

Article XIII. — FORE AND HIND LIMBS OF SAUROPODA FROM THE BONE CABIN QUARRY.

DINOSAUR CONTRIBUTION No. 6.

By HENRY F. OSBORN and WALTER GRANGER.

During the early months of 1900 the large collection of limb bones from the Bone Cabin Quarry was measured and compared by Mr. Granger in preparation for this paper. Measurements are chiefly of value in determining *proportions*; size, of course, constantly increasing with age. Further studies during the present year enable us to establish the following points:

1. The proportions and relations of the radius and ulna in the Sauropoda are remotely analogous or "parallel" with those of the Proboscidea, owing to the marked extension of the ulna, the similar weight, and the perfected quadrupedal progression in the two types.

2. The chief characters of the fore and hind limbs and of the upper part of the manus of *Diplodocus*.

The conclusion reached provisionally by Osborn,¹ that *Diplodocus* was a distinctively long-limbed type, is abundantly confirmed. The bones of the fore and hind limbs of *Diplodocus* can, in fact, be readily identified by their relative length and slenderness as compared with those of *Morosaurus* and *Brontosaurus* (see Fig. 6).

3. The carpus in the Sauropoda includes the probable coösfication of the radiale and intermedium into a "scapho-lunar"; also a large ulnare, and from two to three small osseous carpalia in the distal row.

In his numerous and valuable contributions to this group the late Professor Marsh left the homologies of the carpals undetermined; his figures (of the *Morosaurus* and *Brontosaurus* fore limb) do not indicate the anterior crossing of the radius and ulna; he also left the limb structure of *Diplodocus* practically unknown.

In general, the limbs of the three contemporary Sauropoda of the Como district can be distinguished as follows:

¹ Fore and Hind Limbs of Carnivorous and Herbivorous Dinosaurs from the Jurassic of Wyoming. Bull. Amer. Mus. Nat. Hist., Vol. XII, 1899, pp. 161-172.

Morosaurus, scapula relatively short, spreading superiorly; scapulo-coracoid plate relatively broad; limbs intermediate in length; tibia, fibula and metapodials relatively slender.

Brontosaurus, scapula long, narrow superiorly; scapulo-coracoid plate relatively narrow; limbs long and heavy; tibia, fibula and metapodials relatively robust.

Diplodocus, scapula expanding superiorly with intermediate scapulo-coracoid extension, limbs long and relatively slender, tibia and fibula, radius and ulna, and metacarpals especially elongated.

Camarasaurus, thus far found only in the Colorado Jurassic, is not related to *Brontosaurus*, as Osborn formerly supposed, but is a *Morosaurus* of immense size. The type skeleton will shortly be described.

The distinctive scapulo-coracoid characters are clearly brought out in the accompanying figures (Fig. 1, A, B, C).



Fig. 1. Scapulo-coracoid of: A. *Morosaurus*, Amer. Mus. Coll. No. 332; B. *Diplodocus*, Amer. Mus. Coll. No. 221; C. *Brontosaurus*, Amer. Mus. Coll. No. 222. All from the Bone Cabin Quarry. $\frac{1}{4}$ nat. size.

FORE LIMB OF DIPLODOCUS, No. 594.

In the portion of the quarry explored during 1900, within an area of about 20 feet, were found a scapula and a coracoid which

EXPLANATION OF PLATE XXVI.

Fig. 1.—Map of southeastern Wyoming, showing exposures of Jurassic. The shaded area represents the accompanying map, Fig. 2. This map is a reproduction of Knight's (see page 189).

Fig. 2.—Map as indicated on Figure 1, showing position of quarries and fossil localities on Medicine and Como anticlines; also positions of sections made through the Jurassic, as follows:

A-B, section of Jurassic on Plate XXVII, Fig. 3.

C-D, section of Jurassic on Plate XXVII, Fig. 1.

E-F, section of Jurassic on Plate XXVII, Fig. 2.

L-H, section across Medicine and Como anticlines, Plate XXVI, Fig. 3.

16, quarry of the American Museum (Dinosaur).

13, Marsh's *Stegosaurus* quarry.

12, quarry in bed No. 13, author unknown.

10, 11, 14, 15, quarries made by Marsh.

* Quarries of American Museum.

Fig. 3.—Ideal section across Medicine and Como anticlines, as the strata would have appeared had no erosion taken place.

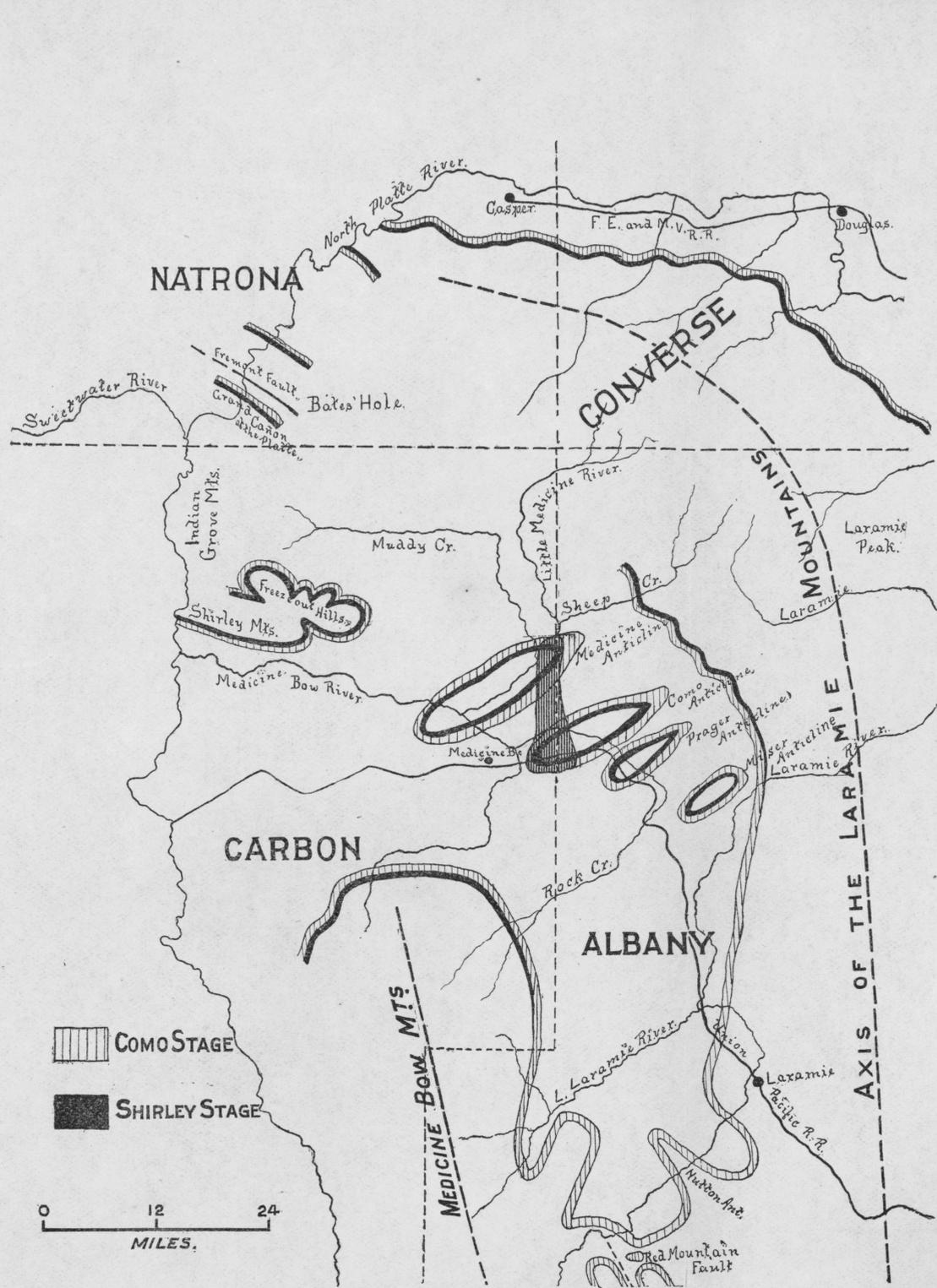


FIG. 1.

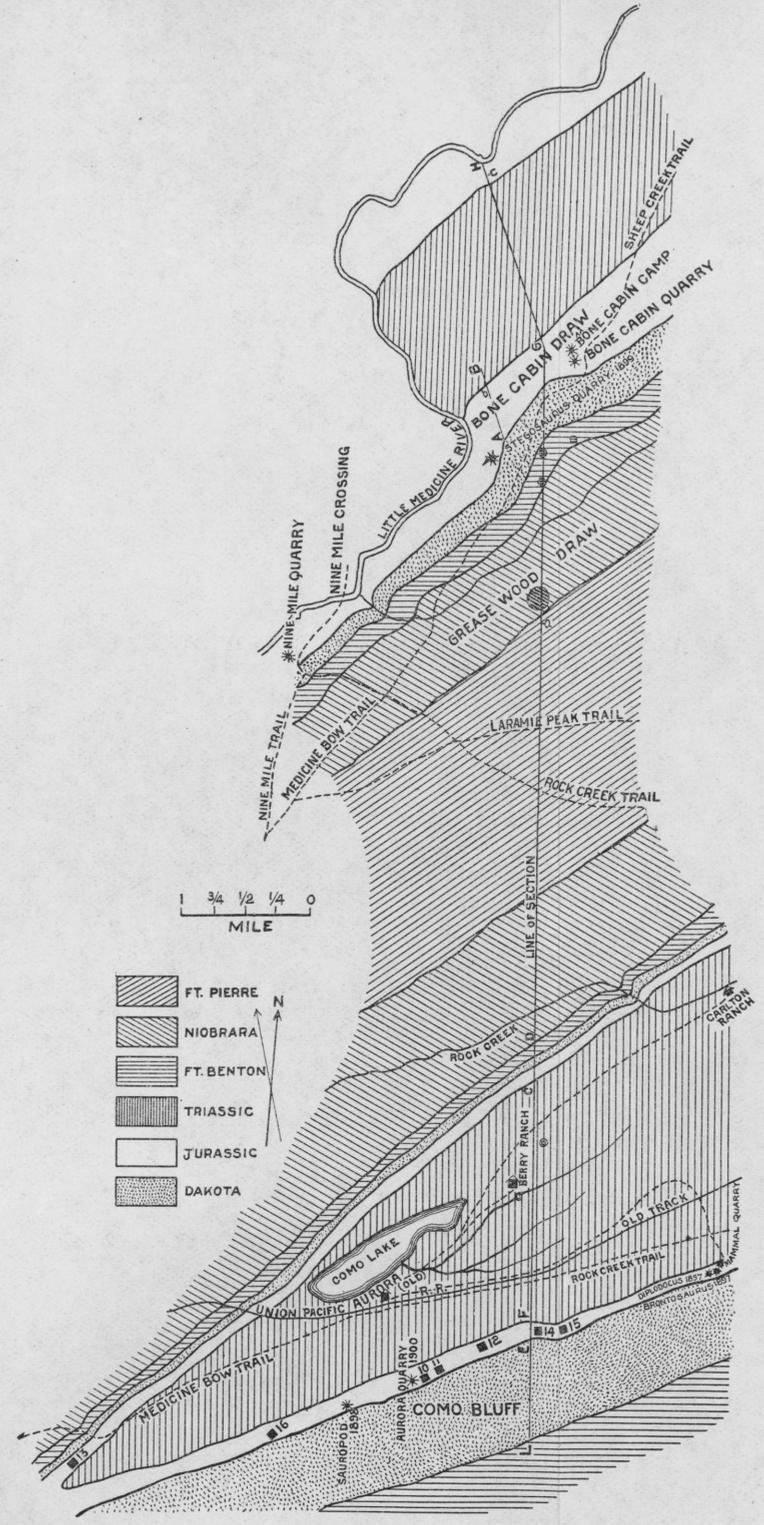


FIG. 2.

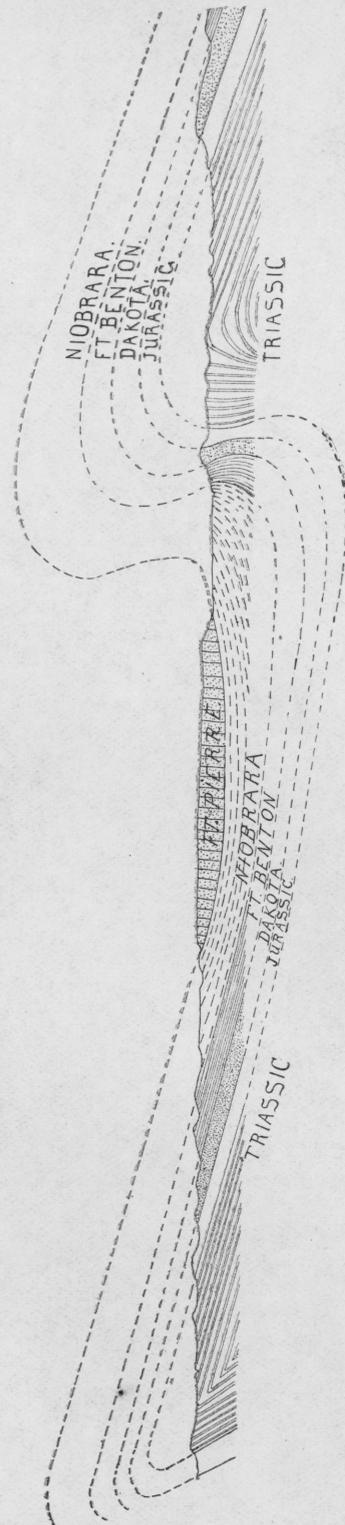


FIG. 3.

EXPLANATION OF PLATE XXVII.

Fig. 1.—Jurassic section across Carleton ridge, north side of Como anticline ; C-D on Plate XXVI, Fig. 2.

Fig. 2.—Jurassic section across Como Bluff, south side of Como anticline ; E-F on Pl. XXVI, Fig. 2.

Fig. 3.—Jurassic section across Bone Cabin Draw, south side of Medicine anticline ; A-B on Pl. XXVI, Fig. 2.

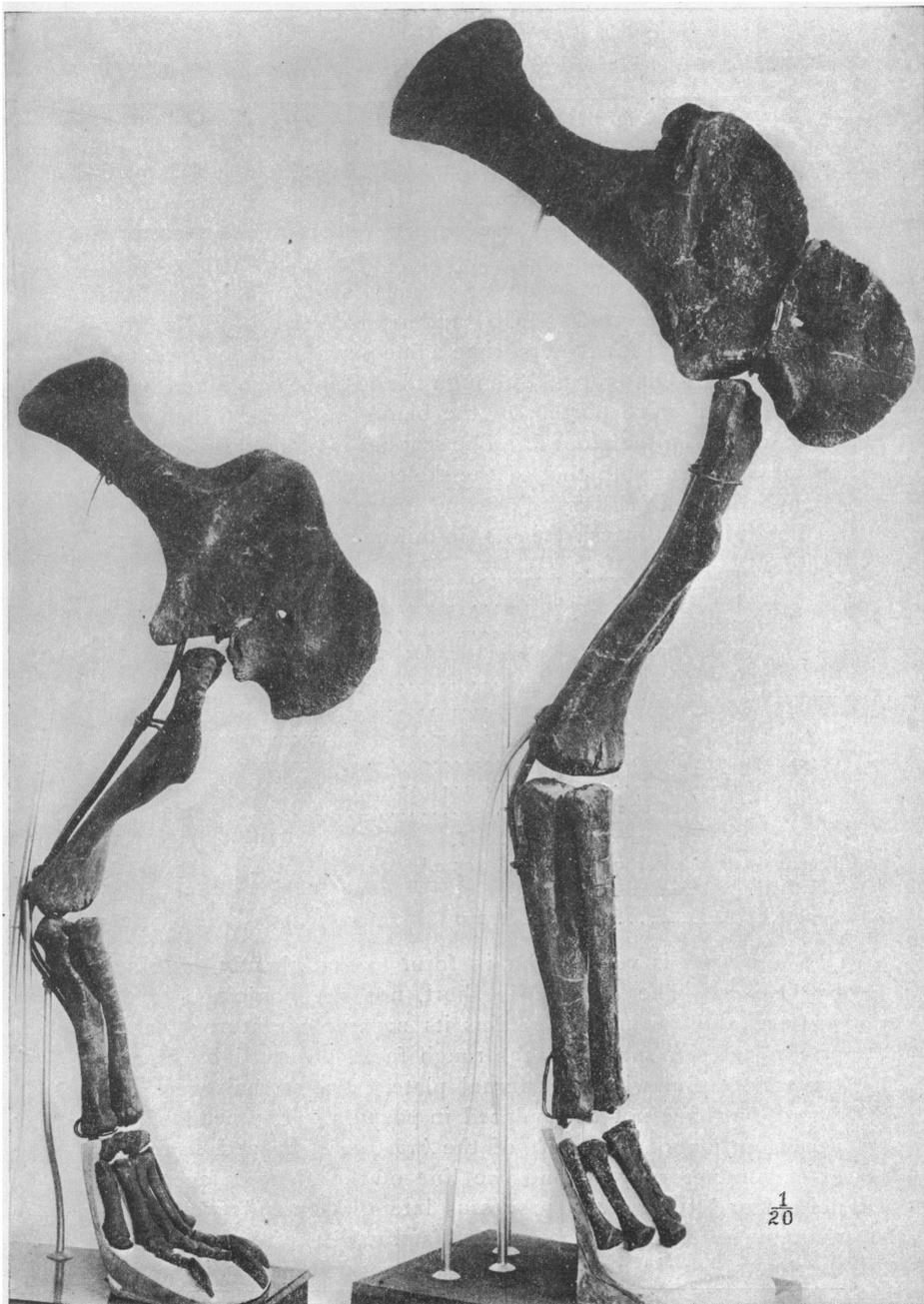


Fig. 2. Fore limbs of *Morosaurus* Amer. Mus. Coll. No. 332, and of *Diplodocus* Amer. Mus. Coll. No. 594.
1/20 nat. size.

fits closely to it, a humerus, ulna and radius lying together on the right side associated with a humerus of the left side; five metacarpals at some little distance associated with metatarsals and a hind limb of *Diplodocus*. These bones were considerably scattered and assigned separate field numbers, but they belong in all probability to one individual of medium size. They have been prepared and mounted (Fig. 2) under the direction of Mr. Hermann and afford for the first time a fine example of the fore limb of this stilted Dinosaur. Although the scapula is inclined backwards, the upward portion of the blade is 10 feet 6 inches, or 3195 mm. from the ground. The scapula is practically identical in measurement with that of the skeleton described in Osborn's Memoir upon *Diplodocus*.

The principal measurements (in millimeters) are as follows :

Scapula, length.....					1285
" greatest breadth.....					500
Scapulo-coracoid conjoined.....					1650
Coracoid, breadth from glenoid border.....					425
Humerus, length.....					1080
" least circumference.....					470
Ulna, length.....					870
" least circumference.....					285
Radius, length.....					840
" least circumference.....					255
Metacarpals.....	I,	II,	III,	IV,	V.
Proximal facets, antero-posterior....	105 e. ¹	113	76 e.	63	85
" " transverse.....	51	64	83	85	43
Length.....	260	290	315	290	285

The *scapula* is very similar in form to that already described by Osborn. The *coracoid* is short, not yet conjoined to the scapula, and fortunately retains its natural curvature; on its postero-inferior surface is the rough facet, observed by Marsh, for articulation with the sternal plate. The sternals were also found, but have not been placed in position. The head of the upper portion of the shaft of the *humerus* is crushed, so that it extends unnaturally beyond the line of the glenoid facet; the deltoid or lateral crest (*processus lateralis*) extends well down upon the outer side of the shaft; distally the shaft terminates on the outer side in a prominent radial condyle which is readily

¹ e = estimated.

distinguished by the deep groove upon its anterior face; the lower articulation of the humerus indicates that the limb was not greatly flexed at the elbow in the standing position, a fact in keeping with the great weight of the anterior portion of the body. In an uncrushed humerus the ulnar condyle is also well defined; the ulna, however, extends around and behind the radius.

Proximally the *radius* articulates on the anterior outer side of the humerus with the radial condyle; it fits in the broad anterior groove of the *ulna*, which element supports the entire posterior as well as the inner portion of the humerus, while the radius supports the anterior and outer portion only. The analogy of these elements with the fore limb of the elephant is obvious, because in both the proboscidian and dinosaurian the ulna is a stouter element than the radius, as shown by reference to the respective circumferences of the shafts, namely:

<i>Diplodocus</i> .	No. 594	No. 588
	mm.	mm.
Ulna	= 285	290
Radius	= 255	265

The shaft of the radius also crosses that of the ulna

completely, as in the elephant and other ungulate mammals. On the posterior face of the radius, in its upper fourth, is a stout tuberosity for the ligaments and muscles connecting this bone with the ulna. Distally, the radius and ulna present approximately equal facets for the carpals.

Two *carpals* were found entirely out of position, making it difficult to determine their homologies; the larger of these apparently belongs to the opposite side and, as the evidence is conflicting, reference must be made to another fore limb, No. 588, described below.

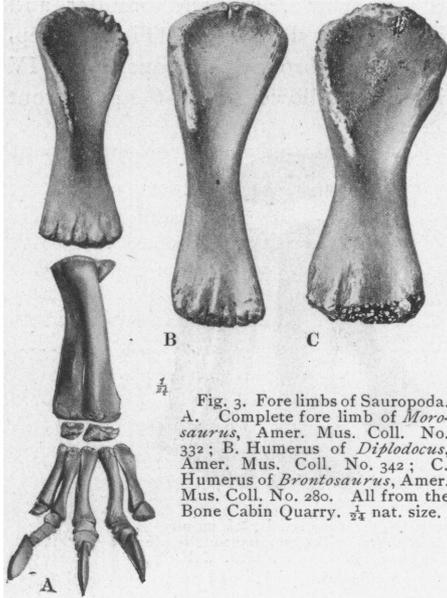


Fig. 3. Fore limbs of Sauropoda. A. Complete fore limb of *Morosaurus*, Amer. Mus. Coll. No. 332; B. Humerus of *Diplodocus*, Amer. Mus. Coll. No. 342; C. Humerus of *Brontosaurus*, Amer. Mus. Coll. No. 280. All from the Bone Cabin Quarry. $\frac{1}{4}$ nat. size.

There is little question that the *metacarpals* belong to this fore limb, although they were found mingled with metatarsals of a hind limb of corresponding size. By comparison with several series of metatarsals belonging to *Morosaurus* and *Brontosaurus* in the American Museum Collection, their homologies can be determined. Examination of the proximal facets for articulation with the carpals, shows that Mtc. I is deep and relatively narrow; Mtc. II is somewhat deeper and broader, and increases in size; Mtc. III is less deep, but much broader in front; Mtc. IV is still shallower, but of equal front

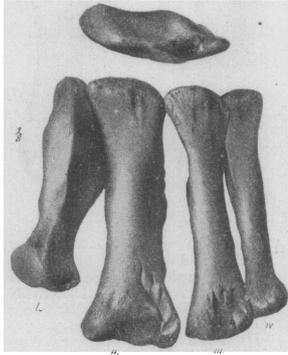


Fig. 4. Metacarpals, left manus, of *Diplodocus*, with supposed radiale plus intermedium. Amer. Mus. Coll. No. 588. $\frac{1}{2}$ nat. size.

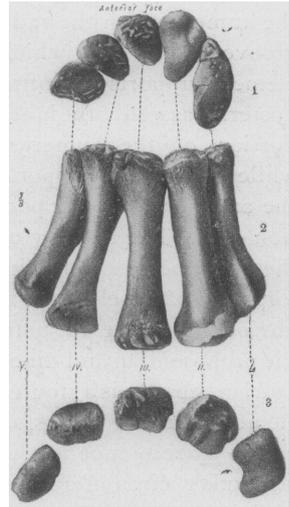


Fig. 5. Metacarpals of right manus of undetermined Sauropod, probably *Morosaurus*.

1. Proximal view of metacarpals.
2. Anterior view of metacarpals.
3. Distal view of metacarpals.
Amer. Mus. Coll. No. 462. $\frac{1}{2}$ nat. size.

breadth; Mtc. V, like Mtc. I, is deep, but narrow in front. The measurements given above are much affected by crushing, but indicate that Mtc. III is the largest and stoutest of the metacarpals, while Mtc. I and Mtc. V are relatively short.

FORE LIMB OF DIPLODOCUS, No. 588.

The above characters are supplemented and confirmed by those of another fore limb (No. 588), consisting of ulna, radius, supposed scapho-lunar, supposed cuneiform, metacarpals I, II, III, IV, and a terminal phalanx. The metacarpals correspond approximately with those figured by Marsh.

Measurements.

	mm.
Radius, length.....	870
“ least circumference.....	265
Ulna, length.....	910
“ least circumference.....	290
Supposed scapho-lunar, transverse.....	151
Metacarpal I, length (vertically crushed).....	235
“ II, “	280
“ III, length.....	280
“ IV, “	265
Terminal phalanx (claw).....	200

Carpals.—There can be little question as to the correctness of the association of these bones since they were found close together, and near by was a long series of *Diplodocus* caudals. Beneath the radius was found a large flattened carpal which from its connection with both radius and ulna is believed to represent a conjoined radiale and intermedium or scapho-lunar bone; this bone is much thicker behind than in front; it has a large radial facet, slightly concave, and a smaller oblique ulnar facet; inferiorly there is a single convexity with ill-defined areas for the cartilaginous trapezium, trapezoid and magnum; the cuneiform in this specimen is crushed beyond recognition; there is a small ossicle which may represent the unciform or one of the other carpalia of the second row.

FORE LIMB OF DIPLODOCUS, No. 380.

This generic reference is somewhat uncertain. The associated parts, consisting of radius, ulna, supposed scapho-lunar, cuneiform and two ossicles probably belong to a young *Diplodocus*. This limb is important, because it includes the terminal phalanges. The position of the latter, however, was not positively determined.

FORE LIMBS OF MOROSAURUS, No. 332.

FIGS. 1, 2, 3.

The right and left manus found with these limbs have already been described by Osborn (*l. c.*, p. 168); the elements were found in position and therefore yield important information, although the limb bones are much crushed. As in *Diplodocus*, the radius

crosses the ulna completely and rests upon the enlarged flattened scapho-lunar, which also presents a narrower face for the ulna ; as in *Diplodocus* this carpal is much thinner in front than behind.

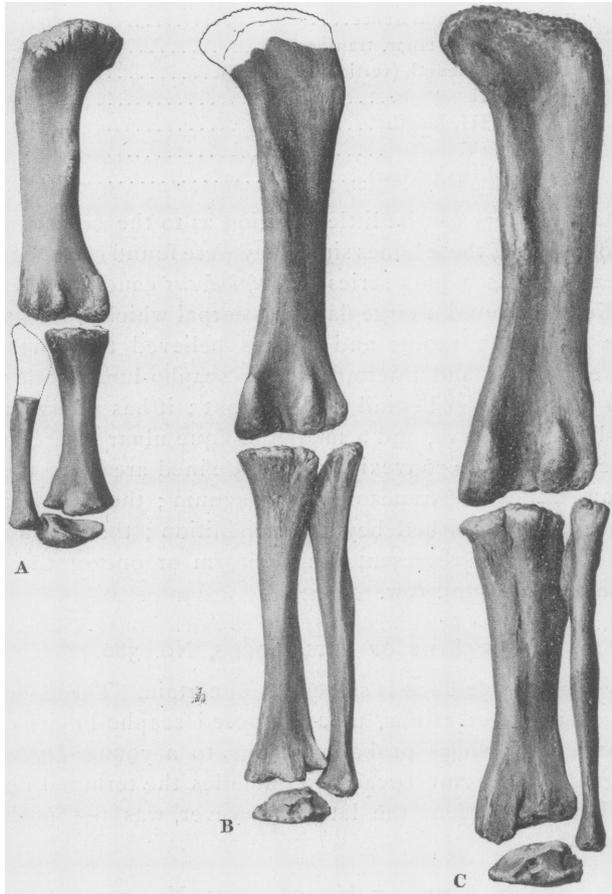


Fig. 6. Hind limbs of Sauropoda, posterior view. A. *Morosaurus*, Amer. Mus. Coll. No. 461; B. *Diplodocus*, Amer. Mus. Coll. No. 251; C. *Brontosaurus*, Amer. Mus. Coll. No. 353. All from the Bone Cabin Quarry. $\frac{1}{2}$ nat. size.

The cuneiform is a smaller bone, oval and flattened as seen from above, cyclindrical in anterior view, with an irregular projection on the lower face. The three median metacarpals are long and

slender, decidedly exceeding in length the outer pair, Mtc. I and Mtc. V. The doubt expressed in the earlier description of this manus as to the presence of terminal phalanges and a claw upon the first digit still remains; the proximal phalanx associated with Mtc. I indicates that the terminal phalanx was missing.

Measurements.

	<i>Morosaurus. Camarasaurus, type.</i>	
	mm.	mm.
Scapulo-coracoid, total length.....	910	2060
Coracoid, breadth opposite glenoid border.....	400	760
Humerus, total length.....	770	
Ulna, total length.....	560	
Radius, " "	550	
Scapho-lunar, transverse.....	120	
Mtc. I, length.....	205	
Mtc. II, "	250	
Mtc. III, "	250	
Mtc. IV, "	225	
Mtc. V, "	205	

CARPALS OF SUPPOSED MOROSAURUS, NO. 462.

These are especially interesting and valuable because of the absence of crushing, which gives the rounded or radial disposition of these bones as seen from above and in front (Fig. 5).

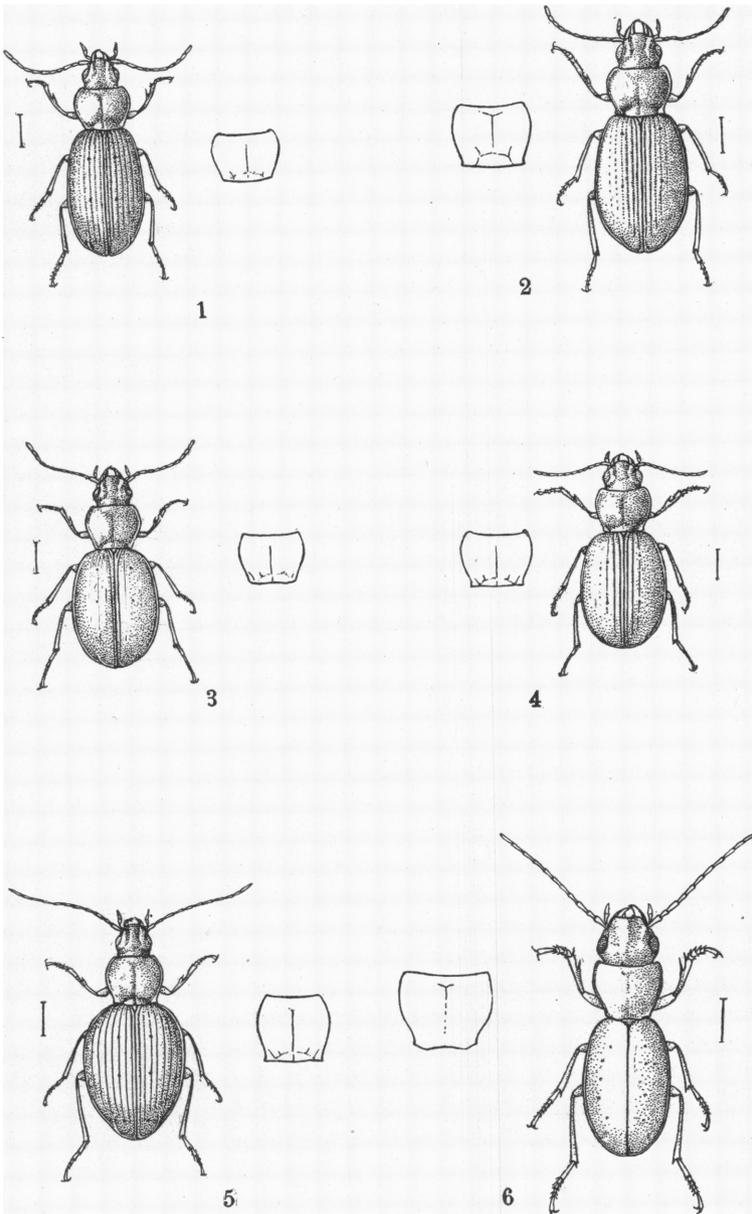
Measurements.

	mm.
Mtc. I, length.....	191
Mtc. II, "	218
Mtc. III, "	219
Mtc. IV, "	209
Mtc. V, "	186

The lateral metacarpals, I, V, have a more flattened section, the median metacarpals II, III, IV, present a more rounded section. Portions of the proximal and distal facets are well illustrated in the figure. As in *Diplodocus* the proximal facets decrease steadily in antero-posterior diameter as we pass from I to V. The posterior faces exhibit rugose areas for retractor tendons.

FORE LIMB OF BRONTOSAURUS, NO. 276.

In our collection are mounted two fore limbs of *Brontosaurus*, neither of which is complete. No. 276 is a young *Brontosaurus* carpus with which have been associated arbitrarily No. 318, ulna and radius, with extensive restoration. The carpals, as compared with those of *Diplodocus*; Nos. 594, 588, or 380, above described, are shorter and more robust. The manus of No. 268 has already been described (Osborn, 1899, p. 171). The metacarpals attain a very considerable length, but also acquire robust proportions, which enable us to readily distinguish them from those of *Diplodocus*; the placing of these elements is, however, somewhat conjectural. With the carpus is found the supposed scapho-lunar and three ossicles, which probably represent the carpals of the second row.



E. L. Hyatt.

- 1. *Trechus rubens*.
- 2. " *chalybeus*.
- 3. " *ovipennis*.

- 4. *Trechus hydropticus*.
- 5. " *carolinæ*.
- 6. " *barbaræ*.

