Where Do the Lance Creek ("Ceratops") Beds Belong, in the Cretaceous or in the Tertiary?

By Oliver P. Hay.

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Historical Résumé.

Ever since the beginning of our knowledge of the geology of the Western plains and the Rocky Mountains there have existed contentions regarding the various deposits to which the names Laramie and Fort Union have been applied. These contentions have concerned the grouping of the various beds, the geological horizons to which the deposits of different basins and of different levels should be referred, and the members to which the names Laramie and Fort Union respectively should be restricted. Up to about the year 1896 certain deposits in the Judith River basin and others in Montana, Wyoming, Colorado and New Mexico were all regarded as the products of a single geological epoch and were all called Laramie. Although as early as 1860, or even earlier, some geologists, especially Dr. F. V. Hayden and Professor Leo Lesquereux, basing their opinion on the fossil plants, held that all or the greater part of the deposits in question belonged to the Tertiary, the prevailing opinion up to 1896 was that the Laramie, taking the term in its widest sense, was the uppermost portion of the Cretaceous. It may be said, however, that Professor Cope in his great work "The Vertebrata of the Tertiary Formations of the West" referred the Laramie, as well as the overlying Puerco

(including what is now known as the Torrejon), to the "Post-Cretaceous," a group holding a position between the Cretaceous and the Tertiary. He had previously assigned the Puerco to the Eocene. However, in 1887 (Amer. Naturalist, xxi, pp. 446, 450) he transferred this "Post-Cretacic System" to what he called the Mesozoic realm. In the year 1896 Messrs. S. F. Emmons, Whitman Cross and G. H. Eldridge published their "Geology of the Denver Basin," in which the previously so-called Laramie in the region of Denver, Colorado, was shown to consist of three distinct formations. The name Laramie was by them restricted to the lowest member of these, the succeeding formations being called respectively the Arapahoe and the Denver. The last two had, however, already been recognized, named and published by Eldridge and Cross as early as 1888.

Although the authors of the Geology of the Denver Basin referred to the Upper Cretaceous the three formations mentioned, Whitman Cross (op. cit., p. 206, seq.) makes a strong argument in favor of including the Arapahoe and the Denver in the Tertiary. His plea was based especially on the existence of a great stratigraphical break between the lower and the middle of the three formations and on the evidence furnished by the fossil plants. Certain deposits in Middle Park, Colorado; others near Canyon, Colorado; others in the Huerfano basin; certain ones along the Animas River; still others in New Mexico, beneath the Puerco; and the so-called "Ceratops" beds of Wyoming were all provisionally correlated with one or other of the formations in the Denver basin.

It is interesting, therefore, to observe that about 1887 and 1888, while Cope was endeavoring to raise the boundary between the Mesozoic and the Cenozoic to a position above what is now known as the Torrejon, Cross was trying to depress it to the parting between the Arapahoe and the formation below it.

It was thought by Cross that the beds of the Judith River valley might be the equivalent of the Arapahoe beds; but it has since been conclusively shown by Stanton and Hatcher that, instead of being younger than the deposits called by Cross the Laramie, the Judith beds are older than the Fox Hills, older than the upper part of the Pierre.

Within the past two years the discussion of the subjects named above has again broken into flame and a number of papers have appeared, all presenting most instructive facts and suggestions, but very diverse con-

clusions.[1] Whether the name Laramie shall be restricted to the lower of the three divisions found in the Denver basin and its equivalents elsewhere, as proposed by Cross and Eldridge, Knowlton and Peale; or to one or both of the upper divisions, as advocated by Veatch; or retained to designate all the formations between the Fox Hills and the Fort Union; or wholly abandoned, is yet to be settled; and with this I have nothing to do. It is the purpose of the present paper to show that those deposits that lie above the Fox Hills and are known to contain remains of dinosaurs: more specifically the Laramie, as understood by Cross and Eldridge; the Arapahoe and the Denver of Colorado; the Lance Creek, or "Ceratops," beds of Converse County, Wyoming; the Hell Creek beds of Montana: and the beds underlying the Puerco in New Mexico, ought not to be referred to the Tertiary, but to be retained in the Upper Cretaceous.

2. Necessity for Accurate Correlation of the Primary Divisions of the Geological Column in the Different Continents.

It appears to the writer that it is a matter of great importance that the primary divisions of geological time, the ages and the periods, and the corresponding systems of rocks of all parts of the world should as far as possible coincide. By this is meant that geologists should not (to employ an illustration) include in the Lower Cretaceous any deposits of one continent that were being formed synchronously with Jurassic deposits of another continent. Nor ought they to include in the Tertiary of America any formations that are the time equivalents of European Cretaceous formations. It may be a matter of great difficulty to attain agreement in some cases, but it ought to be resolutely striven after. And in this connection the writer indorses fully the quotation made by Mr. Cross (Proc. Wash. Acad. Sci., xi, p. 46) from Dr. C. A. White's address. It may be added that modification of the primary divisions ought to be made by international bodies of geologists and paleontologists.

The reasons why the primary divisions of geological history should be fixed as accurately as possible, even though arbitrarily, seem to be simple enough. Geology is the history of the development of the earth and its

[1] Veatch, A. C., Amer. Jour. Sci. (4), xxiv, 1907, pp. 18-22.
Cross, Whitman, Proc. Washington Acad. Sci., xi, 1909, pp. 27-45.
Knowlton, F. H., Washington Acad. Sci., xi, 1909, pp. 179-238.
Stanton, T. W., Washington Acad. Sci., xi, 1909, pp. 239-293.
Peale, A. C., Amer. Jour. Sci. (4), xxviii, pp. 45 58.

inhabitants. For sufficient reasons we divide this history into principal and subordinate portions, each having its own characteristics. Each continent has had its own course of development, physical and biological, this course sometimes agreeing only in a general way with that of other continents, being perhaps ahead of them or behind them, possibly sometimes only different. In order to compare and describe contemporary conditions in different lands there must be a few fixed dates from which to reckon the march of time and progress. These dates are found in the limits between the primary divisions, as that between the Silurian and the Devonian or that between the Cretaceous and the Tertiary. In a similar way we orient the history of even a savage people with reference to such dates as the founding of Rome and the birth of Christ.

3. The Primary Divisions of Geological Time Are Not Usually Indicated by Great Unconformities.

Inasmuch as those geologists and paleontologists who favor the reference of the Arapahoe and the Denver beds of Colorado, the Lance Creek beds of Wyoming and the Hell Creek beds of Montana to the Eocene, give as their principal reason therefor the existence of a great unconformity between the Arapahoe and the formation immediately below it, while there appears to be no similar unconformity below the Fort Union, it may be worth while to examine the adequacy of the reason. I believe that it is fallacious.

It is possible that, as Chamberlin and Salisbury suggest in their general work on geology (Geology, iii, p. 192), there is a natural basis for the larger divisions of geological history: that this basis is to be found in the profounder changes in the earth's crust; and that this basis is of world-wide application. This suggestion may be accepted as valuable without its arousing the expectation that a great stratigraphical break will be discovered everywhere between each great rock system and its predecessor and its successor. As a matter of fact, as geological history is now understood and now divided, such breaks are not commonly found. I will quote from Geikie's Text-book of Geology, ed. 4, 1903, p. 1081:

Though no geologist now admits the abrupt lines of division which were at one time believed to mark off the limits of geological systems and to bear witness to the great terrestial revolutions by which these systems were supposed to have been terminated, nevertheless the influence of the ideas which gave life to these banished beliefs is by no means extinct.

On page 981 the author quoted, in speaking of the Old Red Sandstone, says:

* * * in innumerable sections where the lowest strata of the system are found graduating downward into the top of the Ludlow group; and where its highest beds are seen to pass up into the base of the Carboniferous system.

On page 982 one reads as follows:

The rocks termed Lower Devonian may partly represent some of the later phases of Silurian life. On the other hand, the upper parts of the Devonian system might in several respects be claimed as fairly belonging to the Carboniferous system above.

As to the relation of the Lower Carboniferous to the Devonian, Geikie (Text-book, p. 1014) says:

Both in Europe and America it may be seen passing down conformably into the Devonian and the Old Red Sandstone. So insensible indeed is the gradation in many consecutive sections where the two systems join each other that no sharp line can be drawn between them. The stratigraphical passage is likewise frequently associated with a corresponding commingling of organic remains.

Chamberlin and Salisbury (Geology, ii, p. 499) tell us that the transition from the Devonian to the Mississippian seems to have been accomplished without notable deformative movement. Also (p. 518) it is stated that the Devonian fauna passed by graduation into the Mississippian.

There exists in many places the same doubt regarding the boundary line between the Carboniferous and the Permian. Geikie (Text-book, p. 1064) states that in the Midlands and the west of England no satisfactory line can be drawn between the two systems; (p. 1065) that the flora of the older Permian rocks presents many points of resemblance to that of the Carboniferous; (p. 1063) that in North America no good line of subdivision exists between Permian and Carboniferous; so certain deposits are called Permo-Carboniferous; (p. 1077) that in Russia the Permian attains an enormous development, the horizontal strata nearly lying conformably on the Carboniferous.

Of the Permian of North America Chamberlin and Salisbury write (Geology, ii, p. 620):

The upper Barren Measures are commonly separated from the Pennsylvanian on the basis of the plant species rather than because of any stratigraphic break at their base.

The Artinskian of Russia is placed in the Permian by Lapparent and Geikie, but in the Carboniferous by Tschernyschew, a distinguished Russian geologist.

Similar difficulties are encountered in various parts of the world by geologists when they attempt to draw the line between the Paleozoic and the Mesozoic systems. Chamberlin and Salisbury (Geology, ii, p. 631) have this to say:

The Permian system of Europe seems to be more closely allied, stratigraphically, with the Trias than with the Carboniferous, and while the same is true of the western part of America, the opposite is true for the eastern part.

We have the statement of Geikie (Text-book, p. 1084) that in some regions, as in England, no very satisfactory line of demarcation can always be drawn between Permian and Triassic rocks.

Nor are geologists free from embarrassments when they endeavor to classify the Mesozoic and the Tertiary formations. The Rhætic is arranged by Geikie in the Triassic, by Lapparent in the Jurassic. Clark and Bibbins express doubt regarding the position of the two lower divisions of the Potomac formation of the eastern United States. They refer them provisionally to the Jurassic: the other two divisions are unhesitatingly placed in the Lower Cretaceous. According to Chamberlin and Salisbury, the fossils of the Trinity division of the Comanchean system have raised the question of its reference to the Jurassic. An indefinite number of similar cases could be cited.

The illustrations presented show that the great divisions of geological record are not even commonly separated by physical breaks, great or small. It would be quite as easy to show that important unconformities occur within the limits of systems of rocks. A few cases only need be cited. The following is quoted from Geikie (Text-book, p. 1007):

The Old Red Sandstone of Britain, according to the author's researches, consists of two subdivisions, the lower of which passes down conformably into the Upper Silurian deposits, the upper shading off in the same manner into the base of the Carboniferous system, while they are separated from each other by an unconformability. * * * [In Scotland] it consists of two well-marked groups of strata, separated from each other by a strong unconformability and a complete break in the succession of organic remains.

Geikie states further (p. 1146) that a considerable stratigraphical and paleontological break is to be remarked at the line between the Portlandian and the Purbeckian. Chamberlin and Salisbury (Geology, ii, p. 639) tell us that the close of the Paleozoic was marked by much more considerable geographic changes than the close of any period since the Algonkian. The statement is qualified by the remark that these changes may be said to have been in progress during the Permian rather than to have occurred at its close.

4. The Principal Divisions of Geological History Are Based on Fossil Organisms.

It may therefore be confidently affirmed that the primary divisions of geological history, as this history is now understood, are not based on unconformities and deformations, great or small, between the successive formations, but they are based on the history of the plants and animals whose remains have become entombed in the rocks. I will here quote from Lapparent (Traité de Géologie, ed. 5, p. 717) :

Il résulte de ces diverses considérations que les seules ressources de la stratigraphie, si précieuses et si indispensables qu'elles puissent être, sont insuffisantes pour l'établissement des grandes divisions de la géologie. Il faut donc recourir à quelqu'argument d'une portée plus générale. Cet argument, nous allons le trouver dans la considération des faunes et des flores fossiles.

It must not be supposed that the writer wishes to underestimate the value to the geologist of changes in the materials that constitute successive beds, of deformations of surfaces, or of unconformities, erosional and angular. All these indicate the physical changes that the earth was undergoing and mark the subordinate and more or less local divisions of geological history. Naturally the geologist in the field searches for such interruptions in the course of deposition and, following a bent very human, he may come to attach somewhat undue importance to them. In any case, however, final recourse must be had to the fossils enclosed in the rocks. Fossils are, to use a figure, the sands that, from the hour-glass of the universe, have in an uninterrupted stream dropped into the successive strata to mark the passage of time. Local interruptions of sedimentation enable us to note the changes undergone by the organisms that then existed; but whether there were breaks in deposition or not, the

evolution of the organisms went steadily on. The smaller divisions of time are marked by the less important changes that the animals and plants suffered; while the primary divisions are signalized by the profounder modifications of the living beings. These primary divisions are often indicated by such phrases as the age of mollusks, the age of fishes, and the age of mammals. As there were no universal cataclysms that characterized the terminations of the ages and the eras, so there were no sudden changes in the nature of the animals and the plants. The boundaries between the successive ages and the successive eras must therefore be more or less arbitrarily drawn. If one era is characterized by numerous powerful reptiles and a few inconspicuous mammals, while the next era presents mammals as the dominant animals, the reptiles as decadent, we must draw the line to suit our convenience and to express best the facts; but in the end it will be drawn more or less arbitrarily.

To appreciate the futility of seeking for great unconformities between the rock systems one has only to consider the relations of the Upper Cretaceous to the Tertiary in Europe. Lyell regarded the Thanet sands and certain equivalents in France and Belgium as the base of the Eocene. Between this and the Upper Cretaceous there appeared to be one of the profoundest breaks in geological history. Lyell says that the interval between the Upper Cretaceous and the Eocene must have been greater than that between the Eocene and the present. More recent investigations have shown that even in the north of Europe there are deposits of no great thickness that partly fill the gap between the two systems; while it is almost filled in the south of that country.

The conclusion applicable to the question being considered which I reach is that the magnitude of the break below the Arapahoe formation in the Denver basin has little or nothing to do with the determination of the boundary line between the Mesozoic and the Cenozoic. The position of this line is to be settled through the study of the organic remains found below and above the unconformity and the comparison of these with the fossils found at corresponding levels in regions geologically better understood. If the ensemble of the organisms found in the Arapahoe, the Denver, the Lance Creek and the Hell Creek beds, is essentially of Upper Cretaceous nature, on comparison with accepted standards, those beds belong to the Mesozoic, not to the Cenozoic, notwithstanding the great unconformity.

As has already been said and is well known, the base of the Eocene was established just below the Thanetian of England and its continental equivalents; and this line of separation of the Cenozoic from the Mesozoic has been recognized by practically all geologists since Lyell's time. Considering the great gap between the two systems, as known in Europe at that time, the separation did not appear to be at all an arbitrary one. In his "Text-book of Geology," edition of 1896, Geikie placed the Montian in the Eocene, but in the edition of 1903 this formation is restored to the Upper Cretaceous. Lapparent, too, draws the line above the Montian. Nor does this manner of division appear to arouse objections on the part of the paleontologists.

If, therefore, American geologists and paleontologists wish to have the boundary line between the Mesozoic and the Cenozoic of their country coincide with that of Europe, the type continent of the base of the Eocene, it will be necessary, unless there are compelling reasons for the contrary, to make the base of our Eocene the equivalent of the Thanetian of Europe. I believe that geologists and paleontologists generally will give assent to this proposition.

It is well understood that in the determination of the level of any geological formation not all kinds of fossils are of equal value; some are indeed of little value. It is agreed that the marine animals record most accurately the progress of geological time, because of their abundance, their wide distribution, the slow and steady changes which they undergo during geological periods, and the facility with which they become entombed in accumulating sediments. Furthermore, of marine species the pelagic forms are of greater value, because their remains are dropped indiscriminately into deposits of all kinds, thus enabling geologists to correlate formations widely separated and composed of very different materials. Terrestrial animals are of less value. They are subject to rapid and extreme changes in their environment through changes in climate and through sudden migrations. They suffer accordingly rapid modifications in their structure or sudden extinction. They are also less likely to be preserved in the rocks. Every shell in an oyster bed may be preserved, while from a million horses but a single tooth may escape destruction. In an interesting address at the meeting of the British Association at Montreal, in 1884, Blanford gave it as his opinion that determinations of

geological age based on terrestrial and freshwater faunas and floras only are extremely likely to be incorrect.

Unfortunately for us, the deposits in which we are now especially interested contain few or no marine organisms, but abundant freshwater and terrestrial animals and numerous plants. We must therefore reach our conclusions by somewhat indirect methods and must be on our guard against errors. Still more unfortunately for us, the paleozoologists and the paleobotanists have not attained the same results from their studies.

5. The Value of Plants as Indices of Geological Dates.

I trust that the paleobotanists will not charge me with trying to disparage their science when I proceed to show that, in the present case at least, their results are less to be depended on than those obtained by the paleozoologists. Without doubt, the plants have as interesting, as trustworthy, and as valuable a story to tell, when rightly deciphered, as do the animals. It seems, however, that in some cases, other than the one before us, the significance of fossil plants has not been rightly comprehended. In Blanford's address, cited above, he mentions two important cases in which the determination of the age of certain formations have contradicted those made from the marine animals. One case is found in the Gondwana system of India, where, as Blanford says, "we have a Rhætic flora overlying a Jurassic flora and a Triassic fauna above both." Again he states that "in Australia we find a Jurassic flora associated with a Carboniferous marine fauna and overlain by a Permian freshwater fauna."

The following is quoted from Lapparent (Traité, p. 718):

A plus d'une reprise, l'étude des flores terrestres a paru donner des indications contradictoires avec celles des faunes marines; et en dernière analyse la question a toujours été tranchée en faveur de ces dernières.

Geikie makes the following observation:

Certainly a number of instances are known where an older type of marine fauna is associated with a younger type of flora.

One reason why plants, at least those of the northern hemisphere, which have existed since the beginning of the Upper Cretaceous, seem to be of only secondary value in correlating formations is found in their apparently extreme conservatism. While the species have changed, the genera have changed little. As an illustration of this, one may take the list of plants published by Doctor Knowlton (Wash. Acad. Sci., xi, 1909,

p. 219) as occurring in what he is pleased to call the Lower Fort Union, but which includes the Lance Creek and Hell Creek beds and their supposed equivalents. One might almost imagine it to be a list of plants found in a recently investigated corner of the world on the latitude of Louisiana. On page 225 it is stated that a number of species are yet living, while others are so obviously close to living species as to be separated with difficulty. Such inert organisms, subject also to all the vicissitudes of life on the land, can hardly be regarded as good indicators of the passage of time. Since that epoch the genera, families, and even orders of warm-blooded vertebrates have almost completely changed.

The opinion held by some distinguished geologists and paleontologists that the so-called Laramie beds, or all of these except the lowest, belong to the Tertiary appears to have rested until recently, at least, mostly on the statements of Professor Leo Lesquereux, the paleontologist of the Hayden Survey. He and Dr. Hayden at first regarded these deposits as belonging to the Miocene, but later as belonging to the lowermost Eocene. Passing over Lesquereux's earlier writings I refer to one of his latest utterances on the subject, found in the eighth volume of the monographs of the Geological Survey of the Territories, part three, published in 1883. On page 109 Lesquereux makes this statement:

> The flora of the Laramie group has a relation, remarkably defined, with that of Sézanne.

Now, the flora of Sézanne, a town in France, comes from beds that belong to the Thanetian, at the very base of the Lower Eocene. Lesquereux's statement is followed by a table of the species which he supposed had been found in the Laramie at various localities. The beds at some of these localities are now known to be somewhat older than any Laramie, those at one or two localities a little younger than Laramie. In the table is a column in which are checked off the species of Laramie plants that Lesquereux believed to be identical with or closely related to species found at Sézanne; in another column the species that he supposed were found also in the Oligocene of Europe; in a third column those that he believed to occur also in European Miocene deposits. Naturally, one would expect, in view of Lesquereux's statement quoted above, that the identical and closely related species of the Sézanne column would outnumber those of the Miocene column. On the contrary, only three species were regarded by him as identical with Sézanne species, while twenty-

seven species are recorded as identical with European Miocene species. If we count in each case the plants that were supposed to be closely related to the European species, but not identical, we find twenty-five in the Sézanne column and thirty three in the Miocene column. Adding the identical and the related species in each case it is seen that there are in the Sézanne column twenty-eight species, sixty in the Miocene column. Therefore, it becomes difficult to understand how Professor Lesquereux derived his conclusion from his premises. What his table really proved was that the Laramie deposits belong to the Miocene. Had Cope and other paleontologists examined the table itself, instead of accepting the author's statement regarding it, they would either have distrusted the evidence from the plants more than they did or would have concluded that the dinosaurs ranged up into the Miocene.

It is not to be supposed that all paleobotanists accepted Lesquereux's views. These views were strongly opposed, especially by Newberry, as early as 1874 and as late as 1889. The following is quoted from Newberry (Trans. N. Y., Acad. Sci., ix, 1889, p. 28):

> If Prof. Cope had not accepted Mr. Lesquereux's conclusion in regard to the age of the deposit [at Black Buttes], and had recognized the fact that there are no Tertiary plants in the true Laramie, he would have seen that there is no discrepancy between the testimony of the plant and animal remains.

It is to be taken into consideration here that Newberry believed that the Laramie was directly overlain by the Fort Union. The latter beds have usually been regarded as belonging to the Eocene. However, the following may be quoted from Lester F. Ward, who had studied especially collections of plants from the Fort Union deposits (Bull. Geol. Soc. Amer., i, 1890, p. 531):

> In fact, the material from the Fort Union formation which is still in my hands inclines me to believe that there would really be, as I then stated, no inconsistency in assigning to the Fort Union an age as ancient as the closing period of the Cretaceous system.

6. The Completeness of Record of Animal Life as Compared With That of Plant Life.

There is, in the present state of knowledge, a great contrast between the incompleteness of the plant record above the Fox Hills formation and the fullness of the animal record. Plants are abundant throughout the

series that has been called Laramie and in the Fort Union. Again, they are found in the Green River beds, in the White River beds, and in the deposits at Florissant, Colorado. Otherwise, the record is mostly missing. On the other hand, the history of the vertebrates is quite full. Between the Fox Hills and the present time there are known probably nearly twenty distinct faunas and it has been found possible to correlate these in most cases closely with European faunas. With such a series at command, the extremes of which differ enormously, while the mean terms sometimes grade into their successors, at other times differ greatly from the next comers, the paleontologist need not go far astray in determining the proper level of each fossil-bearing deposit. It may be remarked that when the paleobotanist refers the Green River beds to the Oligocene, while the vertebrate paleontologists put them at the bottom of the middle Eocene, a serious dislocation of views is indicated.

7. The Beginning of the Eocene in Europe and America.

When one comes to correlate formations in America with those of distant countries great difficulties are likely to be experienced. Interruptions in stratification are not likely to occur at the same time in America and Europe and Asia. On account of differences in the character of the deposited materials, the climate, the interposition of barriers, and other features of environment, the contained organisms must differ to a greater or less extent. In the case of the beds about which exists our dispute, they are neither of marine origin nor in contact with strata of purely marine origin. Hence they cannot be compared directly with either the typical uppermost Cretaceous deposits of Europe, the Danian, nor with the Thanetian, the lowermost European Eocene. The Lance Creek beds, the Hell Creek beds, and others related to them have been produced mostly through the action of fresh waters and they contain remains of land plants, freshwater mollusks and fishes, reptiles inhabiting the water and the land, and a few terrestrial mammals. In such a situation we must have recourse to indirect means of correlation.

In the vicinity of Rheims, France, in deposits belonging to the Thanetian, there has been found a considerable number of genera and species of extinct mammals, together with some birds, reptiles, and fishes. The mammals have been studied and described by Lemoine. On the strength of this fauna these Cernaysian beds were correlated with the Puerco at a

time when this term was applied to beds now separated and known as Puerco and Torrejon. There is thus furnished a means of beginning a correlation of our land and freshwater Tertiary deposits with those of Europe; but we need ever to keep in mind the possibilities of error.

I believe that any one who may carefully compare the Cernaysian fauna with the faunas of our Puerco and Torrejon must conclude that the Cernaysian corresponds more closely with that of our Torrejon than with that of the older Puerco. I find that Osborn had reached this conclusion in 1900 (Ann. N. Y. Acad. Sci., xiii, pp. 9, 10); and in his latest matter on the subject he correlates the Torrejon with the Thanetian, or Cernaysian (Bull. 361, U. S. Geol. Surv., p. 34). Indeed, it seems not improbable that the Cernaysian is a little more recent even than our Torrejon.

It has been demonstrated that at least a part of the Fort Union formation is the equivalent of the Torrejon. Hence, wherever the latter is put the Fort Union or some part of it must go. The base of the Tertiary being drawn in Europe at the bottom of the Thanetian, there appears to be no good reason why in our country it should not be drawn above the Puerco, possibly above the Torrejon and the Fort Union. Certainly, when geologists and vertebrate paleontologists have consented to include the Puerco and the Torrejon in the Eocene they have lowered the base of the latter formation to its extreme level. To include now in the Eocene the "Ceratops" beds, the Hell Creek beds, the Arapahoe and the Denver, would be to add to it some hundreds of feet of deposits which, in the opinion of vertebrate paleontologists, contains a considerably older fauna than that occurring in the Cernaysian beds, and which with equal confidence the invertebrate paleontologists refer to the Cretaceous.

8. Relationship of Fauna of Lance Creek Epoch to Those of Puerco and Torrejon.

Inasmuch as those geologists and paleobotanists who favor the transference of a large part of the Laramie (as formerly understood) to the Tertiary insist that the fauna of the Lance Creek and the Hell Creek beds is more closely related to that of the Puerco and that of the Torrejon than to any Cretaceous fauna, this question must be considered. With regard to the relationships of the mammals of the Lance Creek beds to those of the Puerco and Torrejon extremely diverse views have been expressed. Marsh (Amer. Jour. Sci., xliii, 1892, pp. 250, 251) says that the mammals of the Lance Creek deposits

are not transitional between the Mesozoic and Tertiary forms, but their affinities are with the former beyond a doubt; thus indicating a great faunal break. * * * and the great break is between this horizon [the Peurco] and the Ceratops beds of the Laramie. * * * It is safe to say that the faunal break as now known between the Laramie and the lower Wasatch [Puerco] is far more profound than would be the case if the entire Jurassic and the Cretaceous below the Laramie were wanting.

Cope (Amer. Naturalist, xxvi, 1892, p. 762), quoting from Marsh the words "the more the two [Laramie and Puerco] are compared the stronger the contrast between", adds:

It is true that no Ungulata have yet been found in the Laramie, while they abound in the Puerco, but we cannot be sure that they will not yet be found; the probabilities are that they existed during the Laramie and that it is due to accident that they have not been obtained. But the Multituberculata of the two faunæ are much alike.

Osborn (Bull. Amer. Mus. Nat. Hist., v., 1893, p. 311) writes:

This Laramie fauna is widely separated from the Upper Jurassic, and is more nearly parallel with the basal Eocene forms of the Puerco and the Cernaysian of France. * * * These conclusions are directly the reverse of those expressed by Marsh in his three papers upon this fauna.

Cross (Geology of the Denver Basin, p. 220) concludes that this difference of opinion deprives the mammalian remains of much of their value in the present discussion.

To the present writer Marsh's opinion seems to be erroneous. Geologically, of course, the Jurassic mammals are much farther removed from those of the Lance Creek beds than the latter are from those of the Puerco, Torrejon, and Fort Union. The same remark may justly be made regarding the stage of development attained by the Jurassic mammals. Systematically considered, the case is different; and the solution of the problem depends on the systematic relationships of the Jurassic mammals to those of the Lance Creek beds and of the latter to the mammals of the Puerco and Torrejon. If it shall result that all, or nearly all, of the Lance Creek mammals belonged to the Marsupialia and the Monotremata, then Marsh's opinion will be in great measure justified. If, on the other hand, it shall be shown hereafter that a large number of the Lance Creek mammals were placentals and the near-by ancestors of the Puerco and Torrejon faunas the break between the former and the latter will not be a profound one; nevertheless more important than formerly supposed by Osborn.

It must be understood that our knowledge of the mammals of the Lance Creek and related formations is of a very unsatisfactory kind. With few exceptions, all that is known of these animals has been derived from their teeth, not found in place in the jaws, but scattered singly through the rocks. Better known are the Jurassic mammals, for of these many jaws have been secured. Recently considerable light has been thrown on the marsupials of the Lance Creek and Fort Union formations through the discovery of the skull and some parts of the skeleton of *Ptilodus* (Gidley, Proc. U. S. Nat. Mus., xxxvi, p. 611). The other genera await elucidation. Osborn's statement of the situation may be accepted (Evolution of the mammalian molars, 1907, p. 95):

It is possible that, besides Marsupials, we find here Insectivores, primitive Carnivores, and the ancestors of ancient Ungulates; but it is obvious that the determination of relationships from such isolated materials is a very difficult and hazardous matter.

Notwithstanding this appreciation of the situation, Professor Osborn has ventured (op. cit., pp. 12, 22, 115) to refer his Tuberculata, Marsh's Pantotheria, to the infraclass Placentalia. No adverse criticism can be made on this procedure, in case its tentative character is understood.

Now, while this uncertainty reigns regarding the systematic relationships of the mammals of the Lance Creek and related deposits, the case is different as soon as attention is given to the mammals of the Puerco, Torrejon, and Fort Union. Some of them betray by their tooth succession and other characters that they are true placentals. Many of them may be referred with confidence to orders and families that continued long afterwards, some of them probably to the present day.

That a considerable gap existed between the mammals of the Lance Creek formation and those of the Puerco and Torrejon is evident from the state of development of the teeth. Osborn, speaking of the teeth of the Upper Cretaceous mammals [Lance Creek] says (Bull. Amer. Mus. Nat. Hist., v., 1893, p. 321) that in none of the molars hitherto described and in none of his collection of about 400 teeth and some jaws was there any trace of the hypocone, or posterior internal tubercle. Nor was any hypocone recognized in the genera described by him in 1898 (Bull. Amer. Mus., Nat. Hist., x, p. 171). Undoubtedly, however, the hypocone is sometimes present in a rather rudimentary condition, as I have observed in teeth shown me by Mr. Gidley, of the U. S. National Museum. Nevertheless,

the teeth of all the mammals of the Lance Creek stage, except those of the Allotheria, are triangular, showing that the possessors were either insectivorous or flesh-eating in their habits.

On the other hand, there are several genera of Puerco mammals that possess a well developed hypocone and internal cingulum. In some cases, where the hypocone had no great development, the hinder internal part of the tooth had swollen so as to reduce much the gap between the successive teeth and produce a broad triturating surface. In *Polymastodon*, which must have been a vegetarian, an extensive triturating surface was secured in another way. It presents a great advance over the teeth of any of the Lance Creek Allotheria. If it is considered how slowly changes in tooth structure had advanced during the Mesozoic era we must conclude either that a considerable interval had elapsed between the Lance Creek epoch and that of the Puerco or that the animals of the latter were not descendants of the former.

There are important differences between the mammals of the Lance Creek beds and those of the Puerco as regards the size attained. Most of the former are of insignificant proportions, resembling in this respect those of the Jurassic; while many of those of the Puerco are large. Furthermore, there was in the mammals of the Puerco a far greater variety of form, structure, and systematic relationships than among those of the Lance Creek mammals. Of the latter, there have been described about twenty-five genera and about forty-five species, most of them by Marsh. Osborn has regarded himself as justified in reducing these to about ten genera, these representing a very few families. From the Puerco Matthew (Bull. 361, U. S. Geol. Surv., 1909, p. 91) recognizes twenty-nine species, belonging to eighteen genera and nine families. To what extent this increased diversification of the mammalian life of the Puerco is due to immigration we can not now tell; but it does not seem to be necessary to assume that it was due to invasion of mammals from some other region. For, in view of the interval between the two formations that is indicated by the plants and reptiles, it is possible that the Puerco mammals are the direct descendants of those of the Lance Creek epoch.

In case there was no serious interruption in deposition between the Lance Creek beds and the Puerco and Fort Union, one might expect to find close relationships between the reptiles of the two levels. Crocodiles are not abundant in either and, so far as known, no species passes from

the one formation to the other. *Champsosaurus*, belonging to another order, is found in the beds of the Lance Creek region and at Hell Creek and also in the Puerco; but probably no species is common to the lower and the upper levels. This genus, like *Ptilodus*, serves to show that, though there may have been a considerable interval between the Lance Creek and the Puerco, it was not an enormous one. The dinosaurs, which were such a conspicuous feature of the Lance Creek epoch, appear to have disappeared completely before the time of the Puerco and Fort Union. Of turtles, some families passed from the one formation to the other, but probably no species. A pleurodire, representing a large group of turtles found now mostly south of the equator, was present in the "Laramie" of New Mexico; but no member of the group is known to have existed in North America after that time. Certain other genera of turtles (*Adocus*, *Eubaëna*, *Thescelus*, *Basilemys*, *Helopanoplia*) are not known to have passed from the Lance Creek level into that of the Puerco and Fort Union; and other genera (*Alamoscmys*, *Hoplochelys*, *Conchochelys*, *Amyda?*) appear to have had their beginning in the Puerco. It may further be said that, while turtles were very abundant in the Lance Creek epoch, they appear to have been very rare in the Fort Union, though of more frequent occurrence in the Puerco.

As regards the mollusks I find this statement made by Doctor Stanton (Wash. Acad. Sci., xi, p. 264), where he is speaking of a Fort Union locality in Montana:

> The Unios are all of simple type and do not include any of the peculiarly sculptured forms like those of Hell Creek, Converse County, and Black Buttes.

The plants, conservative as they are, testify even more strongly than do the animals to a considerable interval between the Lance Creek epoch and the Fort Union. According to Doctor Knowlton (Wash. Acad. Sci., xi, p. 221), out of 84 identified species found in the Lance Creek epoch ("Lower Fort Union") 68 occur in the Fort Union. Hence 16 species, nearly 20 per cent, appear to have failed to reach the higher beds. It is to be noted here that about 300 plants are known from the Fort Union and only about 200 from the Lance Creek beds. For a group of organisms that even then contained a considerable number of species yet existing, or very close to forms yet existing, the loss of a fifth of their forces, at a time when there appears to have been little change of climate, indicates the lapse of an important interval.

The base of the Eocene is usually regarded as containing a small per cent of the marine mollusks yet living; the beginning of the Miocene, about 17 per cent of yet existing species; and the beginning of the Pliocene about 36 per cent. If now plants have changed in species during the lapse of geological time with about the rapidity that marine mollusks have changed, the Fort Union beds ought to be arranged in the Lower Miocene. This would harmonize quite well with the idea that the Green River beds belong to the Oligocene.

9. Relationship of Lance Creek Fauna to That of the Judith River Epoch.

Having demonstrated, as I think I have, that there was, between the time of the deposition of the Lance Creek beds and those known as Puerco and Fort Union, a nearly complete change in the fauna and a considerable change in the flora, I will endeavor to show that the fauna of the former beds is closely related to that of the Judith River, a formation now recognized as being well down in the Upper Cretaceous and separated from the lowermost Laramie by about 1,000 feet of marine Cretaceous strata (Stanton, Wash. Acad. Sci., xi, p. 256). This close relationship of the two faunas has been recognized, it may be truthfully said, by all paleontologists who have given attention to the subject. For a long time it misled geologists and paleontologists into the conclusion that all the deposits in question belonged to a single epoch. Mr. J. B. Hatcher, who had collected extensively both in the Judith River region and in the Lance Creek beds, and who had studied closely the vertebrates of both regions, writes (Bull. U. S. Geol. Surv., 257, p. 101):

> When considered in its entirety, the vertebrate fauna of these beds [Judith River] is remarkably similar to, though distinctly more primitive than, that of the Laramie [Lance Creek beds]. Almost or quite all of the types of vertebrates are present, though, as a rule, they are represented by smaller and more primitive forms.

Doctor T. W. Stanton, paleontologist of the U. S. Geological Survey, who examined in company with Professor Hatcher the Judith River basin, and who has given especial attention to the invertebrate fauna, records in the same bulletin (p. 121) his opinion:

> When full collections are compared it will usually be easy to distinguish between Judith River and Laramie from the brackish-water fossils alone, but if the collections are meager and fragmentary it may not be

practicable to do so. * * * Taken as a whole, the fresh-water faunas of the Judith River and the Laramie are somewhat more distinct than the brackish-water faunas of the same formations, and with fairly complete collections it should not be very difficult to distinguish them in the laboratory.

When we come to compare the vertebrates of the Judith River beds with those of the Lance Creek deposits it becomes necessary practically to ignore the mammals, inasmuch as only two species of these have up to this time been discovered in the Judith River. These are *Ptilodus primævus* and *Borodon matutinus*, both described by Lambe from the Belly River beds of British America. The former of these fossils is related to species of the same genus found in the Lance Creek beds and in the Torrejon, the latter genus is of undetermined relationship.

Fishes.—Beginning with the fishes, there have been described from the Judith River beds eight species. In the Lance Creek beds, Converse County, Wyoming, Professor Williston (Science, xvi, 1902, p. 952) found materials which he refers to two of these species (*Myledaphus bipartitus*, *Lepisosteus occidentalis*). One of these fishes, *Myledaphus bipartitus*, seems to be a ray. The rays are almost wholly inhabitants of salt water; hence the persistence of this Judith River freshwater form is somewhat remarkable. A supposed sturgeon, *Acipenser albertensis*, found by Lambe in the Belly River beds, occurs, according to Williston, in the Lance Creek beds. From the Belly River beds Mr. Lambe described a remarkable species of fish which he called *Diphyodus*. Hatcher states that similar jaws are common both in the Judith River beds of Montana and in the deposits of Converse County, Wyoming. From the Hell Creek beds of Wyoming Mr. Barnum Brown has reported the discovery of another species of the same genus.

Tailed Amphibians.—Of the tailed amphibians, at all times rare fossils, Cope described from the Judith River region four species, all members of the genus *Scaphirpeton*. Lambe believes that he has found one of these in the Belly River beds, a fact that shows the somewhat extended distribution of the genus at that epoch. Williston found one of the species in the Lance Creek beds and Brown reported a species from the Hell Creek deposits. While it is true that these fishes and amphibians are mostly represented by fragmentary remains, these remains are usually characteristic and capable of accurate comparison. That *Myledaphus* should reappear after an interval allowing the deposition of 1,000 feet of marine

strata and probably some hundreds of feet of freshwater strata, is remarkable enough; but that it should reappear in company with its old companions, the rare *Diphyodus* and *Scaphcrpeton*, not to mention the more highly developed fauna yet to be discussed, is very striking. Had there occurred at both levels only some pebbles of three peculiar forms or compositions, instead of the three genera, the conclusion would have been inevitable that there was some particular connection between the two formations.

Champsosaurus. Crocodiles.—Coming next to the reptiles, it may first be noted that species of *Champsosaurus* occur in the Judith River beds, in the Lance Creek beds, in those of the Hell Creek region, and in the Puerco. It is probable that the species vary from one formation to the other. The same statement can probably be made regarding the crocodiles. These genera, common to all three of the formations under discussion, may be left out of consideration; although it must not be overlooked that none the less they aid in binding together the formations in which they are found. As to the crocodiles, it may be mentioned that Williston recognized, in teeth and scutes found in the Lance Creek beds, Leidy's *Crocodylus humilis*, originally described from the Judith River region. From the Judith River beds of Alberta Lambe described *Leidyosuchus canadensis*. Mr. C. W. Gilmore will soon describe a second species of the genus, collected last summer in the Lance Creek beds of Converse County, Wyoming.

Turtles.—As regards the turtles, certain genera have already been mentioned as appearing not to pass the line between the Lance Creek formation and the Puerco and Fort Union. My study of the fossil turtles indicates that the species of these animals rarely pass from one epoch to another. If they have ever done so they passed from the Judith River into the Lance Creek epoch. There are five or six species of Judith River turtles which are represented in the Lance Creek and Hell Creek beds by turtles of identical or very closely related species. Most of these are marked by such peculiar sculpture that they are easily recognized and some of them likewise are represented by excellent materials. I shall take the pains to give some details.

Compsemys? obscura Leidy was originally described from beds probably belonging to the Lance Creek epoch and found at Long Lake, N. Dakota. Not much of it is known, but the sculpture is distinctive.

It was included by Cope in his list of Judith River vertebrates. Barnum Brown found what appears to be the same species in the Hell Creek beds.

Compsemys victa Leidy was described from the beds of Long Lake. Its sculpture is characteristic, resembling small, closely placed, pustules, that cover all parts of the shell, and appearing in no other turtles. It is fragmentary, but very common in the Lance Creek beds. Barnum Brown has collected it in the Hell Creek deposits. Cope included it in his list of Judith River vertebrates. He also found it in Colorado, in deposits that belong to either the Arapahoe or the Denver. I am able to say that the same genus is represented by an undescribed species in the Fort Union.

Aspideretes foveatus (Leidy) was described from the Judith River basin. Leidy had other specimens from Long Lake, N. Dakota. There are many fragments of the species in a collection made in the Judith Basin for Cope by Charles Sternberg. A nearly complete carapace was found in the Belly River beds by Lambe. Fragments indistinguishable from the type were secured by Barnum Brown in the Hell Creek region. The carapace is ornamented by a characteristic pitting.

Aspideretes beecheri Hay has for its type a specimen in Yale University which lacks little more than the head and a part of the neck. Mr. Hatcher collected in the Judith River beds two quite complete carapaces which I have examined, without being able to distinguish them from the type of *A. beecheri*.

Adocus lineolatus Cope is a turtle that is not well known, but fragments of what appear to be the same species are not uncommon. The sculpturing is peculiar. The type was found in Colorado, in probably the Arapahoe formation. Cope included it among the vertebrates of the Judith basin, and Lambe reported it from Belly River deposits in Alberta. Barnum Brown found in the Hell Creek beds what seems to be the same species.

The genus *Basilemys* is represented by turtles of large size and an extraordinary form of sculpture. The type *B. variolosa* (Cope) has as its type a large part of the plastron and considerable parts of the carapace. This type was found in the Judith River basin. Members of the Canadian Geological Survey found good specimens of the species in the Belly River beds in British America. A second species of the genus has been discovered in beds of the Lance Creek epoch, in Custer County, Montana. The type is a complete shell. Had only fragments been found that did not

include distinctive parts, this specimen would have been regarded as belonging to *B. variolosa*. A species not certainly identified occurs in the Hell Creek beds. During the past season an undescribed, closely related species was discovered in the Lance Creek deposits in Converse County, Wyoming, by a member of the U. S. Geological Survey. Nothing resembling these turtles has ever been found in beds above those equivalent to the Lance Creek deposits. Indeed, all those turtles of the Upper Cretaceous which had the carapace and plastron sculptured in various ways, appear to have become extinct before the beginning of the Tertiary. Not long after the opening of the Tertiary, in the Wasatch, there came in the Emydidæ and the Testudinidæ, and these developed other styles of ornamentation of the shell.

Figures of all the species of turtles named above are to be found in the present writer's "Fossil Turtles of North America."

Dinosaurs.—Both in the Judith River beds and in those of the Lance Creek epoch the most abundant and the most conspicuous reptiles are the dinosaurs. Five families of these, belonging to four superfamilies and to two suborders, are represented in the Judith River epoch, and each of these families reappears in the Lance Creek epoch. Furthermore, many of the genera are common to the two formations and it is believed that the same is true of a considerable number of species. From the Judith River beds Cope described eight species of carnivorous dinosaurs that seem to come under the genus *Dryptosaurus*. Mr. Hatcher (Bull. U. S. Geol. Surv., 257, p. 86) mentions the occurrence of two of these, called by him *Deinodon explanatus* and *D. hazenianus*, in the Lance Creek beds. Another carnivorous dinosaur, *Deinodon horridus*, was originally described from the Judith River beds. Hatcher (loc. cit., p. 83, *Aublysodon mirandus*) believed that it was found likewise in the Lance Creek beds. Another, *Zapsalis abradens*, is thought (p. 84) to occur in both formations. The great carnivorous dinosaur described by Osborn, *Tyrannosaurus rex*, may be a descendant of Marsh's *Ornithomimus grandis*, of the Eagle formation, older still than the Judith beds.

In the herbivorous order Orthopoda are placed the remarkable reptiles called the Stegosauria. Two species, *Troodon formosus* and *Palæoscincus costatus*, are mentioned by Hatcher (loc. cit., pp. 83, 88) as being represented in the Lance Creek deposits by numerous teeth of size and pattern similar to the types, which were described from the Judith River

formation. In addition to these, Barnum Brown has described from the Hell Creek beds a large stegosaur, *Ankylosaurus magniventris*, the type of a new family. We can not doubt that some day a closely related form will be discovered in the Judith River beds; and indeed, its immediate ancestor may be Lambe's *Stereocephalus tutus*, from the Belly River deposits.

The large herbivorous dinosaurs, the Hadrosauridæ, which were accustomed to walk about on their hinder limbs only, are, according to Cope's identifications, represented in the Judith River formation by about nine species. The Lance Creek and the Hell Creek beds furnish three or four species of the family, most of which are referred to the genus *Hadrosaurus*, or *Trachodon*. Whether or not there are species common to the two formations cannot now be definitely determined; but certainly their relationships are very close.

Of all the dinosaurs that are found in the formations in which our interest is now centered the Ceratopsia have received the most careful study. What the present state of knowledge is with regard to these remarkable reptiles, may be learned from Hatcher's monograph of the group, completed and edited by Dr. Lull (Mon. 49, U. S. Geol. Surv.). Unfortunately much needs yet to be learned about them, especially about those of the Judith River forms. Approximately nine species are known from the Judith River deposits of Montana and British America; and about fifteen species are credited to the Lance Creek beds, of Wyoming, and to the Arapahoe and the Denver, of Colorado. Hatcher and Lull conclude that those of the Judith epoch are somewhat more primitive than those of the beds higher up, being somewhat smaller, with a less completely developed nuchal frill, with the nasal horn relatively larger and the supraorbital horns relatively smaller than in the younger forms. It is, however, to be noted that the nasal horn of *Ceratops*, of the Judith River epoch, is not yet certainly known. For the most part the genera are based on the characters mentioned above. They may have the importance assigned to them, but they do not indicate radical differences. Such differences might easily have arisen during an interval of moderate duration. There can be no doubt that the Ceratopsia of the higher beds were derived directly from those of the lower.

The possibility may be fully granted that further investigations may prove that few or no species of vertebrates continued from the Judith

River epoch to that which witnessed the deposition of the Lance Creek and Hell Creek beds. Nevertheless, nothing can impair the force of the evidence that many species included among the fishes, the tailed amphibians, the turtles, the crocodiles, the champsosaurians, and the carnivorous and herbivorous dinosaurs are represented in both formations by closely related forms. The remarkable thing about the matter is that the faunas of the two formations, separated by so great a thickness of strata, should be so similar. We must conclude that deposition went on rapidly in that interval, so that it may not have been so long as otherwise might appear. There could hardly have been movements of the land in that region that produced any considerable changes of climate. During the Bearpaw epoch the sea probably quietly invaded a part of the territory that had previously been occupied by the Judith River animals; but around the border of this invading sea the turtles, the crocodiles, and the many genera of the dinosaurs continued their existence and their evolution undisturbed until that sea retired. And doubtless had all those animals in that region been destroyed there was an extensive territory, nearly the whole of North America as far as the Atlantic, that harbored similar forms, from which territory new recruits could swarm in. As far away as New Jersey there were living herbivorous and carnivorous dinosaurs not greatly different from those of the Judith River beds. This appears to be true, that whatever happened to the plants between the time of the Judith River and the Lance Creek beds, nothing of serious importance happened to the animals.

By those who insist on elevating the deposits of the Lance Creek epoch into the Tertiary, a persistent effort has been made to minimize or nullify the significance of the presence of dinosaurs. As long ago as 1880 Heer wrote thus (Arctic Flora, vol. 6, pt. 2, p. 7):

Der *Agathaumas* von Black Buttes beweist daher keineswegs, dass dort eine Tertiär-Flora zu gleicher Zeit mit einer Kreide-Fauna gelebt habe, wie Prof. Cope dies behauptet, denn ein einzelnes Thier macht so wenig eine Fauna aus, als eine Pflanzenart eine Flora. Wir können daher Hrn. King nicht beistimmen, wenn er, mit Cope und Marsh, die Laramie-Gruppe zur Kreide bringt.

Mr. Cross and Dr. Knowlton have argued that the dinosaurs might have continued on into the Eocene, and in fact did so. As to the vertebrate paleontologists, it is not probable that any of them would have asserted that this was impossible and some of them have granted the possibility. In holding that the dinosaur beds belong to the Mesozoic, they

have reasoned that, inasmuch as these animals are characteristic of the Mesozoic and are not known to occur in the Tertiary of any other region, they probably did not exist during any part of the Tertiary of this country. And certainly, there is a mass of confirmatory evidence for this conclusion. The plants have appeared to furnish evidence against it; but, in view of the discrepancy between Lesquereux's conclusion and his premises, it seems that the paleozoologists were justified in their conservatism.

Mr. Cross writes (Mon. U. S. Geol. Surv., xxvii, p. 251):

> If the dinosaurs of the Ceratops fauna did actually live in the Laramie epoch of Colorado they survived a great orographic movement and its accompanying climatic changes, and continued through the Arapahoe and Denver epochs so little modified that Professor Marsh has not detected any changes corresponding to the stratigraphic time divisions.

Since this was written it has been found that the Judith River beds, which contain so many dinosaurs, were deposited long before the time of the Laramie. We thus have proof that these dinosaurs and many other forms of vertebrates survived, without important changes, the orographic movement mentioned by Mr. Cross. It seems probable, therefore, that this movement was not so widely extended and so long continued as has been supposed. Why the dinosaurs died out finally we do not know, any more than we know why numerous other vigorous races of animals have perished from the earth. That the causes were not local is shown by the fact that in Europe likewise they became extinct just before the appearance of the Cernaysian fauna. It may be regarded as very reprehensible in them that they thus permitted themselves to perish before the Eocene came on, but we are compelled to believe the record.

In the preceding pages I have endeavored to show that the deposits of the Lance Creek epoch are well separated from those of the Fort Union, as indicated by both the fauna and the flora. In case a biological break is required between the Cretaceous and the Tertiary such a break seems to be present here. The stratigraphical break appears to be less conspicuous; yet unconformities are not absent and the character of the deposits appears to be such that there is seldom difficulty in separating the one formation from the other. Nevertheless, it seems that accurate correlation demands that the line between the Mesozoic and the Cenozoic in that region ought to be drawn at least above the Puerco and probably through or above both the Torrejon and the Fort Union. The exact position of the parting must be settled after further investigations.

10. Conclusions.

1. The answer that the writer would give to the question at the head of this paper is that the Lance Creek beds belong to the Upper Cretaceous.

2. In the Upper Cretaceous ought to be included also the Puerco and not improbably also the Torrejon and the Fort Union.

3. In case of a conflict between the evidence furnished by the flora and the fauna of the Lance Creek beds and those of the Fort Union respectively, the evidence obtained from the faunas is to be preferred, as being part of a more complete and better understood history. Present knowledge regarding plants seems to indicate that they were precocious, having reached something like their present stage of development long before the mammals attained anything like their present stage of differentiation. There are also indications that the floras of the western world were, during the Cretaceous, considerably in advance of those of Europe.

4. Even if it were conceded that the Fort Union belongs to the Tertiary, and that the fauna and flora of the Lance Creek epoch are more closely related to those of the Fort Union than they are to those of the Judith River, it does not follow that the Lance Creek epoch must be included in the Tertiary. A quarter before midnight on Monday is much nearer to Tuesday than it is to the previous six o'clock; nevertheless, it is not yet Tuesday.

U. S. National Museum,
Washington, D. C.