necessary to compare as well the effect of the rising of the isogeotherms in fusing stratified formations. This paper has already assumed such proportions that that subject may well be left in abeyance. Suffice it only to point out that the igneous rocks of most intrusive bodies are demonstrably exotic and have penetrated considerable distances vertically into their invaded formations which are *not* fused because of the rising of the isogeotherms. The fusion of rocks by this method cannot, therefore, of itself explain the formation of the actual chambers opened to human sight by secular denudation.

One must feel a certain hesitancy in taking a definite position on a matter of such fundamental importance; yet a categorical statement may bring into sharper relief the main conclusions to which the writer has come. Dikes, sheets, laccoliths, "bysmaliths," and perhaps a few of the smaller stock-like, plutonic bodies are conceived to be due to crustal displacement *permitting* intrusion; in the preparation of the greater and much more important subterranean magma chambers, marginal assimilation is believed to be a true cause, but, in the large, to be quite subordinate to magmatic overhead stoping, while bodily crustal displacement is in but indirect control inasmuch as it only localizes the areas where stoping is to form the chambers; and abyssal assimilation of stoped-out blocks, supplemented by the subordinate marginal assimilation, may be held responsible for the preparation or notable modification of magmas, whence come, through differentiation, most of the igneous rocks of the globe. The plateau-basalts would appear to represent the one widely distributed kind of magma not essentially affected by assimilation.

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Art. XXX.—*Brachiosaurus altithorax, the largest known Dinosaur;* by Elmer S. Riggs.

The writer some time since called attention* to a partial skeleton of an herbivorous dinosaur of unusual proportions obtained from the Jurassic of western Colorado. On account of the difficulty in distinguishing between a number of genera already referred to the Sauropoda, it did not then appear advisable to further complicate the problem by proposing a new generic name. But as the unique characters of this animal have become more and more evident it now seems desirable to give it a name, even though it ultimately be found to fall within one of the three or four uncertain genera proposed by Marsh and Cope. The term *Brachiosaurus altithorax* is therefore proposed in recognition of the great size and unusually long humerus of this specimen.

The generic characters are: humerus longer than femur; thorax unusually deep; centra of posterior thoracic vertebrae longer than wide; anterior caudal vertebrae amphicoelian and their diapophyses not vertically expanded; coracoid elongate in direction of scapular suture and having glenoid cavity facing antero-externally.

The specimen upon which this genus is based was collected by the Field Columbian Museum paleontological expedition of 1900, from the Grand River valley of western Colorado. Credit for its discovery is due to Mr. H. W. Menke of this Museum. The specimen consists of the humerus, coracoid, femur and ilium, all from the right side; the sacrum, seven thoracic and two caudal vertebrae, together with a number of ribs and other bones. The parts were, with the exception of the ribs, preserved in their relative positions, and as the specimen was isolated there can be no question that all belonged to one individual.

The distal end of the humerus was exposed, broken and displaced as surface fragments. Associated with its proximal end was the fairly well-preserved coracoid. Some fifteen feet farther along the hillside the sacrum and pelvic bones appeared lying with spines downward. Two partially weathered caudals were closely connected with the posterior end of the sacrum. The thoracic vertebrae stretched forward in an unbroken series with the ribs scattered on either side and more or less displaced. Up to this point there seemed every reason to hope that the whole anterior portion of the skeleton would be found. But at the end of the seventh presacral vertebra the thin clay

* Science, April 5, 1901.

stratum in which the bones were imbedded "pinched out" and was replaced by a thickening of the massive ledge of sandstone which overlaid it. The presence of pebbles at the base of this sandstone, as well as the uniform direction in which the ribs were displaced, showed that the anterior portion of the skeleton had been carried away by the action of a water-current before it had become thoroughly imbedded.

When the surface fragments of the humerus had been carefully collected and fitted to the portion still in position, that bone stretched out to such an unheard-of length that the writer was for the time convinced that it must be a crushed femur. This conclusion was given additional weight by finding, soon after, a well preserved femur of almost identical length. However, when removed from the matrix in the laboratory and the two compared, all doubt was removed by the characteristic form of the head of the humerus as well as the presence of a well defined deltoid crest.

The length of the humerus and femur, together with the immense size of the thorax, at once establishes the fact that this is the largest and longest-limbed of all known land animals, as well as the only dinosaur known to science in which the humerus is longer than the femur. Assuming that the lower fore-leg bones were proportionately long, we have to do with a creature whose shoulders were carried far above his hips and whose fore-legs played a more important part than the hind ones. Such proportions at once suggest arboreal food-habits. Instead of rearing upon the hind legs and supporting itself by means of a ponderous tail, as were the evident habits of *Brontosaurus* and *Diplodocus*, this animal may from sheer length of limb have been able to browse at will upon the foliage of tree and shrub. What were the proportions of the neck can only be conjectured; to be consistent with the proportions of body and limbs it must have been long and flexible. The short spines and the slight processes of the anterior caudals show that the tail was much reduced both in size and in length. This then was the giraffe among dinosaurs, just as *Claosaurus* was the kangaroo.

Description of Skeleton.

The humerus is somewhat crushed antero-posteriorly and twisted so that the head and distal end are brought into the same plane (fig. 1). The surface of the distal end has flaked away in the process of weathering to a firm chalcedony core. In proportions the humerus approaches more nearly to that of *Diplodocus* than to any other well-known American genus. The head is considerably expanded, forming a rounded prominence

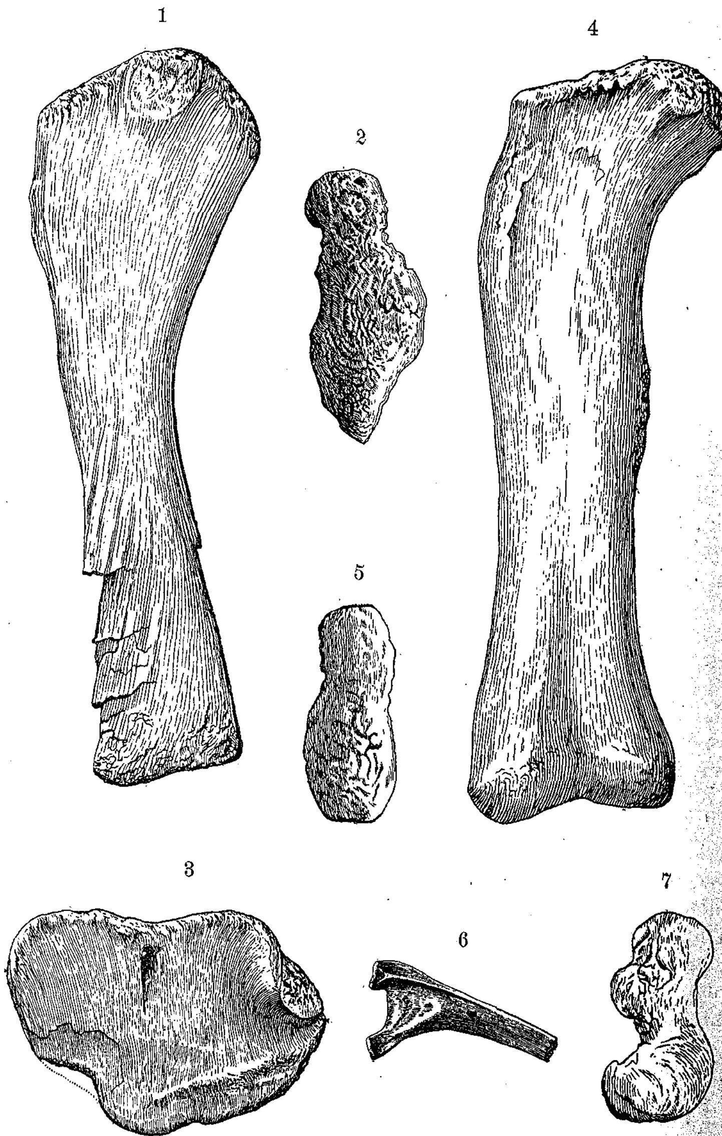
especially conspicuous in its posterior aspect (fig. 2). The great tuberosity is stout and rugose; its proximal surface meets the lateral margin of the shaft in a pronounced angle. This angle is not produced posteriorly to enclose a fossa as in *Morosaurus*. The mesial border below the head is drawn out into a rather thin margin, but roughened for muscular attachment. The deltoid crest is partially broken away, but was evidently prominent. Its base forms, with the anterior surface of the shaft, a broad and shallow concavity. Midway between the deltoid crest and the great tuberosity is a second rugose surface evidently for insertion of other shoulder muscles. The epicondylar ridge is entirely lost owing to the weathering to which the distal end has been subjected. The direction of the bone fiber on the lateral margin indicates that it was quite prominent. All traces of rugosity have likewise disappeared from the articular end, indicating that the humerus was probably some inches longer than it now appears.

The coracoid is a less massive bone than that of *Brontosaurus* (fig. 3). It is elongate antero-posteriorly, rounded below and straight at the coraco-scapular suture. The glenoid articular surface is directed outward as well as forward, a feature noted in no other Sauropod genus. The antero-inferior surface is thick and rugose near the glenoid cavity, from which it is separated by a narrow notch only. The inferior border becomes gradually thinner and its rugose character disappears midway between the glenoid cavity and the anterior scapular border. The marginal concavity noticeable in the specimen at this point is partially due to crushing from contact with the head of the humerus while in the matrix.

The femur is well preserved though somewhat compressed antero-posteriorly (fig. 4). Regardless of its great length this bone is quite as stout in the shaft as that of *Brontosaurus*, though the articular ends are proportionately less expanded. The lateral surface of the shaft has a prominent convexity one-fourth of its length below the great trochanter. A marked rugosity, possibly for the insertion of one of the gluteal muscles, extends downward from the great trochanter to this point. The fourth trochanter* forms a rugose prominence on the posterior margin of the shaft, as in all of the Sauropoda.

The presacral vertebrae are of the pronounced opisthocoelian type. They are distinguishable from other Sauropod genera by the unusual length of their centra. This, in the first presacral, is slightly greater than the breadth; it gradually increases in the succeeding members of the series until at the seventh it exceeds the breadth by one-fourth. The centra

* Dollo, Bull. d. Mus. d. Hist. Nat. d. Belgique, Mars, 1883. Osborn, Memoirs of Am. Mus. of Nat. Hist., Part V.



BRACHIOSAURUS ALTITHORAX.

Fig. 1. Posterior view of right humerus.
Fig. 2. Proximal end of same.
Fig. 3. Lateral view of coracoid.
Fig. 4. Anterior view of right femur.
Fig. 5. Proximal end of same.
Fig. 6. Posterior view of proximal end of a thoracic rib.
Fig. 7. Distal end of femur.

are deeply hollowed by lateral cavities. The whole character of their sculpturing tends toward a lightness bordering upon fragility. In this particular they are approached most nearly by the vertebrae of *Diplodocus*.

The sacrum is composed of four firmly coalesced vertebrae. Its most distinctive feature is its great breadth in comparison with its length. The measurement across the anterior end of the transverse processes is one-fourth greater than that of the posterior end and one-third greater than the type specimen of *Brontosaurus*. The first sacral rib arises from the anterior end of the centrum and is relatively unimportant. The second arises from the whole length of the centrum and is by far the strongest of the series. Its iliac articular surface is much expanded and marks the axial point in the sacrum. The third and fourth sacral ribs arise from the anterior half of their respective centra. As neither the sacral nor presacral vertebrae have yet been removed from the matrix, the description of their spinal elements will be deferred until a future publication.

The anterior caudal vertebrae are amphicoelian in form and relatively small in comparison with those of other Sauropoda. The anterior faces of the centra are more deeply concave than the posterior faces. Since the vertebrae were found lying upon their sides in close apposition with the sacrum, the marked posterior concavity can hardly be attributed to distortion. Unfortunately the spine in caudal I is not preserved. In caudal II the neural arch is as simple as in caudal VIII* of *Brontosaurus* and the spine is scarcely as long. There is no trace of lateral cavities in the centra, or of the broad vertical plates developed from the diapophyses in that genus. On the contrary, these lateral processes are simple, peg-like prominences slightly flattened vertically. The zygapophyses are imperfectly preserved in this specimen, but were apparently slight. The neural spine is short, stout, laterally compressed at the middle but expanded into a rugose knob at its extremity.

The unusual length of the ribs bears evidence of the immense thorax of this animal. In the mid-thoracic region they measure fully nine feet ($2{\cdot}745^{m}$) in length. The capitulum and tuberculum are almost equally developed and widely separated, to give the firm anchorage necessary to the great length of the ribs (fig. 5). In some instances the attachment is strengthened by a second tubercle on the posterior surface of the head similar to that figured by Marsh† in the cervical ribs of *Apatosaurus*. The anterior surface of the shaft below the head is perforated

* Caudal VII according to Marsh's restoration.
† The Dinosaurs of North America, p. 167.

by a large foramen which leads to an internal cavity in the shaft.

Measurements.

	M.
Humerus, length parallel to axis	2·04
" greatest breadth of proximal end	·65
" thickness of head antero-posteriorly	·28
" least breadth of middle of shaft	·24
" distance from angle of great tuberosity to upper margin of deltoid crest	·51
" length of deltoid crest	·24
Femur, length parallel to axis	2·03
" breadth of head and great trochanter	·59
" breadth at fourth trochanter	·43
" breadth at distal end	·58
" distance from head to upper margin of fourth trochanter	·78
Coracoid, greatest breadth	·87
" inferior border to scapular margin	·54
" glenoid margin to foramen	·34
Presacral I, length of centrum	·39
" I, breadth of centrum	·37
" VI, length of centrum	·43
" VI, breadth of centrum	·35
Sacrum, breadth at second transverse process	1·12
" breadth at fourth transverse process	·88
" length of the four centra	·975
Thoracic rib, length	2·745
" " breadth across capitulum and capitellum	·54
Caudal II, height over all	·60
" " transverse breadth of centrum	·32
" " length of centrum	·155
" " height of spine above centrum	·32
" " height of spine above zygapophyses	·18

Relationships.

There have been four genera referred to the Sauropoda whose validity may be more or less called in question. These are *Atlantosaurus* and *Apatosaurus* Marsh, and *Camarasaurus* and *Amphicoelias* Cope. Some of these genera are certainly valid, others probably synonyms. The fact that three of the four are based upon scattered parts of skeletons of which no two have enough in common to make correlation certain, complicates the problem. Added to this is the uncertainty as to whether the type specimens represent one individual or more than one.

The genus *Camarasaurus* has usually been regarded as valid and as representing an extreme Morosauroid type. This conclusion is borne out by the presence of four ankylosed vertebrae in the sacrum, the subquadrate form of the coracoid, the relatively short tibia, the Morosaur-like thoracic vertebrae and the expanded blade of the scapula. Unfortunately there are parts of two skeletons represented in the type of *C. supremus*, which accounts for Cope's describing it as having twenty or more thoracic vertebrae.

There are reasons both for and against considering *Atlantosaurus* as a synonym of *Camarasaurus*. The size of the type specimens is almost identical, as is shown by the length of their respective femora. The similarity between the sacra holds so far as the number and size of the vertebrae are concerned. The one difference in evidence lies between the hollow centra described by Marsh and the solid structure of the same as stoutly maintained by Cope. The ischium of *Camarasaurus* is not known; that figured by Marsh is far from the Morosauroid type. Neither is the pituitary canal described in the skull of *Atlantosaurus* consistent with the characters which one would expect in this genus. The writer was in error in stating in a recent note on this form* that the type specimens of both genera came from the same locality. That of *Camarasaurus* was collected near Cañon City, Colorado, while the type of *Atlantosaurus* came from near Morrison, one hundred miles farther north.

Apatosaurus is clearly distinguishable from *Camarasaurus* by the narrow blade of the scapula if not by the doubtfully constant character of three coalesced vertebrae in the sacrum. With *Atlantosaurus* the sacrum forms the sole basis of comparison. If it be conceded that the primitive dinosaurian sacrum is made up of three coalesced vertebrae, we may fairly assume that the *Apatosaur* type represents merely a young specimen of *Brontosaurus*. The size of the specimen, the straight blade of the scapula, the imperfectly ossified border of both scapula and coracoid and the character of the dorsal vertebrae all bear out this conclusion.

Amphicoelias is unique in the length and slenderness of its femur. The biconcave type of caudal centrum is common to a number of Sauropod genera; but that this type of vertebra persisted throughout the thoracic series may well be questioned. The closest affinities of this genus seem to be with *Diplodocus*.

In view of this complexity of uncertain relationships, little can be said of the affinities of *Brachiosaurus*. As the humerus in the most nearly allied genera is not known, the fore leg offers no basis of comparison other than the coracoid. This bone differs from that of the type *Camarasaurus supremus* in

* Field Columbian Mus. Pub. Geol. Ser., vol. i, No. 10.

its greater length, its subovate outline, the lateral direction of its glenoid surface and the proximity of the same to the surface for sternal articulation. The femur is considerably longer, but making allowance for distortion the two could not be generically distinguished. The sacra differ in the presence of small cavities' in the centra of this form. The anterior caudals of both are biconcave, their diapophyses similar, but the neural spine in *Camarasaurus,* according to Cope's measurement, is fully twice as long as that of this specimen. The essential difference in the vertebrae lies in the thoracic centra. Those of *Brachiosawus,* as has been pointed out, range from 39 to 43 centimeters in length and from 37 to 35 centimeters iu breadth. A " lumbar" vertebrae of *Camarascmrus* is described by Cope as being 17 centimeters in length and 42 in breadth. This difference alone would seem to warrant generic distinction. If *Atlantosaurus* be regarded as a valid genus, there is not enough in common between its type specimen and this one to determine their relationships. *Amphicoelias* need hardly be considered in this connection.

The further description of the sacral and presacral vertebrae of *Brachiosaurus* will be taken up in another paper. It is to be hoped that their removal from the matrix and careful study will establish the position of this genus.

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