

APPENDIX.

ART. XXXIV.—*Comparison of the Principal Forms of the Dinosauria of Europe and America*;* by Professor O. C. MARSH.

THE remains of Dinosaurian reptiles are very abundant in the Rocky Mountain region, especially in deposits of Jurassic age, and during the past ten years, the author has made extensive collections of these fossils, as a basis for investigating the entire group. The results of this work will be included in several volumes, two of which are now well advanced towards completion, and will soon be published by the United States Geological Survey.

In the study of these reptiles, it was necessary to examine the European forms, and the author has now seen nearly every known specimen of importance. The object of the present paper is to give, in few words, some of the more obvious results of a comparison between these forms and those of America which he has investigated.

With this purpose in view, it will not be necessary to discuss here the classification of the Dinosauria, their affinities, or their origin. These topics will be treated fully in the volumes in preparation. For the sake of convenience, however, the ordinal names proposed by the author, and now in general use, will be employed.

* Abstract of a paper read before Section C, of the British Association for the Advancement of Science, at the Bath Meeting, Sept. 8th, 1888.

SAUROPODA.

The great group which the author has called *Sauropoda*, and which is represented in America by at least three well-marked families, appears to be rare in Europe. Nearly all the remains hitherto discovered there have been found in England, and most of them, in a fragmentary condition. The skull is represented only by a single fragment of a lower jaw and various isolated teeth, and, although numerous portions of the skeleton are known, in but few cases have characteristic bones of the same individual been secured.

Quite a number of generic names have been proposed for the remains found in England, and several are still in use, but the absence of the skull, and the fact that most of the type specimens pertain to different parts of the skeleton, render it difficult, if not impossible, to determine the forms described.

In the large collections of *Sauropoda* secured by the author in America, which include the remains of more than one hundred individuals, both the skull and skeleton are well represented. On this material, his classification of three families, *Atlantosauridæ*, *Morosauridæ*, and *Diplodocidæ*, has been based. The *Pleurocelidæ*, also, appear to be distinct, but the remains at present known are less numerous and characteristic than those pertaining to the other divisions of this group.

In examining the European *Sauropoda* with some care, the author was soon impressed by three prominent features in the specimens investigated :

(1) The apparent absence of any characteristic remains of the *Atlantosauridæ*, which embrace the most gigantic of American forms.

(2) The comparative abundance of another family (*Cetiosauridæ*), nearly allied to the *Morosauridæ*, but, as a rule, less specialized.

(3) The absence, apparently, of all remains of the *Diplodocidæ*.

A number of isolated teeth, and a few vertebræ of one immature individual appeared to be closely related to the *Pleurocelidæ*, but this, for the present, must be left in doubt.

Among the American forms of *Sauropoda*, the skull is now comparatively well known in the principal families and genera. *Brontosaurus*, *Morosaurus*, and *Diplodocus*, typical of their respective families, are each represented by several skulls, some of which are nearly complete, and characteristic portions are known of the skulls of other genera.

The vertebræ, also, and especially the pelvic arch, afford distinctive characters. By the latter alone, the *Atlantosauridæ* and *Morosauridæ* may be readily distinguished. In the absence of the skull, this is a point of importance in a comparison of European with American forms.

In the *Atlantosauridæ*, the ischia are nearly straight, and when in position, extend downward and inward, meeting on the median line by a symphysis of the two ends, as in crocodiles. In the *Morosauridæ*, the ischia are twisted, and extend inward and backward, with the inner margins alone meeting each other on the median line, the ends being free.

All the ischia of *Sauropoda* known from Europe appear to be of the latter type, although proportionally broader and more massive than those of the corresponding American forms. The ilia and pubes associated with these ischia agree in their main features with those of the American genus *Morosaurus*, so that there can be little doubt that the same general form is represented in both countries.

A striking difference between the *Cetiosauridæ* and the allied American forms is that, in the former, the fore and hind limbs appear to be more nearly of the same length, indicating a more primitive or generalized type. Nearly all the American *Sauropoda*, indeed, show a higher degree of specialization than those of Europe, both in this feature and in some other respects.

The identity of any of the generic forms of European *Sauropoda* with those of America is at present doubtful. In one or two instances, it is impossible, from the remains now known, to separate closely allied forms from the two countries. Portions of one animal from the Wealden, referred by Mantell to *Pelorosaurus* under the name *P. Becklesii*,* are certainly very similar to some of the smaller forms of *Morosaurus*, especially in the proportions of the fore limbs which are unusually short. This fact would distinguish them at once from *Pelorosaurus*, and until the skull and more of the skeleton are known, they cannot be separated from *Morosaurus*, and should be known as *Morosaurus Becklesii*. During the examination of this specimen, which is in the collection of its discoverer, Mr. S. H. Beckles, of St. Leonards, England, the author found, attached to the humerus, portions of the osseous dermal covering, the first detected in the *Sauropoda*, and known only in the present specimen.

A dozen or more generic names have been proposed for the European forms of *Sauropoda*, and of these, *Cetiosaurus*.

* Morris' Catalogue of British Fossils, p. 351, 1854.

Owen, 1841, is the earliest, and must be retained. The remains on which this genus was based are from the Great Oolite, or Middle Jurassic. *Cardiodon*, Owen, 1845, is from nearly the same horizon, and there appears no evidence that the two forms are not identical. *Pelorosaurus*, Mantell, 1850, is from the Wealden, and may be distinct, but, at present, the proof is wanting. *Oplosaurus*, Gervais, 1852, also from the Wealden of England, cannot well be separated from *Pelorosaurus*. *Gigantosaurus*, Seeley, 1869, from the Kimmeridge of the Upper Jurassic, may prove to be different from the above, but the type specimens alone do not indicate it. *Bothriospondylus*, Owen, 1875, is also from the Kimmeridge, and, although the type specimen pertains to a very young, if not foetal individual, it seems to be distinct, and may be nearly allied to the American genus *Pleurocalus*. The author failed to find conclusive evidence in the type specimens themselves for the use of the other generic names proposed, namely: *Ornithopsis*, Seeley, 1870, from the Wealden; *Eucamerotus*, Hulke, 1872, Wealden; *Ischyrosaurus* (preoccupied), Hulke, 1874, Kimmeridge; and *Chondrosteosaurus*, Owen, 1876, Wealden.

Epyosaurus, Gervais, 1852; *Macrurosaurus*, Seeley, 1876; and *Dinodocus*, Owen, 1884, all represent forms from the Cretaceous, but their relations to each other cannot yet be determined.

Discoveries of more perfect specimens may establish the fact that the forms in the different geological horizons are distinct, but as long as the known remains are so isolated and fragmentary, this point must be left in doubt.

The European *Sauropoda* at present known are from deposits more recent than the Lias, and none have been found above the Upper Greensand. In America, this group apparently has representatives in the Trias, was very abundant in the Jurassic, but, so far as now known, did not extend into the Cretaceous.

STEGOSAURIA.

Another group of Dinosaurian reptiles, which the author has called the *Stegosauria*, from the typical American genus *Stegosaurus*, is well represented in European deposits. The remains already discovered are more numerous, and in better preservation, than those of the *Sauropoda*, and the number of distinct generic forms is much larger. The geological range, also, is greater, the oldest forms known being from the Lias, and the latest, from the Cretaceous.

These reptiles, although very large, were less gigantic in size than the *Sauropoda*, and were widely different from them in their most important features. Their nearest allies were the *Ornithopoda*, to which they were closely related.

All the known members of the group appear to have had an osseous dermal armor, more or less complete.

One of the best preserved specimens of the *Stegosauria* in Europe was described by Owen, in 1875, as *Omosaurus armatus*, and the type specimen is in the British Museum. It is from the Kimmeridge Clay (Upper Jurassic), of Swindon, England. The skull is wanting, but the more important parts of the skeleton are preserved. Various portions of the skeleton of several other individuals have also been found in England, but the skull and teeth still remain unknown.

A recent examination of these specimens by the author disclosed no characters of sufficient importance to separate them from the genus *Stegosaurus*, and, as the name *Omosaurus* is preoccupied, they should, for the present, at least, be referred to *Stegosaurus*. The discovery of the skull and the dermal armor may not unlikely prove them to be distinct, but the parts now available for comparison do not alone authorize their separation.

The type specimen of *Anthodon serrarius*, Owen, a fragment of a jaw from South Africa, and now in the British Museum, has teeth so very similar to the American forms of *Stegosaurus*, that, judging from these alone, it would naturally be referred to that genus. *Hylæosaurus*, Mantell, from the Wealden, has teeth of the same general type, but most of those referred to it, by Mantell and others, pertain to the *Sauropoda*. This genus, as well as *Polacanthus*, Hulke, from the same formation, *Acanthopholis*, Huxley, from the Cretaceous, and *Scelidosaurus*, Owen, from the Lias, are known from English specimens, but have not yet been found on the continent. No American forms of these genera have yet been discovered.

An interesting Cretaceous member of this group is the *Struthiosaurus*, Bunzel, 1871, apparently identical with *Danubiosaurus* of the same author, 1871, and *Crataëmus*, Seeley, 1881. It is from the Gosau formation of Austria. Although only fragments of the skeleton and dermal armor are known, some of these are very characteristic. One specimen of the latter, figured by Seeley, and regarded as a dermal plate, bearing a horn-like spine "exactly like the horn-core of an ox,"* is very similar in form to some problematical fossils from America, the exact horizon of which is in doubt.†

* Quarterly Journal of the Geological Society of London, vol. xxxvii, Plate XXVIII, fig. 4, 1881.

† Additional remains secured during the past season prove conclusively that some of these "horn-cores," if not all, were attached to the skull in pairs, and one specimen found in place has since been described by the author as *Ceratops montanus* (This Journal, vol. xxxvi, p. 477. December, 1888). It is from the Laramie formation of Montana. Others have been found in Colorado and in Wyoming. These are all much larger than the European specimens.

Palæoscincus, Leidy, 1856, from the Cretaceous, and *Priconodon* of the author, 1888, from the Potomac formation, are, perhaps, allied forms of the *Stegosauria*, but, until additional remains are found, their exact affinities cannot be determined. Apparently, the oldest known member of this group in America is the *Dystrophæus*, Cope, 1877, from the Trias of Arizona. In Europe, none have yet been found below the Jurassic. The *Euskelesaurus*, of Huxley, 1867, from the Trias of South Africa, is apparently a member of this group.

ORNITHOPODA.

The great group which the author has called the *Ornithopoda* is well represented in Europe by *Iguanodon* and its allies. The remarkable discoveries in the Wealden of Belgium, of a score or more skeletons of *Iguanodon*, have furnished material for an accurate study of the genus which they represent, and, indirectly, of the family. The genus *Iguanodon*, founded by Mantell in 1824, is now the best known of European forms, and need not here be discussed. *Hypsilophodon*, Huxley, 1870, from the Wealden, is likewise well represented, and its most important characters fully determined. The other genera of this group, among which are *Mochlodon*, Bunzel, 1871, *Vectisaurus*, Hulke, 1879, *Orthomerus*, Seeley, 1883, and *Sphenospondylus*, Seeley, 1883, are described from less perfect material, and further discoveries must decide their distinctive characters.

None of these genera are known from America, but allied forms are not wanting. A distinct family, the *Hadrosauridæ*, is especially abundant in the Cretaceous, and another, the *Camptosauridæ*, includes most of the Jurassic species. The latter are the American representatives of the *Iguanodontidæ*. The nearest allied genera are, apparently, *Iguanodon* and *Camptosaurus* for the larger forms, and *Hypsilophodon* and *Laosaurus* for those of small size. A few isolated teeth from each country suggest that more nearly related forms may at any time be brought to light.

Many generic names have been proposed for members of this group found in America and in Europe, but, in most cases, they are based on fragmentary, detached specimens, which must await future discoveries before they can be assigned to their true place in the order.

As a whole, the European *Ornithopoda* now known seem to be less specialized than those of America, but additional discoveries may modify this opinion. The geological range of this group, so far as known, is essentially the same on each continent, being confined to the Jurassic and Cretaceous.

There is some evidence, from footprints, at least, that, in America, the order was represented in the Trias.

THEROPODA.

The carnivorous *Dinosauria* have all been included, by the author, in one order, *Theropoda*, although there are two or three suborders quite distinct from each other. This great group is well represented both in Europe and America in the Trias, is especially abundant in the Jurassic, and diminishes in the Cretaceous, at the close of which, it apparently becomes extinct.

The typical genus is *Megalosaurus*, Buckland, 1824, the type of which was the first Dinosaurian reptile described. Although its remains are comparatively abundant in Europe, they have been found only in a fragmentary condition, and many important points in the structure of the skull and skeleton are still in doubt.

The oldest representatives of this group in Europe are *Thecodontosaurus*, Riley and Stutchbury, 1836, and *Plateosaurus*, von Meyer, 1837, both from the Trias. The former genus is from the lower horizon, near Bristol, England; the latter, from the Keuper of Germany. *Zanclodon*, Plieninger, 1846, is from the same horizon as *Plateosaurus*, and appears to be the same thing. *Massospondylus*, Owen, 1854, from the Trias of South Africa, is apparently a form allied to *Thecodontosaurus*. The nearest American genus is *Anchisaurus*, two species of which are known from the Connecticut River sandstone.

The most interesting member of the *Theropoda* known in Europe is the diminutive specimen described by Wagner, in 1861, as *Compsognathus longipes*. The type specimen, the only one known, is from the lithographic slates of Solenhofen, Bavaria, and is now preserved in the museum in Munich. Fortunately, the skull and nearly all the skeleton are preserved, and as it has been studied by many anatomists, its more important characters have been made out. It is regarded as representing a distinct suborder, and no nearly related forms are known in Europe. Its nearest ally is probably the specimen from Colorado, described by the author, in 1881, as *Hallopus victor*. This animal was about the same size as *Compsognathus*, and resembles it in some important features. It is probably from nearly the same geological horizon, but may be somewhat older. Each of these specimens appears to be unique, and until a careful comparison of the two is made, their relations to each other can only be conjectured.

The American representative of *Megalosaurus* is apparently *Allosaurus*, a genus established by the author, in 1877. The

type specimen is from Colorado, from a higher horizon in the Jurassic than that of *Megalosaurus*. Nearly every part of the skeleton of this genus is now known, and the more important portions have been described and figured by the author. *Creosaurus*, also from the Jurassic, is an allied form, and *Dryptosaurus*, from the Cretaceous, is, perhaps, also closely related. A very distinct form in the Jurassic is *Labrosaurus*, described by the author, in 1879. It is known from detached specimens only, but these, especially the jaws, edentulous in front, show it to represent a distinct family.

The most perfectly known of American *Theropoda*, and by far the most interesting, is the genus *Ceratosaurus*, founded by the author, in 1884. This is the representative of a very peculiar family, which differs in some important respects from all other known Dinosaurs. The skull and nearly all the various parts of the skeleton are known. When found, they were entire, and in the position in which the animal died. The skull and some of the more interesting parts of the skeleton have been figured by the author, and all will soon be fully described.

The skull bears a large elevated horn-core on the median line of the nasals. The cervical vertebræ differ in type from those of any other known reptiles, having the centra plano-concave. All behind the axis have the anterior end of each centrum perfectly flat, while the posterior end is deeply cupped. This genus, moreover, differs from all known Dinosaurs in having the elements of the pelvis (ilium, pubis, and ischium) coösfified, as in all existing birds. The metatarsals, also, are firmly united, as in birds. No representatives of the *Ceratosauridæ* are known in Europe.

In conclusion, it may safely be said that the four great groups of *Dinosauria* are each well represented both in Europe and America. Some of the families, also, of each order have representatives in the two regions, and future discoveries will doubtless prove that others occur in both.

No genera common to the two continents are known with certainty, although a few are so closely allied, that they cannot be distinguished from each other by the fragmentary specimens that now represent them. It must be remembered that the great majority of genera have been named from portions of skeletons, of which the skull was unknown, and until the latter is found, and definitely associated with the remains described, the characters and affinities of the genus can be only a matter of conjecture, more or less definite, in proportion to the perfection of the type specimens.

From Asia and Africa, also, a few remains of Dinosaurs have been described, and the latter continent promises to yield many interesting forms. Characteristic specimens, representing two genera, one apparently belonging to the *Stegosauria*, and one to the *Theropoda*, are already known from South Africa, from the region so rich in other extinct Reptilia.

From Australia, no *Dinosauria* have as yet been recorded, but they will undoubtedly be found there, as this great group of Reptiles were the dominant land animals of the earth, during all Mesozoic time.