Article IX.—ON THE DIVISIONS OF THE WHITE RIVER OR LOWER MIOCENE OF DAKOTA.

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The palæontological expedition from the American Museum of Natural History into the Miocene deposits of Dakota during the past summer was exceedingly fortunate in bringing to light a comparatively new fauna for this horizon. Notwithstanding the fact that these localities have been collected over for the past fifty years, and have yielded perhaps a greater number of individual specimens of fossil mammals than almost any other in North America, it has never apparently been suspected that the uppermost strata of this deposit contain a fauna, in many respects different from those of the middle and lower divisions.

Fossils have undoubtedly been collected in these upper beds and are not unknown in the rich collections from this horizon in our various museums, but no systematic attempt has to my knowledge ever been made to point out their more exact faunal characters. Especial attention was given to this part of the subject during our exploration of these bad-lands, and each specimen was carefully marked with reference to its exact position in the sedimentary mass. From these data I have found it possible to construct a catalogue of our collections showing the more important facts relating to the succession of genera and species during the time that this sediment was being laid down. The very considerable thickness of the deposit indicates of itself a long period of time, and it is not at all unnatural to suppose that important changes in the evolution of genera and species should have taken place, and be indicated by the fossils from the different levels of the sediment. That such is the case I will attempt to show in this present communication. Before passing to a discussion of this important problem, however, I will notice briefly the physical characters of the sediments themselves together with their divisions.

That part of the White River deposits to which our attention was especially directed is that which forms the main divide

between the White and Cheyenne Rivers in South Dakota in the vicinity of the Black Hills. This is the thickest portion of the White River sediment with which I am acquainted, and it is probable that it represents somewhere near the entire thickness of the accumulation which took place in the Miocene lake. Although no accurate measurements were taken its vertical depth was estimated to be about 800 feet. In this region it rests upon the black shale (Cretaceous No. 4), and in many places has been cut through by the streams, so that a complete section is exposed.

I.—Description of the Sediment and its Main Divisions.

Heretofore there have been two main divisions recognized in the classification of the White River sediments, viz.: a lower division, under the name of the *Titanotherium Beds*, and an upper division, known as the *Oreodon Beds*. This latter division was made to include all those strata lying above the Titanotherium Beds, and was estimated at somewhere in the vicinity of 600 feet in thickness. I now propose a third primary division, which will include the uppermost strata of the Oreodon Beds of other authors. This division may be called the *Protoceras Beds*, from the relative abundance of this characteristic fossil. As in the other two divisions, the separation is made largely upon the faunal characters which will be discussed later on.

The Titanotherium Beds.

This division of the Miocene has recently formed the subject of a very exhaustive and excellent article by Mr. J. B. Hatcher,[1] and what is here said upon this topic is drawn largely from his statements. The beds are composed of clays, sandstones and conglomerates; the clays greatly predominate. Near the bottom of the beds the color is often red or variegated, but the prevailing color is a very characteristic and delicate greenish white. The sandstones are never entirely continuous, and never more than a

[1] The Titanotherium Beds. American Naturalist, March, 1893.

few feet in thickness. They present every degree of compactness, from beds of loose sand to the most solid sandstones. The conglomerates are very similar in character, with the exception that they are usually harder.

By actual measurements, Mr. Hatcher found the Titanotherium Beds in this locality to present a total thickness of 180 feet. Of this the first 50 feet constitutes the lower division, the next 100 feet the middle division, and the remaining 30 feet the upper division. These divisions are made upon the characteristic forms of Titanotheriidæ found in each layer. This is well shown in the accompanying table which is taken from Mr. Hatcher's article.

The fauna of the Titanotherium Beds is very limited, so far as the variety of forms is concerned. While the remains of the Titanotheriidæ are relatively very numerous other genera are but very sparsely represented by the merest fragments. The only remains other than *Titanotherium* which I could identify with any degree of certainty were those of a small *Aceratherium*, a species of *Hyopotamus*, and probably of *Elotherium mortoni* and *Mesohippus*. With the exception of the *Hyopotamus* none of these remains were found in place, but I am inclined to the opinion that these genera will yet be found well down in the Titanotherium Beds. At the point where the Titanotherium Beds pass into the overlying Oreodon Beds, mingled remains of *Titanotherium*, *Aceratherium*, *Mesohippus*, and *Elotherium mortoni* occur; and it is a matter of the greatest interest to note that the *Aceratherium* here found is not only the oldest but the most primitive member of the true rhinoceroses which has been found in this country. Our collection contains two fairly good specimens from this layer, and they are sufficiently well preserved to fully make out the characters of the dentition. I will again refer to this subject later on.

The Oreodon Beds.

The changes which led up to and caused the extinction of the gigantic Titanotheriidæ also witnessed a remarkable transformation in the fauna on the shores of the White River lake, for no sooner do we pass from the Titanotherium Beds into the Oreodon

Stratigraphic Table of White River Miocene.

Approximate estimate of the thickness of the Beds.	Characteristic Species and General Character of Rock.	Genera obtained by Expedition of 1892. The numbers are those of the Museum Catalogue.
100 feet.	Leptauchenia Layer: nodule-bearing, pink-colored clays widely distributed.	Eucrotaphus (Eporeodon), 612–619. Leptauchenia, 620–629.
Protoceras Beds. 50–75 feet.	Coarse sandstones occupying different levels, not continuous.	Protoceras, 639–646. Pogonodon (?), 656. Artionyx, 685. Protapirus, 659, 661–663. Elotherium, 573, 574. Hyopotamus, 580–584, 590, 592. Anchitherium, 678–683. Hyracodon, 560. Hyopotamus, 585–589, 591, 593. Aceratherium, 538–545, 564.
Barren Clays. 100 feet.	Light-colored clays.	
75 to 100 feet.	Nodulous clay stratum. Bones white.	Oreodon, 611. Poëbrotherium, 638. Hyænodon, 648. Metamynodon, 548, 696. Aceratherium, 537. Elotherium, 572. Hyopotamus, 578, 579.
	Sandstones and clays. Bones rusty colored.	Aceratherium, 533, 534, 535 (?), 536. Mesohippus (?), 684.
Oreodon Beds. 10 to 20 feet.	Oreodon Layer: nodule-bearing, very constant and widely distributed. Numerous Oreodons and turtles imbedded in nodules. Bones always covered with scale of ferruginous oxide. 'Red layer' of collectors.	Aceratherium, 525, 526, 529–532, 561–563. Hyracodon, 556–559. Mesohippus, 664–668, 671–677. Elotherium, 566–570. Hyopotamus, 577. Oreodon, 594, 595–610, 657. Poëbrotherium, 630–637. Hyænodon, 647, 649. Hoplophoneus, 650, 651–655. Leptomeryx, 686–688. Leptictis, 689–691. Ischyromys, 692–694.

OREODON BEDS. (*Continued.*) 50 feet.	Metamynodon Layer: sandstones, sometimes replaced by light-colored barren clays. Bones usually rusty colored.	Aceratherium, 524, 527. Metamynodon, 546, 547, 549–555. Mesohippus. Protapirus, 660. Colodon, 658. Elotherium, 571. Hyopotamus, 575, 576.
	Reddish gritty clay, sometimes bluish. Bones white.	Aceratherium, 521, 522, 704. Mesohippus, 669, 670.
	Mingled remains of Titanotherium, Aceratherium, Mesohippus.	Aceratherium, 523, 528. Mesohippus, 544. Elotherium mortoni and Hyopotamus.
Upper Beds, 30 feet.	Clays, sandstones and conglomerates.	Titanotherium. Elotherium (?), 565. *Titanotherium* of large size. Horns 10–18 in. long, elliptical to sub-ovate in cross-section. Nasals very short and pointed. Incisors never more than 2. Internal cingulum on upper premolars not strongly marked in either sex. Posterior inner cone on last upper molar. Third trochanter present. Trapezium absent.
TITANOTHERIUM BEDS. (Total thickness, 180 feet.) Middle Beds, 100 feet.	Clays, towards the base often reddish, or variegated. The prevailing color, however, is a delicate greenish white. Bones are always light colored or white, sometimes rusty.	Titanotherium, Aceratherium (?), Hyopotamus, Elotherium (?), Mesohippus (?), Trionyx. *Titanotherium* of medium size. Horns 4–10 in. long, circular to sub-triangular in cross-section. Nasals of moderate length, with broad or pointed extremities. Incisors never more than 2. *Strong* internal cingulum on upper premolars of males only. Posterior inner cone on last upper molar. Third trochanter present. Trapezium absent.
Lower Beds, 50 feet.		Titanotherium. *Titanotherium* of small size. Horns rudimentary or from 1–4 in. long, circular in cross-section. Nasals long and pointed. Incisors occasionally as many as 3. *Strong* internal cingulum on upper premolars in males only. No posterior inner cone on last upper molar. Third trochanter somewhat rudimentary. Trapezium present in earliest forms.

Beds than we find the remains of a fauna remarkable alike for its richness and variety. Just what caused this change I am at a loss to even conjecture. The dividing line between these two primary divisions of the White River sediment is sharply indicated, not only by the extinction of the Titanotheriidæ, but by the introduction of the variety of forms which followed with little or no previous announcement in the underlying strata.

Like the Titanotherium division the Oreodon Beds are composed of sandstones and clays, of which the latter largely predominate. These strata are seldom continuous over a wide area. They change not only in color but in the materials of which the sediment is composed sometimes with considerable abruptness. In some places the Titanotherium Beds are overlaid by a reddish gritty clay, while in others it is light or buff-colored clay, which may be interrupted by layers of sandstone. There is one layer found in the Oreodon Beds which is highly characteristic and is perhaps more constant and widely distributed than any other single stratum in the whole White River formation. This is a buff-colored clay carrying numerous calcareous nodules in which are imbedded remains of turtles and oreodons. The fossils are almost invariably covered with a scale of ferruginous oxide when first removed from the matrix, and are of a decidedly reddish cast. Upon this account this stratum is known to the collector as the 'red layer.' It is situated somewhere between 40 and 50 feet above the top of the Titanotherium Beds and can almost always be easily identified. It varies in thickness from 10 to 20 feet, and in some rare instances it is replaced by sandstone. I have also found it without the nodules in places, but this is also quite a rare occurrence.

In the particular region examined by us there is a very considerable belt of sandstone found just below the Oreodon or red layer just described. It has an average thickness of about 20 feet, and as nearly as could be determined covers an area of 12 miles in length by a mile or a mile and a half in width. I mention this belt of sandstone in particular for the reason that it has with a single exception produced the only remains of *Metamynodon* so far known. Upon either side it is replaced by a bluish or light-colored clay which appears to be entirely barren of

vertebrate remains. Between this Metamynodon layer and the top of the Titanotherium Beds is found the reddish-colored gritty clay already mentioned. It has a thickness of about 25 feet and contains numerous remains of *Aceratherium*, *Mesohippus*, *Elotherium*, *Oreodon*, *Hyopotamus*, and in fact nearly all the genera which are found in the Oreodon Beds proper.

The character of the strata overlying the typical nodule-bearing Oreodon layer is very various in different parts of the bed. Sometimes it is a moderately thick bluish-colored standstone containing numerous remains of *Aceratherium*, but more frequently it is a light-colored clay containing few fossils. In one stratum of this sandstone we obtained the remains of a *Metamynodon* at the highest point in which it has been known to occur. At a distance of from 75 to 100 feet above the Oreodon layer there is a second distinct and tolerably constant nodule-bearing layer from which we obtained *Oreodon*, *Poëbrotherium* and *Hyænodon crucians*. This appears to be the uppermost limit of the fossil-bearing Oreodon Beds, so far at least as this region is concerned, and it is at this point, therefore, that I draw the line between the middle primary division (Oreodon Beds) and the uppermost division, Protoceras Beds. If it is desirable to subdivide the Oreodon Beds I would suggest that all those strata between the top of the Titanotherium Beds and the typical Oreodon layer would constitute the first division, the Oreodon layer itself would form a second division, and all those strata above the Oreodon layer, between it and the Protoceras Beds, would constitute the third division.

Protoceras Beds.

Between what I have taken to represent the uppermost limit of the Oreodon Beds and the Protoceras Beds there is a very considerable thickness of light-colored clay in which very few fossils occur. These strata reach a thickness of 100 feet or more, and upon this account it is easy to distinguish, in this region at least, between the Oreodon and Protoceras Beds. In other localities, however, these clays may yet be found to be fossiliferous, in which event the line of demarkation between these two divisions will be found to be much less distinct, and their separation

accomplished with much more difficulty. They are in many places capped by isolated patches of coarse sandstone which occupy different levels. They are almost always highly fossiliferous, and it was mostly in them that our collections from this horizon were obtained. These sandstone ledges are seldom continuous for any great distance, and often change abruptly into a fine-grained clay, which, according to our experience, is almost always barren. Immediately overlying the sandstones comes a tolerably constant, pinkish-colored, nodule-bearing clay, in which numerous remains of *Eporeodon* (*Eucrotaphus*) and *Leptauchenia* occur. The thickness of sediment above this is somewhat difficult to determine, but judging from the highest points in the yicinity it cannot be less than 75 or 100 feet. The strata, therefore, which constitute the Protoceras Beds are the sandstones, the nodule-bearing layer and its capping. The entire thickness of these beds is estimated at 150 feet.

II.—Faunal Distribution and Succession of Types.

Faunal Distribution.

1. *Titanotherium Beds.*—The Titanotherium Beds contain *Titanotherium* with its several forms, *Aceratherium*, *Hyopotamus*, *Elotherium* (?), *Mesohippus* (?). We also discovered fragmentary remains of turtles of the genera *Emys* and *Trionyx*. This latter genus is apparently new to this formation, since it has been supposed that they disappeared from the interior lakes at the close of the Eocene.

2. *Oreodon Beds.*—The Oreodon Beds contain the following genera: *Oreodon*, *Agriochœrus*, *Poëbrotherium*, *Leptomeryx*, *Hyopotamus*, *Elotherium*, *Thinohyus*, *Aceratherium*, *Hyracodon*, *Mesohippus*, *Colodon*, *Protapirus*, *Metamynodon*, *Hyœnodon*, *Dinictis*, *Hoplophoneus*, *Daphœnus*, *Leptictis*, *Ictops*, *Mesodectis*, *Ischyromys*, *Paleolagus*.

3. *Protoceras Beds.*—In the Protoceras Beds are *Protoceras*, *Eporeodon* (*Eucrotaphus*), *Leptauchenia*, Cameloids, *Hyopotamus*,

Elotherium, Peccaries, *Ceratherium*, *Hyracodon*, *Protapirus*, *Pogonodon* (?), *Artionyx*, Rodents, Primates.

Succession of Types.

I will now take up the question of the change in form and structure, to be noted among the more characteristic genera as we pass from the lower to the upper beds. With reference to the Titanotheriidæ, Mr. Hatcher has shown that important modifications took place, amounting in some instances to changes of true generic significance, between the first appearance in the lowermost beds and the time of the extinction of these forms. The rhinoceros line furnishes equally striking examples of these modifications. From the very lowermost part of the Oreodon Beds we obtained two specimens of *Ceratherium* (Nos. 523, 528), which are the smallest and most primitive in structure of any members of the genus. This is especially noticeable in the character of the fourth superior premolar, which is essentially tritubercular. With both specimens there is also associated a tooth which I take to be a rudimental superior canine. The front of the skull in both instances is so damaged, however, that this is not certain. From the succeeding layer, within a vertical range of twenty-five feet, we have three other specimens of skulls, two of which are in a good state of preservation. In one of these specimens the milk dentition is preserved, and it is a matter of the greatest interest to note that in this specimen we find a well developed and functional superior canine present. In the other skull the dentition shows the animal to have been adult and only the remains of the alveoli of the canines are to be seen. In the third specimen the last molar was just coming into place, and the canine is present. I think, therefore, that it can be safely assumed that these small forms of *Ceratherium*, which are found below the typical nodular layer of the Oreodon Beds, possessed a more or less *persistent superior canine*. In the fourth upper premolar of the three last-mentioned specimens the hypocone or posterior internal tubercle is in the first stages of development, and shows a considerable advance over the two specimens from the lowermost strata, in which it is entirely absent. The foot structure of these small forms from this horizon is unknown, but

some light is thrown upon this question by two specimens from the typical nodular layer. In these specimens the manus is provided with four digits,[1] and I am strongly inclined to the opinion that all the species of *Aceratherium* in the Oreodon Beds possessed four well-developed toes upon the front feet.

The next important change in this genus is met with in the specimens from the strata of the Oreodon Beds lying above the typical nodular layer. In them we note that the superior canine has *completely disappeared* from the milk dentition, as is shown by a very perfect and well-preserved skull in this stage. It is also to be remarked that the fourth superior premolar is now fully quadritubercular and that there is a tendency, especially in those from the uppermost of these strata, for the post-glenoid and post-tympanic processes to become approximated below so as to enclose the external auditory meatus. The species have also become considerably larger, and there is some evidence that the superior lateral incisors were becoming somewhat reduced in size.

The final stage in this development of *Aceratherium* is met with in the large species from the Protoceras Beds. Fortunately we have an unusually perfect skeleton of this form. Its size is almost double that of the small species from the base of the Oreodon Beds. The manus is provided with only three digits, the lateral incisors of the upper jaw are much reduced, almost rudimental it may be said, the external auditory meatus is completely enclosed by the post-tympanic and post-glenoid processes, and the fourth superior premolar is fully molariform.

In the horse series we have *Mesohippus* from the lower Oreodon Beds, but when the Protoceras Beds are reached *Anchitherium* appears. Now the most important generic distinction between these two genera is to be found in the circumstance that *Mesohippus* has a rudiment of digit V in the manus while *Anchitherium* is without it. This character is associated with other important modifications of the teeth. It can thus be plainly demonstrated

[1] In the Princeton collection there is a carpus of *Aceratherium mite* which both Professors Osborn and Scott believe had only three toes. In the absence of the metacarpals this is very difficult to decide, as one can readily appreciate by reference to the tapir or any four-toed form. In both the tapir and the foot of our specimen just referred to there is but a *single* distal facet upon the unciform, and with only this bone to guide us it would be very difficult if not impossible to tell whether the specimen under consideration was a three or four-toed form.

that one is the outgrowth of the other. Again in a species of *Protapirus* from the Oreodon Beds the superior premolars are all tritubercular, while in the Protoceras Beds a species is met with in which there is a marked tendency for the fourth tubercle to appear.

Among the Oreodons all the skulls from the typical nodular layer are without an inflated tympanic bulla. In the uppermost strata of the Oreodon Beds there is one skull in the collection which has a very small bulla, while in the nodular layer of the Protoceras Beds all the skulls show a well-developed bulla.

These instances could undoubtedly be multiplied if collections were made with this object in view, but I deem the examples already given sufficient to establish the main proposition advanced, namely, that the Lower Miocene or White River of America represents a great period of time in which the Titanotheriidæ, Rhinocerotidæ, Equidæ and Oreodontidæ underwent a very marked series of changes. The topmost, or Protoceras Beds, may very possible prove to overlap the John Day or Middle Miocene of Oregon.