

Article XI.—FORE AND HIND LIMBS OF CARNIVOROUS AND HERBIVOROUS DINOSAURS FROM THE JURASSIC OF WYOMING. DINOSAUR CONTRIBUTIONS, NO. 3.

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In the Bone Cabin Quarry, opened by the American Museum Expedition of 1898, under the direction of Dr. J. L. Wortman, assisted by Mr. W. W. Granger, were found mingled together bones of all the most characteristic Upper Jurassic Dinosaurs, including six nearly or quite complete limbs and three fore feet, which form the subject of this paper. Four of these are shown, as mounted, upon a subsequent page. They are not only grand objects of their kind, but they bring out a number of new and important facts relating to the limbs of Dinosaurs of the *Megalosaur* and *Cetiosaur* divisions or *Ornithopoda* and *Sauropoda*.

I. HIND LIMBS OF CARNIVOROUS DINOSAURS.

FIGURES 1-5.

The late Professor O. C. Marsh described¹ five genera of flesh-eating Dinosaurs from our Jurassic, namely: *Allosaurus*, the largest of the flesh-eaters; *Creosaurus*, a smaller allied form; *Labrosaurus*, of another type; *Cœlurus*, a very small animal distinguished by hollow bones (related to the somewhat older *Hallopus*); and finally *Ceratosaurus*, a large animal with horned nasals.

Of these, the most nearly allied to *Megalosaurus* of the English Purbeck is *Allosaurus*, distinguished by possessing less than five vertebræ in the sacrum, also by other characters of doubtful value (*op. cit.*, p. 239), and figured (*op. cit.*, Pl. XI.) as possessing *three* digits in the pes, while *Megalosaurus* is assigned *four* digits in the pes (*op. cit.*, p. 239). Whether or not *Allosaurus* is distinct from *Megalosaurus* cannot be positively determined at present. The distinction based upon the number of digits is here shown not to hold good.

Two hind limbs from the Bone Cabin Quarry, which correspond in other respects with those of *Allosaurus*, appear to show that the hallux had been detached in Marsh's specimens. They

¹ The Dinosaurs of North America, 1896.

(Nos. 290 and 324) both possess four digits in the pes; the first digit or hallux exhibits an interrupted metatarsal, and is turned inwards as a subsidiary grasping toe.

The proportions between these limbs and those of the two Sauropoda described below are well shown in the accompanying photographs (Fig. 1). The heights in the Table include the curvatures; they give us therefore the usual height of the acetabulum, or head of the femur, not the total length of the limb.

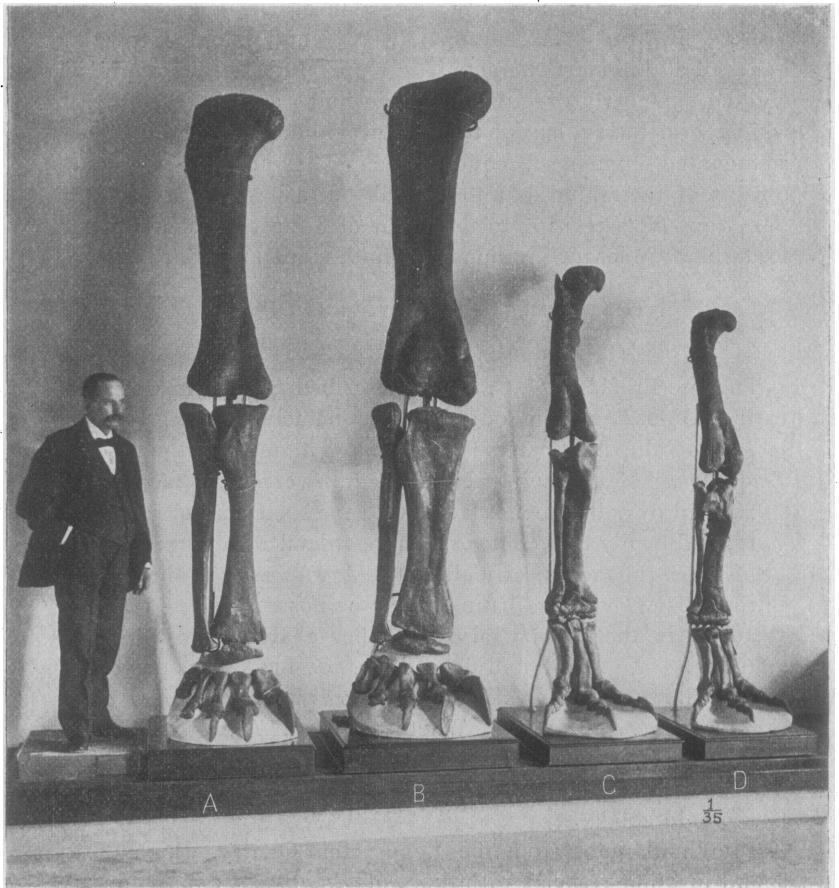


Fig. 1. Right Hind Limbs of Dinosaurs. A, Herbivorous Dinosaur, probably *Diplodocus*, No. 251. B, Herbivorous Dinosaur, *Brontosaurus*, Nos. 309, 353. C, Carnivorous Dinosaur, *Allosaurus*, or *Megalosaurus*, No. 290. D, Carnivorous Dinosaur, *Allosaurus* or *Megalosaurus*, Nos. 324, 275. Approximately $\frac{1}{3}$ nat. size.

The larger of the limbs (No. 290) is the more perfect, except that it lacks the proximal portion of Mt. I. The smaller (No. 324) has the calcaneum and astragalus restored, and a femur (No. 275), which was found at some little distance, is arbitrarily placed with it. Except for differences in size, due to age or sex, the limbs are practically identical in character.

Measurements.

	No. 290.	No. 324.	No. 275.
Length of femur.....	985	910
" " tibia.....	810	698	
" " fibula.....	764	665	
" metatarsal II.....	375	315	
" " III.....	425	352	
" " IV.....	360	330	
Width of ankle joint.....			
Calcaneum and astragalus.....	241		
Total height of limb.....	2182	1980

Of greatest interest is the *first digit, or hallux*, not before described. Proximally (Fig. 4 a) its metatarsal fits in a shallow groove of the upper portion of the large metatarsal II. The shaft is entirely interrupted or composed of cartilage in the middle portion. Distally it is fitted to the rounded posterior shaft of Mt. II, demonstrating that this digit was directed inwards like the small hallux of *Apteryx* (Fig. 5). It possesses, however, a complete and functional phalanx and claw, which undoubtedly were of service in grasping.

The digits II, III, IV, with phalanges numbering 3, 4, and 5, respectively, are well shown in the photographs (Figs. 4, 4 a). The lower row of tarsals is represented by two bony elements only, probably tarsalia 3 and 4.

The upper tarsals, astragalus and calcaneum are closely conjoined if not actually co-ossified.

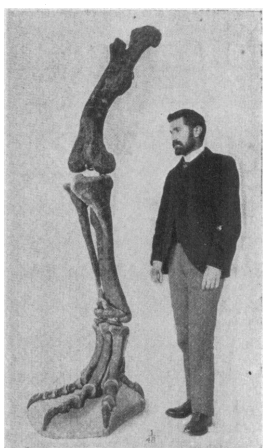


Fig. 2. Carnivorous Dinosaur, No. 290. Same Limb as Fig. 1, C, showing proportions to human stature (Dr. J. L. W.). $\frac{1}{3}$ nat. size.



Fig. 3. Right Hind Limb of Carnivorous Dinosaur, No. 290. Oblique internal view. $\frac{1}{16}$ nat. size.

The tibia forms the entire back portion of the ankle joint, the fibula lying in front of it; this bone is further distinguished by its curved shaft, and powerful muscular crest projecting towards the fibula at its upper third. There is a very prominent cnemial crest, which has a deep groove upon its outer side towards the fibula; this groove is entirely concealed from the front. This bone is very different from that assigned to *Megalosaurus* by Owen.¹

The fibula has a slender, subrounded shaft, but expands proximally and distally upon the tibial side.

The femur is distinguished by its marked curvature and well-rounded head, by the laterally compressed and inferiorly placed great trochanter, by an internal trochanter much more elevated than in the Iguanodontia, and by a large rugose area on the inferior front face of the shaft above the internal condyle. The inner trochanter is broken off in the smaller femur, No. 275.

¹ Fossil Reptilia of the Wealden and Purbeck Formations, Pt. III, 1857, p. 18, Tab. lx.

2. HIND LIMBS OF CETIOSAURS.

FIGURE I.

The *smaller* of these limbs (Fig. 1, A, No. 251) was fortunately found nearly complete and in position, all parts being preserved excepting the head of the femur. It was removed and worked out with the greatest care by Mr. Granger. There is thus absolutely no doubt about the position of the phalanges.

This limb is of a type distinct from the larger one, which is undoubtedly a *Brontosaurus*. We should unhesitatingly refer it to *Diplodocus*, were it not that the fourth trochanter has a more elevated position than in the *Diplodocus* femur recently described by the writer,¹ and that the pes differs from the pes of *Diplodocus* figured by Marsh ('96, Plate 28). None the less it is a *long-limbed type*, and this we believe to be a characteristic distinction of *Diplodocus*. It has the following characters:

1. Tibia and fibula very long and slender.
2. Femur long with relatively slender shaft.
3. Metatarsals I and II as in *Brontosaurus*.
4. Metatarsal III much more slender than in *Brontosaurus*.
5. Metatarsal IV still more slender, two osseous phalanges.
6. Metatarsal V more slender, no osseous phalanges.

This limb may prove, therefore, to represent merely a form of *Brontosaurus* distinct specifically from *B. excelsus*. But, in spite of the exceptions noted above, the probabilities are that it belongs to *Diplodocus*, for this animal is abundantly represented in the Bone Cabin Quarry by parts of several series of caudal vertebræ, besides pelvic and other bones.

Measurements.

	No. 251.	No. 309.	No. 353.
Total height of limb.....	e 2920		3040
Femur, height.....	e 1430		1640
Femur, circumference below tr. 4.....	560		e 730
Tibia, length.....	1060	1080	
Tibia, circumference.....	390		e 480
Fibula, length.....	1120	1130	
Astragalus, width of.....	227	280	
Pes, width of proximal metatarsal surfaces,	410	445	

The circumferences of the various shafts are very important

¹ Osborn, "A Skeleton of *Diplodocus*." *Mem. Am. Mus. Nat. Hist.*, I, Pt. IV, 1899.

when compared with the total lengths. In each case the least circumference is taken. The total height of the limbs is measured *as mounted*—that is, including the curves.

The larger limb (*Brontosaurus*) is 10 feet high. The smaller limb (? *Diplodocus*) is 9 feet 7 inches high.

The *larger* limb (Fig. 1, B, Nos. 309, 353) is of the true *Bronto-*

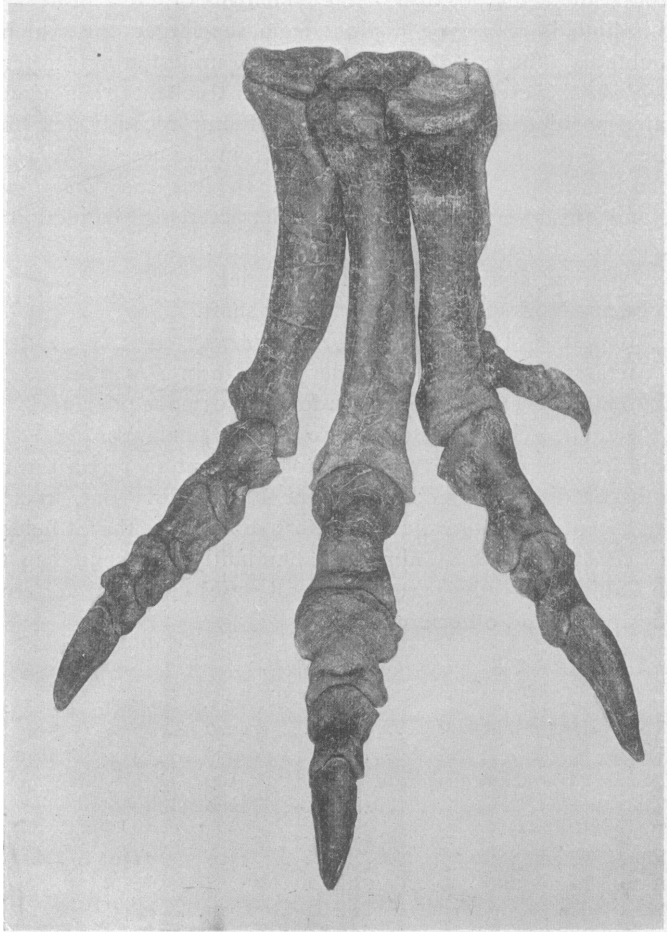


Fig. 4. Right Hind Foot of Carnivorous Dinosaur, probably *Allosaurus* (No. 324, same specimen as Fig. 1, D¹). Front view. $\frac{1}{4}$ nat. size.

saurus type. All of the bones of the lower leg and pes belong to one individual, excepting the terminal claws I and II. The femur was found at some distance and is arbitrarily associated. The phalanges are complete and osseous upon D. I, II, III.

This and the foregoing specimen prove conclusively that Marsh was in error in restoring a complete series of bony phalanges and

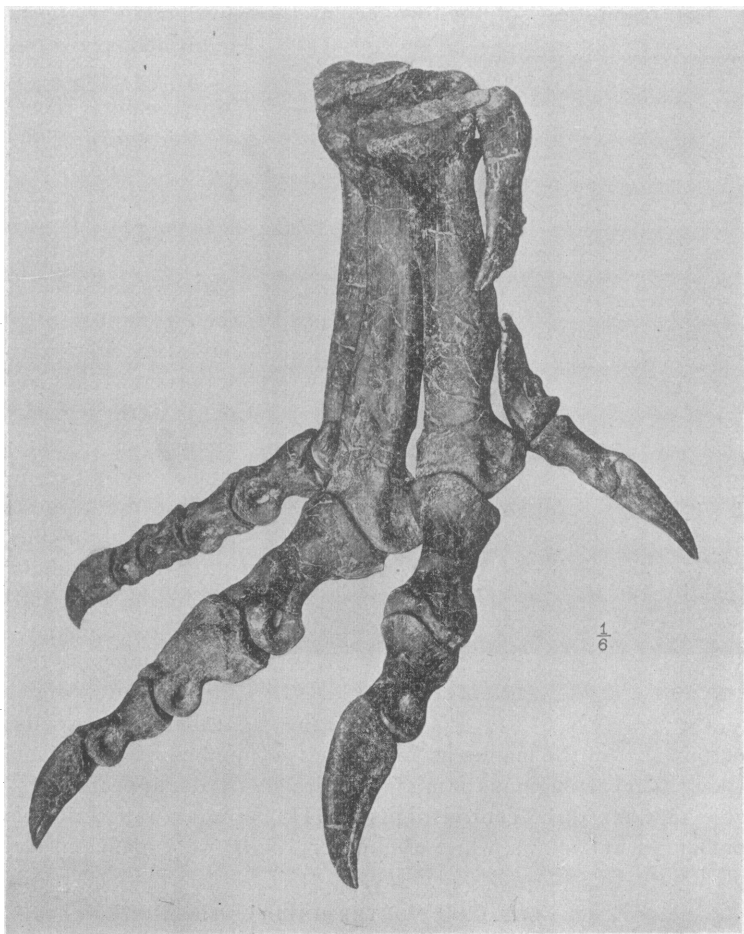


Fig. 4a. Right Hind Foot of Carnivorous Dinosaur, probably *Allosaurus* (No. 324, same specimen as Fig. 1, D.) Oblique side view. $\frac{1}{6}$ nat. size.

claws upon digits IV and V. The phalanges upon digits IV and V were cartilaginous or incomplete; these outer digits functioned only in supporting the foot pad. Every known Sauropod pes shows the same deficiency upon the outer side.

3. FORE FEET OF CETIOSAURS.

FIGURES 6, 7.

Two restorations of the fore feet of the Sauropoda have been

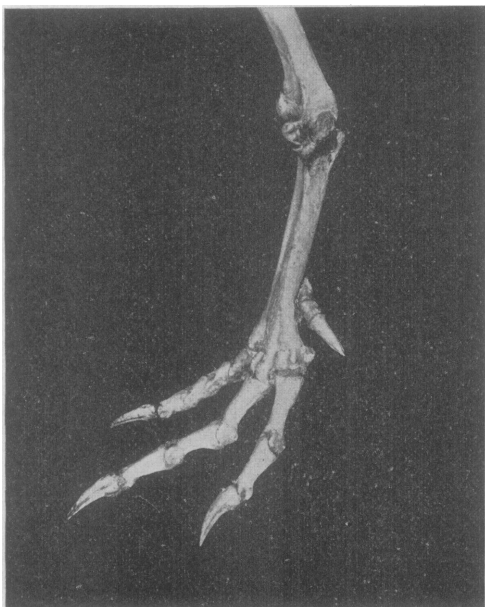


Fig. 5. *Aptyryx*. Internal view of right pes.

published by the late Professor Marsh, namely those of *Morosaurus* ('96, Plate 38) and *Brontosaurus* (*op. cit.*, Plate 42). It appears probable that both are incorrect; the error apparently has arisen, first, from supplying all the digits with a complete series of phalanges; second, from placing the largest phalanges upon the inner or 1st digit (as in the pes) and grading off the smaller phalanges to the 5th or outer digit.

It is now practically certain that in the manus as in the pes a number of phalanges were either cartilaginous or missing entirely. It also appears probable that the three central digits II, III, IV bore a full series of phalanges and claws, while the outer digits were deficient in phalanges.

FORE FEET OF UNDETERMINED CETIOSAUR.

The strongest evidence comes from the two fore feet of one individual (No. 332), one of which was found with all its parts in

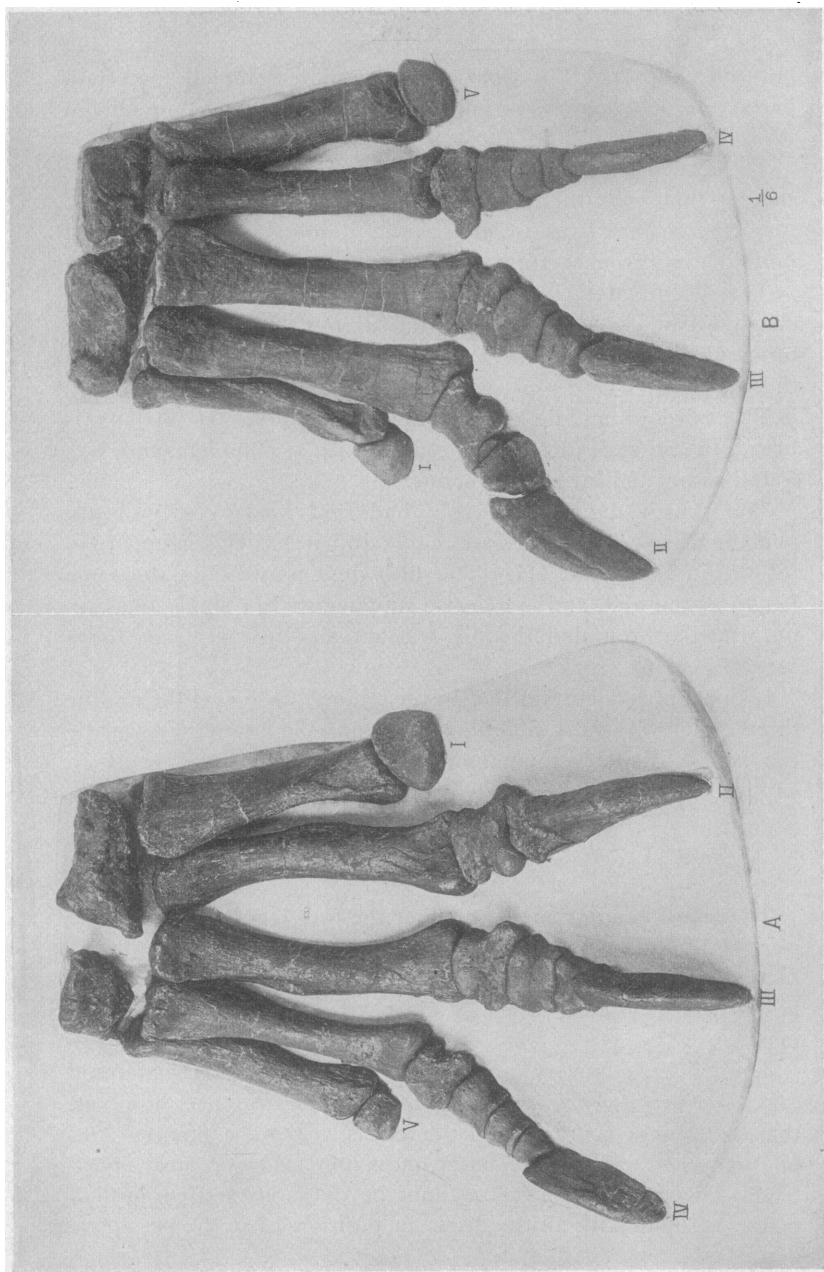


Fig. 6. Right (A) and Left (B) Fore Feet of Herbivorous Dinosaur, No. 332. At present indeterminate. $\frac{1}{6}$ natural size.

position (Fig. 6). The right manus is more complete in certain parts, the left manus in others. The animal is possibly a *Morosaurus agilis*.

The Metacarpal of the first digit is much longer and more slender than in either the typical *Morosaurus* or *Brontosaurus*. A single phalanx was found near it, rounding off distally and quite distinct from the first phalanges of digits II, III, IV.

The second Metacarpal is still longer and is supplied with the characteristic broad phalanx 1, the narrow phalanx 2, and the terminal claw or phalanx 3. This digit is slightly heavier than the 3d.

The third or middle digit is the longest; the 1st phalanx is broad, the 2d and 3d are restored, the 4th is complete, and was found associated in the left manus.

The fourth digit presumably had four phalanges, but only phalanx 1 is preserved in each case; and it has the same broad form as in D. II and III. The fifth digit is of about the same length as the first, and is likewise supplied with a single phalanx unformed or rounded distally, without any distinct facet for a second phalanx.

It thus appears certain that in this animal (No. 332) the middle three digits were fully functional and provided with claws, while the lateral digits were incomplete distally and served only to support the weight of the body.

FORE FEET OF BRONTOSAURUS.

FIGURE 7.

The question now remains whether the fore feet of *Brontosaurus* were also similarly constructed upon a mesaxonic plan.

Marsh restored (*Brontosaurus*; *Morosaurus*) the manus like the pes with a complete series of claws, the largest being on the inside.

The evidence is very positive in the two feet here mounted that *there was a deficiency of phalanges*. The evidence, however, that the actual construction of the foot is as we have mounted and photographed it (Fig. 7), namely, mesaxonic, is by no means positive. The question, in fact, cannot be definitely settled until a manus is found with all the digits in position, as in the pes above described.

The large fore foot (No. 268) was found with the metacarpals in position, and the phalanges scattered. The two terminal claws of digits III, IV, were not found with this foot, but some distance from it. Phalanges 2, 3, 4, of digit IV are restored in plaster. The foot is therefore nearly but not quite complete.

The broad 1st metacarpal has no distinct distal articular facet, such as are observed upon digits II, III, IV, and it seems probable

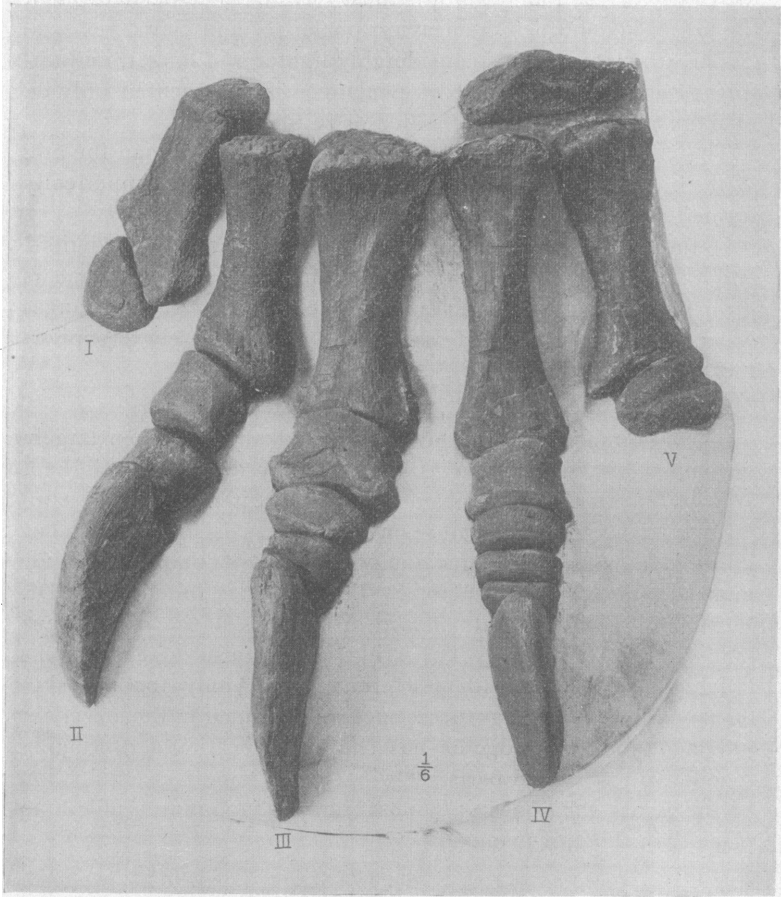


Fig. 7. Left Fore Foot of Large *Brontosaurus*, No. 268. The position of the phalanges is somewhat conjectural. $\frac{1}{6}$ nat. size.

that we are correct in associating with it the short phalanx with an imperfectly rounded distal extremity.

The 2d metacarpal is very powerful, with a heavy rounded shaft and distinct distal articulation, from which three phalanges extend, the terminal a heavy claw, if our placing is correct.

The 3d digit affords the strongest support for the mesaxonic hypothesis, for it is by far the largest metacarpal, and is obviously the centre of the foot. With it must have been associated (as in the present mounting) the heaviest phalanges and claw.

The 4th metacarpal is considerably lighter and longer, and unfortunately its complement of phalanges is represented only by phalanx 1, the others being added or restored.

The 5th metacarpal is stout but slightly shorter than the 4th. With it was apparently associated the remaining imperfectly formed phalanx 1, which was found with this foot.

If these two imperfect phalanges are not placed upon digits I and V, it is very difficult to place them at all. It thus appears probable that digits I and V were deficient in all the phalanges except the first or first and second, and served merely to support the weight of the animal.

The admirable methods in the field, which have been largely developed by Dr. J. L. Wortman, whereby every piece is kept and transported in the position in which it was found, supplemented by admirable museum methods, will soon render our knowledge of the Dinosaurs not only far more complete, but far more accurate than ever before. The writer is indebted to Dr. Wortman for many hints in the discussion of the carnivorous limbs above described. The writer desires also to express his indebtedness to Mr. Adam Hermann, not only for the skill displayed in mounting these specimens, but for the excellent judgment and knowledge he has shown in locating and bringing together the scattered parts. Owing to the imperfect ossification of the joints, the bones of Dinosaurs are much more difficult to place than those of mammals.