstone – formation in which the bones of reptiles were discovered in several places indicated on the map (fig. 1), which will be described further on. The richest locality is that indicated under No. 1, near the river, SE of Maevarana; most of the *Titanosaurus* bones were found there, except the humerus, which came from locality No. 3, situated to the east on the other side of the first plateau. The locality indicated under No. 2, on the north slope of an elevated hillock crowned by a tomb, produced the two small teeth of *Megalosaurus* and numerous fragments of turtle carapace. On this point, according to what Mr. Landillon wrote me, "the dispersal of bones was continued for more than a hundred meters." It can be seen by

these very exact directions that the fossil bones must be very abundant in this entire region amidst this clayey-sand formation which, if excavations are made carefully, promises to reveal the magnificent remains of dinosaurs and other Cretaceous reptiles to paleontologists .

2nd. Paleontology and geologic age.

In summary, the Maevarana region appears to be constituted of regular, horizontal plateaus where the following succession of three beds is presented:

3. Hard limestones, chalky on top, with gastropod and lamellibranch molds, and echinoids at the summit.

2. Marly-limestones with banks of oysters.

1. Clays and sandstones with dinosaur and turtle bones.

Bed no. 3. — In spite of the often defective state of these specimens, I have been able to recognize the following forms with sufficient certainty, all from the Upper Cretaceous of India:

CYPROEA KAYEI Forbes (in Stoliczka, *Cretaceous gastrop. from south. India*, *Paleont. Indica*, ser. IV, vol. II, pl. IV, fig. 7-10). This species, well characterized by its wide, short, strongly depressed shape, was described from the two Trichonopoly and Arrialoor Groups on the east coast of Hindustan. The single specimen from Madagascar conforms perfectly to the specimens from this latter bed.

TURRITELLA PONDICHERRIENSIS Forbes (in Stolickza, *loc. cit*., pl. XVI, fig. 18-19). Numerous molds, occasionally fairly well preserved, of a large turritelle with a flat spire, slightly excavated turns in the middle, a blunt sutural pad in front and behind, and indications of several intermediate spiral bands. It seemed to me extremely similar to *T. pondicherriensis* from the Arrialoor Group of Pondicherry.

AMPULLINA cf. MARIOE d'Orb. *Astrolabe*, pl. 3, fig. 32-33. — Id., Stolickza, *loc. cit*., pl. XXII.

Species with a short but strongly canaliculous and layered spire, described by d'Orbigny from the Trichonopoly beds near Pondicherry. It is likewise very close to *A. lyrata* Sow. from the Turonian of Europe and India.

Small determinable mussels of the genera *Cardium, Cytherea, Modiota*, etc.

CYPHOSOMA, n. sp. This species, very probably new, is fairly close to *C. baylei* Cotteau from the Turonian of Batna (*Paleont. fr., Ter. cret*., vol. 7, p. 584, pl. 1138-1139) based on its generally depressed and subcircular form, poriferous untwinned zones, and numerous granules grouped about tubercles in regular circles. It differs by its slightly more undulating poriferous zones and its relatively fatter tubercles in the interambulacreous zones.

A single, well-preserved specimen in the chalky beds at the summit of the plateau.

?MICRASTER. A single specimen from the summit of the plateau, associated with the preceding species, belongs to a form from the family Spatangidae, but it is too worn to permit recognizing surely the genus by the character of the fasciole.

Bed No. 2. — This bed is principally characterized by banks of oysters of diverse species.

OSTREA VESICULARIS Lam. A large variety with a very thick test and a wide ligamentous surface, conforms perfectly to specimens from the *Arrialoor Group* of India figured by Stoliczka (*Paleont. indica, Cretac. Pelecypoda of south. India*, p. 465, pl. XLII, fig. 2-4, and XLIII, fig. 1). The species has already been noted from Ambohitrombikely, not far from Maevarana, by Mr. Newton [1]. These Malagasy oysters could be mistaken for specimens of *Ostrea vesicularis* var. *major* from the upper Senonian of Vercours.

ALECTRYONIA UNGULATA Schlot. A fairly variable form, either from the point of view of the valve size, or above all from the folds and denticles of the valve edges, which are sometimes nearly as serrated as in *A. carinata*, and sometimes more spaced as in *A. larva*. These latter individuals could hardly be distinguished from *A. larva* of Europe; they conform to specimens from the *Arrialoor Group* of India figured by Stoliczka (*loc. cit*., pl. XLVII, fig. 3-4) under the name *A. ungulata*. Mr. Newton has already indicated the presence of this form at Ambohitrombikely, not far from Maevarana.

ALECTRYONIA cf. SANTONENSIS d'Orb. A single specimen very close to the European species, already noted by Mr. Newton from Ambohitrombikely.

EXOGYRA CANALICULATA Sow. Several specimens of this small exogyral oyster, very recognizable by the salient, regular, concentric lamellae that ornament the opercular valve, cannot be distinguished from the form from the Upper Cretaceous of Europe (d'Orb., *Paléont. fr., T. crét*., pl. 471, fig. 4-9). The species is likewise cited from the *Ootaloor Group* of India by Stoliczka (*loc. cit*., pl. XLVIII, fig. 6-8), but the author only figured young specimens whose identity with the European and Malagasy species is far from certain. In Europe, the species extends from the Albian to the Senonian.

EXOGYRA sp. An exogyral form, smooth on the two valves and transversely straight, which is not identical to any species figured and which I believe is new.

Furthermore, gastropod and lamellibranch molds similar to those from the plateau are found in a layer below the oyster bed.

Bed No. 1. — This clayey-sandstone bed uniquely contains terrestrial dinosaur and turtle bones. Its facies must therefore be much less marine than those of other beds, perhaps more or less completely fluvio-lacustrine.

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[1] *Quart. Journ. geol. Soc*., 1889, p. 331.

The Upper Cretaceous age of the marine beds of Maevarana (beds 2 and 3) follows from evidence from the preceding paleontological study. One cannot fail to be amazed to encounter again littoral species more characteristic of the Cretaceous seas of Europe, such as *Ostrea vesicularis, ungulata, canaliculata, santonensis*, with characters almost identical with northern types, so far in the southern hemisphere. The Cretaceous sea thus seems to have possessed a much more homogeneous littoral fauna than the Tertiary and Recent seas. Also the synchrony of the Cretaceous marine beds of Maevarana with the whole *Senonian* stage can hardly be doubted.

The parallelism is further confirmed by the complete similarity presented between the Malagasy beds and the marine beds from the east coast of Hindustan, known under the name *Arrialoor Group*. It is in this Indian stage where most of the species in the preceding list are encountered, such as *Ostrea vesicularis* (thick variety), *O. ungulata, O. santonensis, Cypraea kayei, Turritella pondicherriensis*, to indicate only the forms whose determination is certain. Further, the Arrialoor Group is considered by Indian geologists, in particular Blanford and Stoliczka (*loc. cit*., p. 510), as equivalent to the upper part of the *Turonian* and to the whole *Senonian* of Europe. This whole parallelism is applied as a consequence to beds 2 and 3 of the Maevarana section.

Regarding clayey-sandstone formation No. 1 with terrestrial reptiles which forms the substrate of these marine beds, at this moment it is difficult to determine its age with some certainty. For it to be fixed, it will be necessary to study the relations of these beds with the other Cretaceous marine beds of the west coast of Madagascar, in particular with the *Cenomanian*, which is present in this same region near Ambohitrombikely, according to Mr. Newton, beneath a marine facies with oysters (*Exogyra ratisbonnensis* Schlot.). Therefore it seems probable to me that the clayey sandstones with dinosaurs are intercalated between the Cenomanian marine beds and those of the Senonian, and belong to the middle part of the Upper Cretaceous, perhaps the Turonian, as fluvio-lacustrine facies.

3rd. Description of reptile bones.

DINOSAURS

The dinosaurs of Maevarana belong to two very distinct types both by their size and by their zoological characters:

I. — Suborder SAUROPODA.

(Plantigrade herbivores).

***Titanosaurus madagascariensis*, n. sp.**

(Fig. 2 and pl. VI, fig. 1-3).

Descriptions. — A form of large size is represented by the following elements:

1st. A portion of the shaft of a *humerus*, 0.32 m long (fig. 2). The bone is filled, with an elliptical cross-section, and is strongly anteroposteriorly compressed, with a transverse diameter of 0.15 m and an anteroposterior diameter of 0.07 m at the midshaft. The olecranon fossa is fairly deep, and well defined on the external side by a strong projection of the humerus behind. This external projection is very well pronounced in *Aepisaurus* Gervais from the Cretaceous of Mont Ventoux and in *Cetiosaurus* from England. If its proportions are compared with the humerus of other sauropod dinosaurs, such as *Aepisaurus* [1] and *Cetiosaurus* [2], the Malagasy humerus should measure about 0.90 to 1.0 m in length.

2nd. *A vertebra from the anterior caudal region* (pl. VI, fig. 1-1a), only the centrum of which is preserved. This centrum is shortened, only 0.16 m in length for a vertical diameter of 0.14 m and a transverse diameter of 0.133 m. It is strongly *procoelous* and presents a strongly convex articular head behind, forming a veritable cone 0.07 m long. Below, the centrum is hollowed by a deep median furrow, bordered by two crests brought together near the middle, diverging forwards and behind, where they each end in an articular surface for the chevrons; these surfaces are only demi-facets, which permit inferring a double mode of articulation for these chevrons, that is to say each of them rests on two vertebrae at once. The general form of this centrum is nearly circular, and a little compressed on the sides, which show a fairly notable excavation. Several asymmetrical openings for the vascular canals are also visible.

3rd. *Another caudal vertebra* (pl. VI, fig. 2-2a), smaller and more elongated, which belongs to a more distant region of the tail of the same animal. The *strongly procoelous* centrum is elongated, 0.11 m long for a vertical diameter of 0.06 m; behind it forms an 0.045 m articular cone, partly corroded on this element. As in the preceding vertebra, a fairly wide longitudinal canal exists below the centrum, bordered by two thick and blunt crests. The articular surfaces for the chevrons have been destroyed by wear. Above the centrum is observed a rounded medullary canal 0.02 m in diameter, surrounded by a neural arch placed *very near the anterior border of the centrum*, such that the whole posterior

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[1] GERVAIS. *Zool. et paléont. franç.*, pl. 63, fig. 3-4.

[2] OWEN, *Mesozoic Reptilia* (Palaeont. Society, vol. XXIX, p. 33, fig. 3-4).

part of the centrum is entirely free. The neural arches undoubtedly met above to form a *spinous process*, which is broken in the described specimen; they probably bore two *prezygapophyses* in front, of which only the broken insertion base is seen; further, near the junction of the centrum and the neural arches, the insertion base of a *transverse process* is visible, whose size is impossible to appreciate.

4th. Finally, I refer to the same animal, but without absolute certainty, a large *dermal ossification* (pl. VI, fig. 3-3a), partly broken on the side, generally rounded or slightly oval in shape, and very thick (0.70 m in the middle) relative to its diameter, which is 0.25 m. The nearly smooth internal face shows a very particular interlaced fibrous structure, whereas the external face, with slightly raised edges towards the center in the form of a subcircular cone, presently a coarsely radiating ornamentation, formed of furrows and areolar cavities of various sizes. These rugosities evidently constitute an insertion base for a horny covering or a sharp spine. The position of this dermal bone on the body of the animal is difficult to specify for the moment; I suppose that it could be placed, as in some other dinosaurs (*stegosaurids, ceratopsids*), on the posterior part of the back or above the base of the tail.

Relationships and differences. — The attribution of this large dinosaur to the *sauropod* group is proved by the present of a solid humerus, lacking a medullary cavity, as well as by the great size of this humerus (about 1 m), involving a quadrupedal posture. Solid limb bones clearly exist in certain families of *orthopodous* dinosaurs, such as *stegosaurids* and *ceratopsids*, but in these the forelimb is more reduced and implies a bipedal posture; at the same time their vertebrae are *platycoelous* or *amphicoelous*, and not *procoelous* as in the Malagasy form.

The shape of the caudal vertebrae of this latter form is entirely unique: their *deeply procoelous* formation, as well as the *very advanced position of the neural arch* on the centrum is only observed among sauropods in the single genus *Titanosaurus*, established by Mr. Lydekker [1] first after some caudal vertebrae from the Cretaceous of India (*Lameta Group*), and noted afterwards by the same paleontologist in the *Wealden* and *Upper Greensand* of the Isle of Wight [2]. The attribution of the Malagasy animal to the genus *Titanosaurus* is confirmed by other details of the structure of these caudal vertebrae, such as the presence of a wide median groove under the centrum, the double articulation of the chevrons, the existence of anterior zygapophyses, etc.

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[1] *Records Geol. Survey Ind*., vol. X, 1877, p. 38. — Id., *Palaeontologia Indica*, ser. IV, vol. I, *Foss. Rept. a. Amphibia*, p. 20, pl. IV-V. — Id., *Catal. of foss. Rept. Brit. Mus*., part I, 1888, p. 134.

[2] *Quart. Journ. geol. Soc.,* vol. XLIII, p. 156, and vol. XLIV, p. 54.

Other genera of sauropods [1] whose caudal vertebrae are known show very different characters from *Titanosaurus*. *Cetiosaurus* Owen has amphicoelous caudal vertebrae, a little more hollowed anteriorly than posteriorly. *Brontosaurus* Marsh likewise has amphicoelous caudal vertebrae, and further has chevrons with a simple articulation. *Morosaurus* Marsh possesses chevrons with a double articulation like *Titanosaurus*, but much more *weakly procoelous* anterior caudal vertebrae. The caudal vertebrae of *Atlantosaurus* Marsh resemble those of *Morosaurus*. *Pleurocoelus* Marsh and *Diplodocus* Marsh have platycoelous caudals. Finally, *Macrurosaurus* Seeley possesses *slightly procoelous* caudals, but different from those of *Titanosaurus* in their elongation, the median position of the neural arch, and the compressed form of the centrum, provided with a simple inferior crest. The form of the caudals in other genera, such as *Pelorosaurus* Mantell, *Ornithopsis* Seeley, *Thecospondylus* Seeley, *Aepisaurus* Gerv, are ignored.

In summary, the form of the caudal vertebrae and the double articulation of the chevrons seem to refer *Titanosaurus* to the family *Cetiosauridae* Lyd. (= *Morosauridae* Marsh) and more specifically to the American genus *Morosaurus*, perhaps identical to *Ornithopsis* of England.

However the existence of bony dermal elements, like that which I have figured (pl. VI, fig. 3) and attributed provisionally to the same animal because they were found at the same place as the vertebrae, would give *Titanosaurus* a special character unknown in other *cetiosaurids*. It is true that paired (*Brontosaurus*) or unpaired (*Cetiosaurus*) dermal sternal ossifications (sternal shield) exist in several genera of this family; but these elements are much thinner and more finely rugose than the Malagasy element, and can, I think, be compared to it neither in form nor in location.

The only dinosaurs possessing a true dermal skeleton composed of thick bony plates are several theropods (*ceratosaurids*) and above all the orthopods (*stegosaurids, ceratopsids*).

Ceratosaurus Marsh from the Upper Jurassic of Colorado bears, according to Mr. Marsh [1], a series of bony dermal elements in the neck region supported on the cervical vertebrae; these elements have not been figured, and I cannot say whether they resemble the dermal plate from Madagascar.

Stegosaurus Marsh from the Upper Jurassic of Colorado, identical to *Omosaurus* Ow. from the Kimmeridgian of England according to Messrs. Marsh and Lydekker, was

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[1] I will refer to the *Traité de paléontologie* of Mr. Zittel for the bibliography of the diverse cited dinosaur genera, where these indications are very complete.

[1] *Americ. Journ. of sc.*, vol. 27, p. 330.

clad in a cuirass of dermal elements, of variable form according to the species. The Malagasy element cannot, in all cases, be compared to the enormous flattened, uneven plates, triangular in profile, that were arranged vertically along the midline of the trunk and tail [2], and a comparison cannot be imagined with the paired bony plates of the cervical and dorsal region. In particular, Mr. Marsh figured [3] a dermal plate of *Stegosaurus ungulatus* under the name "*tubercular spine*", whose general form, although of half the dimensions, resembles the Malagasy element; like in this latter, the inferior face is nearly smooth, the edge is undulating, and the superior surface rugose; but these rugosities do not have the radiating arrangement of the Malagasy form and the center of the plate is elevated into a much more accentuated conical eminence. According to Hulke [4], in *Omosaurus armatus* Ow. from England, the dermal cuirass was formed from thin plaques and plates.

The family *Ceratopsidae* likewise presents a strongly developed dermal skeleton, in particular in *Ceratops* and *Triceratops* Marsh from the Upper Cretaceous of the Rocky Mountains (Laramie Stage). Some of the dermal elements of *Triceratops* [5] figured by Mr. Marsh do not lack a certain similarity with the Malagasy element in the general form, undulating border, and more or less conical elevation of the central part; but I found in none of these figures the rugose radiating ornamentation so particular to this latter element. In *Nodosaurus textilis* Marsh [6] from the medial Cretaceous of Wyoming, there exists a complete dermal cuirass formed by rows of plates, whose entire surface shows a fibrous structure latticed along two directions at right angles, which does not resemble the Malagasy element at all.

A dinosaur from the Upper Cretaceous beds of Neue Welt (Austria) has been referred to the family Ceratopsidae, whose diverse skeletal elements were recognized under the name *Struthiosaurus* Bunzel, *Danubiosaurus* Bunzel, and *Crataeomus* Seeley. This latter paleontologist figured [1] several elements of the dermal armor of this dinosaur; neither the long spines, ornamented at the base with rows of conical polygonal shields, nor the dorso-caudal paired or unpaired plates, 6 to 7 centimeters long, all provided on their external face by *a longitudinal carina*, can be closely compared to the enormous plate from Madagascar; there is only a certain resemblance between this latter and the

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[2] *Amer. Journ. of sc.*, vol. XLII, pl. IX, and vol. XIX, pl. XI.
[3] *Amer. Journ. of sc.*, vol. XIX, pl. X, fig. 4.
[4] *Quart. Journ. geol. Soc.*, vol. XLIII, 1887, p. 699.
[5] *American Journ. of sc.*, vol. XLI, pl. X, fig. 4-10.
[6] *Amer. Journ.*, vol. XXXVIII, p. 175, fig. in the text.
[1] *Quart. Journ. geol. Soc.*, 1881, vol. XXXVII, p. 637, pl. XXVIII, XXX and XXXI.

dorso-caudal plates of *Crataeomus* from the point of view of the undulating aspect of the edges and the disposition of the vascular grooves.

The very developed bony plates of the dermal skeleton in *Scelidosaurus* Ow. [2] from the Liassic of England are characterized, as in *Crataeomus*, by a longitudinal carina that does not exist on the Malagasy element. It is the same with the bony plates, furthermore of small dimensions, of *Acanthopholis* Huxley [3] from the marly chalk of Folkstone.

To summarize these comparisons, it can be said that the Malagasy dermal element is characterized by its large dimensions, its great thickness, the deep radiating grooves and cavities of its surface, and a slight elevation of the central part into a relatively low cone. It does not resemble any described element of dinosaurian dermal armor. Moreover, it is still the reason that engages me to attribute it to *Titanosaurus*, whose vertebrae were found in the same locality. It is true that the existence of a dermal skeleton has not been noted in sauropods until here, and it is not impossible that the dermal element in question belongs to some other orthopodous dinosaur, still unknown in Madagascar; this question merits thus still to be reserved.

Specific determination. — Now it remains for me to compare the bones of *Titanosaurus* from Madagascar with those of other described species of this genus, still incompletely known. The form of the caudal vertebrae will be of great assistance in this.

Titanosaurus indicus Lyd. [1], from the *Lameta beds* near Jabalpur and Pisdura (attributed to the middle Cretaceous), differs from the Malagasy type by its caudal vertebrae, whose centrum is very transversely compressed in such a way that the sides of the vertebra are not visible when it is examined from below. The size should be fairly similar in the two species, because the type-vertebra figured by Mr. Lydekker (pl. IV) is intermediate in dimensions between the two Malagasy vertebrae and should, in effect, occupy a slightly more distal position in the caudal series than the larger Malagasy vertebrae, because it is more elongated.

Titanosaurus blanfordi Lyd. [2], from the *Lameta beds* of Pisdura, is based on two caudal vertebrae whose centra are cylindrical in cross-section, with the transverse diameter is slightly larger than the vertical diameter. In spite of this resemblance in general form, the Malagasy vertebrae differ from these: 1st, because the sides of the centrum are more depressed and excavated, so that there is a more marked angle between

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[2] *Liassic Reptilia* (Palaeont. Society, part 1, 1861).
[3] *Geol. Magaz*., 1867, vol. IV, pl. V.
[1] *Palaeont. Indica*, ser. IV, vol. I, pl. IV and V, fig. 3-6.
[2] *Pal. Indica, loc. cit*., pl. V, fig. 2, 4 and 5.

the inferior and lateral faces of the vertebrae; 2nd, because the two inferior crests and the medial longitudinal groove of the centrum are much more marked, nearly as much as in *T. indicus*. It can therefore be said that the Malagasy vertebrae represent a particular form that is intermediate between the two Indian species.

Likewise, Mr. Lydekker has made known European forms of the genus *Titanosaurus*. From the Wealden Clay of Brook (Isle of Wight) comes a caudal vertebra [3] that possesses the strongly procoelous character and the advanced position of the neural arch characteristic of *Titanosaurus*. It very much resembles the Malagasy vertebra in the degree of compression of the centrum and the projection of the inferior crests; the articular surfaces for the chevrons cannot be estimated. The species, which has not received a specific name, seems to differ very little from the Malagasy species.

Another *Titanosaurus* vertebra from the Upper Greensand of the Isle of Wight [4] is larger than the preceding one and its centrum is more laterally compressed.

In summary, the species of *Titanosaurus* from Maevarana is not identical to any of the forms described from India or Europe, while appearing very close to the Wealden form from the Isle of Wight, at least in the shape of the caudal vertebrae. I will designate it under the name *Titanosaurus madagascariensis* n. sp.

II. – Suborder THEROPODA.

(*Digitigrade predators*).

Megalosaurus crenatissimus, n. sp.

(Pl. VI, fig. 4-8).

Descriptions. — I attribute the following elements to a megalosaurid of moderate size:

1st. *Two teeth*, of which one is nearly complete up to the base of the crown (Fig. 4), and the other is larger but incomplete below (Fig. 5). These teeth show the typical characters of megalosaurid teeth: a transversely compressed shape with two sharp ridges anteriorly and posteriorly, the latter more trenchant than the anterior: a recurved posterior profile in the shape of a saber blade; fine transverse serrations on the trenchant ridges: *these serrations extend along the entire length of the anterior edge*. The enamel is finely striated lengthwise.

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[3] *Quart. Journ. geol. Soc*., 1887, p. 156. — Id., *Catal. foss. Rept. Brit. Mus*., part I, p. 135, fig. 22.

[4] *Catal. foss. Rept. Brit. Mus*., part I, p. 136.

2nd. *An ungual phalanx* (Fig. 8, 8a) in the shape of a recurved claw, unfortunately broken near the point. A blunt ridge that runs over the convex or superior edge along its entire length separates two oblique lateral faces, of which one – doubtless located on the external side – is more developed than the other: this asymmetry of the phalanx makes it possible to think that it is the claw of a lateral digit. Each of the two faces is covered near the base by a wide, curved vascular groove that leaves the inferior edge and moves while rising towards the terminal point of the claw. The posterior or articular face shows indications of two shallow articular excavations, the external being wider, separated by a slightly vertical ridge.

3rd. Two sacral vertebrae are compressed in the middle of the centrum (Fig. 6), according to the ordinary type of megalosaurids.

4th. A very elongated *caudal vertebra*, clearly amphicoelous (Fig. 7), whose centrum shows a quadrangular cross-section, higher than wide. A slight median longitudinal crest is visible below, bordered by two weakly marked grooves. The neural arch is inserted along nearly the entire length of the centrum, only a centimeter of which is free posteriorly. A median longitudinal ridge represents the only indication of a spinous process. No surface for the chevrons is seen, which permits attributing this element to the post-median region of the tail. There is an extremely straight neural canal, of elliptical shape. The anterior and posterior zygapophyses are broken.

Relationships and differences. — The characters drawn together from the teeth, the ungual phalanx, and the amphicoelous caudal vertebra described above do not allow any doubt regarding the existence of a predatory dinosaur in Madagascar close to *Megalosaurus* Buckland from the Jurassic and Cretaceous of Europe, and of a genus near *Dryptosaurus* Marsh (*Laelaps* Cope) from the Cretaceous of the United States.

If the elements from Madagascar are compared with those of the type species, *Megalosaurus bucklandi* Meyer from the Lower Jurassic of England and France, important differences are recognized: the mandibular teeth [1] are higher, but straighter, with much coarser serrations on the posterior edge, and above all on the anterior edge where they exist only on the superior part of the crown; this character is important to note, because the teeth from Madagascar, that of Fig. 4 in particular whose crown is less nearly complete, show serrations along the entire visible part of the anterior edge. The upper teeth of *M. bucklandi* [2] are similar to the lowers; the serrations only appear less marked. The sacral vertebrae of this species [3] clearly have the short, compressed shape

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[1] OWEN. *Wealden a. Purbeck Reptilia*, part III, pl. XII (*Palaeont. Soc*., 1856).
[2] HUXLEY. *Quart. Journ. geol. Soc*., vol. XXV, 1869, pl. XII.
[3] OWEN. *Loc. cit*., pl. II and III.

in the middle of the centrum shown by the Malagasy vertebrae; these are only much smaller. The caudal vertebrae from Madagascar entirely resemble the caudal vertebrae of *M. bucklandi* [4] in their general shape and details; it is only still of more elongate proportions and smaller dimensions by about a quarter. Finally, the ungual phalanx is less transversely compressed and more flattened dorsoventrally than in *M. bucklandi* [5]; it differs further because the lateral groove ends behind the inferior edge of the bone much earlier than in the European species, where this short groove parallels the inferior edge nearly up to the proximal end of the phalanx.

Megalosaurus insignis Desl. from the Upper Jurassic of England and France [1] is a very large species whose teeth have the same straight, elongated form as those of *M. bucklandi*; they are less strongly recurved posteriorly than in the Malagasy species, the serrations of the trenchant anterior edge are weaker and cease on the inferior third of the length of the crown.

In *M. dunkeri* Koken [2] from the Wealden of England and Germany, the form of the teeth is likewise straighter and more elongated than in the Malagasy species; but the serrations are already finer and more closely resemble those of this latter type; however they disappear near the middle of the anterior ridge, as in the other European species, and are attenuated fairly easily by use along the entire length of this edge. The ungual phalanges of *M. dunkeri* [3] are more slender and more transversely compressed than those of the Malagasy species, and the lateral groove remains parallel to the inferior edge instead of recurving below near the posterior third.

Mr. Seeley has described [4] two teeth from the Upper Cretaceous beds of Neue Welt, near Vienna, under the name *Megalosaurus pannoniensis* that are much closer to the Malagasy teeth in the shape of the crown, which is shorter and wider at the base, and more finely serrated anteroposteriorly than in the other European species. However the posterior curvature is weaker than in the Malagasy species and the serrations cease on the inferior third of the anterior ridge instead of continuing along the entire length of this edge. I do not think that they could be attributed to the same species.

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[4] DESLONGCHAMPS. *Mém. Soc. Linn. Norm.,* vol. VI, 1834, pl. II (*Poekilopleuron bucklandi*).
[5] DESLONGCHAMPS. *Loc. cit*., pl. VIII, fig. 22-26.
[1] SAUVAGE. *Mém. Soc. Géol. France*, 2nd ser., vol. X, pl. V, fig. 1-3.
[2] *Palaeont. Abhandl*., vol. III, part 5, pl. II, fig. 2. — OWEN. *Wealden a. Purbeck Rept*., pl. XI.
[3] OWEN, *Loc. cit*., pl. X.
[4] *Quart. Journ. geol. Soc*., 1881, vol. XXXVII, p. 670, pl. XXVII, fig. 21-23.

Above all, it is the species from the Arrialoor Group of Trichinopoly (British India), figured by Mr. Lydekker [5] without specific designation, that the Malagasy teeth resemble entirely in shape, which is short, wide at the base, and strongly posteriorly recurved, and in the fineness of the serrations, which are likewise extended along the entire length of the anterior edge. Except for the much greater dimensions of the Indian type, no appreciable difference can be found with the Malagasy form, and this difference of size can be due either to the age of the subject or to the positional order of the tooth in the jaws. Therefore I think that I can join these two types together, and I will give the name *Megalosaurus crenatissimus* n. sp. to the species because of the serrations which are extended along the entire length of the two trenchant ridges of the teeth.

Some genera from the Jurassic and Cretaceous of America show great affinities with *Megalosaurus*. The best known is *Dryptosaurus* Marsh (= *Laelaps* Cope) [1] from the Upper Cretaceous of New Jersey. The type species *D. aquilunguis* Cope is very large, attaining the size of *M. bucklandi*; the teeth differ entirely from those of *Megalosaurus* in the serrations of the anterior edge, which are extended along the entire length of this edge to near the root, instead of being limited to the upper part of the crown. It is interesting to note that this character is found exactly in the Malagasy and Indian form, therefore the attribution to the genus *Dryptosaurus* is shown as entirely probable. It is true to add that Leidy expressed the opinion that the American genus was close enough to *Megalosaurus* of Europe not to be distinguished from it, and this opinion is all the more probable because that the known parts of the skeleton of *Dryptosaurus* are extremely similar to those of *Megalosaurus*. Therefore I will attribute the Malagasy species to the large genus *Megalosaurus*, while emphasizing its affinities with the species from the Upper Cretaceous of America distinguished under the name *Dryptosaurus*.

4th. Summary and Conclusions.

The *clayey-sandstone formation*, which is exposed on the plain and at the base of the plateaus of Maevarana and which is immediately subordinate to the marls and limestones with the Senonian marine fauna which constitutes these plateaus, contains in some places abundant debris of terrestrial reptiles that belong to the following forms:

DINOSAURS.

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[5] *Palaeont. Indica*, ser. IV, vol. I, pl. VI, fig. 6.

[1] COPE. *Proc. Ac. nat. Sci.*, Philadelphia, 1866, p. 27. — *Trans. Amer. phil. soc.*, vol. XIV, pl. 8-11.

I. — Order Sauropoda.

Titanosaurus madagascariensis, n. sp. — Characterized as a genus by its *strongly procoelous* caudal vertebrae, whose neural arch is placed very anteriorly on the centrum.

The shape of the caudal centra permits distinguishing the Malagasy species from *T. indicus* Lyd., whose caudal vertebrae are strongly transversely compressed, and from *T. blanfordi* Lyd., in which the centrum has a more regularly circular cross-section, without trace of the lateral depression shown in *T. madagascariensis*. Regarding the shape and degree of compression of the caudal vertebrae, this latter species approaches much more the Wealden form from the Isle of Wight, referred by Mr. Lydekker to the genus *Titanosaurus* without specific designation.

I provisionally attribute to *T. madagascariensis* a large, thick dermal ossification with an external surface slightly elevated into a central cone, ornamented with deep radiating rugosities, which does not resemble any element described among the diverse dinosaurs furnished with dermal armor. However, the fact that sauropods are generally lacking of a cutaneous skeleton renders this attribution somewhat uncertain. It is not impossible that it announces the presence of a large dinosaur from an entirely separate group.

II. — Order Theropoda.

Megalosaurus crenatissimus, n. sp. — A predatory dinosaur is represented by two small, compressed teeth, anteroposteriorly recurved in the shape of a saber blade, of the typical form of *Megalosaurus* but shorter and wider than in all the European species of this genus and characterized above all by fine serrations that ornament the two trenchant ridges anterior and posterior to the crown, extended along the entire length of the anterior edge instead of only occupying part or two thirds of this trenchant edge. The name *Megalosaurus crenatissimus*, n. sp., is intended to emphasize this character, which is found in a *Megalosaurus* sp. noted by Mr. Lydekker in the Upper Cretaceous of India, and also in *Dryptosaurus* Marsh (*Laelaps* Cope) from the Upper Cretaceous of the United States. I am thus brought to refer the type from Madagascar to the genus *Dryptosaurus*, which it is doubtless better to consider as a simple section of the large genus *Megalosaurus*.

The other elements of *M. crenatissimus* are: a sacral vertebra, a caudal of more elongate form than *M. bucklandi*, and finally an ungual phalanx in the shape of a recurved

claw, less transversely compressed than in other *Megalosaurus*, and furnished with a lateral groove that is less prolonged posteriorly than in the described species.

CHELONIANS. — Numerous fragments of carapace and plastron indeterminable even to genus.

From the point of view of the geographic distribution of dinosaurs, the Malagasy localities are of great interest because of the presence, noted by Mr. Lydekker, of the genus *Titanosaurus* (*Lameta beds*) and *Megalosaurus* (*Arrialoor Group*) at the same time in the Cretaceous of India, which seemed to me to belong to a species extremely close to that of Madagascar.

This coincidence in the distribution of two genera of terrestrial reptiles belonging to two very distinct groups of dinosaurs seems to me an important confirmation of the hypothesis, formulated by Neumayr, of a junction between India and Madagascar during the Mesozoic Era.

It is advisable to recall however that the genus *Titanosaurus* had a vast geographic distribution: outside of India and Madagascar, it has been noted in the *Wealden* and the *Upper Greensand* of the *Isle of Wight*; finally, Mr. Lydekker found it up into the Cretaceous of Patagonia. *Megalosaurus* likewise had a vast geographic extension, going from India and Madagascar to Europe and the United States, if one returns to this large genus the American species designated under the name *Dryptosaurus*.

Finally, I should not fail to recall that Mr. Lydekker has already indicated the existence in Madagascar (*Quart. Journ. geol. Soc*., 1895, p. 329) of a sauropod dinosaur that he attributed to the genus *Bothriospondylus* (*B. madagascariensis*, n. sp.) from the Jurassic of England, and that he supposed came from the Jurassic beds around Narinda, on the NW coast of the island. The detailed geological exploration of this large land therefore promises to be fertile in reptiles from the interesting group of dinosaurs.

EXPLANATION OF PLATE VI

Fig. 1-3. — *Titanosaurus madagascariensis*, n. sp.

1. Vertebra from the anterior caudal region, from the side. 1/3 natural size.
1a. The same vertebra from below.
2. Vertebra from the middle caudal region, viewed from the procoelous anterior face. 1/3 natural size.
2a. The same vertebra from the side.
3. Bony dermal element, from the external face. About 1/4 natural size.
3a. The same element, from the side.

Fig. 4-8. — *Megalosaurus crenatissimus*, n. sp.

4. Tooth whose crown is a little near complete, from the side. The figure is enlarged by a quarter.
4a. Same tooth; cross-section at the base.
5. Another tooth, incomplete at the base of the crown, from the side. Enlarged by a quarter.
5a. Same tooth; cross-section at the base.
6. Centrum of one of the sacral vertebrae. 2/3 natural size.
7. Amphicoelous caudal vertebra, from the side. 2/3 natural size.
8. Ungual phalanx of a lateral digit, side view. 2/3 natural size.
8a. Same phalanx, proximal articular view.

FIGURE CAPTIONS

Fig. 1. — Topographic map of the Maevarana region (after the map of Colonel Beyliè, completed by Mr. Landillon, company sergeant-major of the marines). — 1, 2, 3, 4, localities of dinosaurs.

Fig. 2. — Portion of the humerus of *Titanosaurus madagascariensis*, n. sp. *a)* view of the posterior face; *b)* cross-section of the same bone from above. 1/3 natural size.