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EVIDENCE OF THE PALEOCENE VERTEBRATE FAUNA ON
THE CRETACEOUS-TERTIARY PROBLEM ¹

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USE OF THE TERM PALEOCENE

The character of the Paleocene fauna, its relations to the preceding and following faunæ, and its European correlations are an important part of the evidence on this problem.

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Contribution to the symposium held by the Paleontological Society at the Princeton meeting December 31, 1913, and January 1, 1914.

The term Paleocene, current in Europe,² has hardly come into use in this country. As applied here it denotes what we have been calling Basal Eocene, comprising the Fort Union, Puerco and Torrejon, and other equivalent formations older than the Wasatch or typical Lower Eocene. The reasons will appear later for its acceptance as an epoch distinct from the Eocene.

The typical and best known Paleocene fauna is that of the Puerco and Torrejon formations, Nacimiento terrane, of New Mexico. The stratigraphic relations of the faunæ of the four fossiliferous levels of this terrane have been explained by Doctor Sinclair. There is no marked stratigraphic break in the terrane, but there are two distinct faunæ, no species surviving from one to the other. Some of the genera and most of the families pass through, represented in the later horizon by distinct species or genera, usually more progressive. In their broader aspects the two faunæ have much in common to distinguish them from those of earlier or later age.

The Fort Union (not including the Lance) is provisionally correlated with the Nacimiento terrane. In its upper part is found a mammalian fauna composed in part of species identified with Torrejon species, but the rest of this fauna is not comparable with anything in either Puerco or Torrejon. A small flora from the Puerco is identified by Doctor Knowlton as indicating "Denver or perhaps as late as Fort Union" age. The diverse element of the Fort Union fauna is best interpreted as indicating a somewhat different environmental facies, somewhat more of a swampy delta and less of a floodplain type of deposit being indicated by the lithologic features.

CHARACTERS OF THE PALEOCENE VERTEBRATE FAUNAS

(1) The mammals are dominantly Placentals of archaic orders. A minority are Multituberculates, related (auct. Broom)³ to the existing Monotremes. Approximately 10 per cent of the fauna is Multituberculate. The remainder belong to groups of placentals which became extinct during the Eocene. The later Tertiary and modern orders of mammals are not present except the Carnivora and certain groups doubtfully referred to Insectivora and Edentates. There are no Perissodactyls, Artiodactyls, Rodents, or Primates, these orders appearing suddenly at the beginning of the true Eocene.

² But not always with the significance here given to it. Some authors include in it the London Clay, equivalent to our Wasatch or Lower Eocene.

³ I do not indorse this view. New evidence bearing on it will shortly be published by Mr. Granger.

(2) The Multituberculates are nearly related to those of the Lance formation, but the species of each phylum are larger and more specialized. The placentals have apparently no predecessors in the Lance; at least this is true, in my judgment, of the bulk of the placental fauna and so far as the present evidence indicates. The Lance mammal fauna is so fragmentary that statements about its composition should be carefully qualified.

(3) The reptiles are chiefly Chelonia, Crocodilia, and Choristodera. One snake has been recorded; lizards were present, although not recorded. No dinosaurs are present;⁴ the marine reptiles of the Mesozoic would not be expected. The reptiles all belong to families that originated in the Cretaceous (Belly River) or earlier. Three of the families still survive, one disappeared with the Eocene, another with the Paleocene. The dominant Tertiary families of Chelonians (Emydidae and Testudinidae) are not present, appearing first in the Lower Eocene. The absence of Tertiary types of lizards and snakes is of little weight, as it may be merely a matter of defective record.

LIST OF TYPICAL PALEOCENE VERTEBRATE FAUNAS

	Puerco.	Torreon.	Clark Fork.
REPTILIA			
Order Testudines			
Fam. Baenidae (Cretaceous-Eocene)			
<i>Baena excavata</i> Hay.....		×	
Fam. Dermatemydidae (Cretaceous-Recent)			
<i>Hoplochelys crassa</i> Hay.....	×		
" <i>saliena</i> Hay.....		×	
" <i>paludosa</i> Hay.....		×	
<i>Alamosmys substriata</i> Hay.....		×	
Fam. Trionychidae (Cretaceous-Recent)			
<i>Conchochelys admirabilis</i> Hay.....	×		
<i>Aspideretes sagatus</i> Hay.....	×		
" <i>puercensis</i> Hay.....	×		
" <i>singularis</i> Hay.....		×	
Order Choristodera			
Fam. Champsosauridae (Cretaceous-Paleocene)			
<i>Champsosaurus australis</i> Cope.....		×	
" <i>saponensis</i> Cope.....		×	
Order Serpentes			
Fam. ?? Crocotalidae (?? Cretaceous-Recent)			
<i>Helagras prisciformis</i> Cope ⁵		×	
Order Crocodilia			
Fam. Crocodylidae (Cretaceous-Recent)			
<i>Crocodylus stavelandianus</i> Cope ⁶		×	

⁴ But see appendix, p. 400.

⁵ Generic and family reference needs revision.

⁶ The generic position of these Eocene and Paleocene crocodiles is wholly doubtful.

	Puero.	Torrejon.	Clark Fork.
MAMMALIA			
Order Multituberculata (Triassic-Paleocene)			
Fam. Plagiaulacidae			
<i>"Neoplagiaulax" americanus</i> Cope.....	×		
" <i>molestus</i> Cope.....		×	
" sp.			*
<i>Ptilodus mediævus</i> Cope.....		×	
" <i>trovessartianus</i> Cope.....		×	
<i>Polymastodon taoensis</i> Cope.....	×		
" <i>attenuatus</i> Cope.....	×		
" <i>fissidens</i> Cope.....		?	
<i>Catopsalis foliatus</i> Cope.....	×		
Order Feræ (sub-ord. Creodonta)			
Fam. Miacidae (Paleocene-Eocene)			
<i>Didymictis haydenianus</i> Cope.....		×	
" cf. <i>leptomylus</i> Cope.....			×
Fam. Arctocyonidae (Paleocene-Lower Eocene)			
<i>Clænodon corrugatus</i>		×	
" <i>ferox</i>		×	
? " <i>protogonioides</i>	?	×	
Fam. Mesonychidae (Paleocene-Eocene)			
<i>Trisodon quivirensis</i> Cope.....	×		
" <i>heilprinianus</i> Cope.....	×		
" <i>gaurianus</i> Cope.....	×		
<i>Sarcothraustes antiquus</i> Cope.....		×	
<i>Goniædon levisanus</i> Cope.....		×	
<i>Microclænodon assurgens</i> Cope.....		×	
<i>Dissacus saurognathus</i> Wortman.....		×	
" <i>navajovius</i> Cope.....		×	
Fam. Oxyclenidae (Paleocene) [†]			
<i>Oxyclenus cuspidatus</i> Cope.....	×		
" <i>simplex</i> Cope.....	×		
<i>Loxolophus hyattianus</i> Cope.....	×		
" <i>priscus</i> Cope.....	×		
" <i>attenuatus</i> O. & E.....	×		
<i>Carcinodon filholianus</i> Cope.....	×		
<i>Paradoxodon rutimeyeranus</i> Cope.....	×		
<i>Protogonodon pentacus</i>	×		
<i>Chriacus pelvidens</i>		×	
" <i>truncatus</i>		×	
" <i>baldwini</i>		×	
" <i>schlosserianus</i>		×	
<i>Tricentcs subtrigonus</i>		×	
" <i>crassicolldens</i>		×	
<i>Deltatherium fundaminis</i>		×	
Fam. Oxyenidae (Upper Paleocene-Eocene)			
<i>Dipsalidictis platypus</i> indesc.....			×
<i>Palæonictis</i> or <i>Oxyæna</i> , sp. indesc.....			×
<i>Oxyæna æquidens</i> sp. indesc.....			×
Order Insectivora (Paleocene-Recent)			
Fam.? Centetidae (? Paleocene-Recent)			
<i>Palæoryctes puercensis</i> Matthew.....		×	
Fam.? Pantolestidae (? Paleocene-Eocene)			
<i>Pentacodon inversus</i> Cope.....		×	

* Sand Coulee beds, at base of true Eocene.

† One doubtful species of *Chriacus* in the Lower Eocene.

	Puerco.	Torreon.	Clark Fork.
Fam. Mixodectidae (Paleocene-? Eocene)			
<i>Mixodectes pungens</i>		×	
“ <i>crassiusculus</i>		×	
<i>Indrodon malaris</i>		×	
Order Taniodonta (?? = Xenarthra)			
Fam. Stylinodontidae (Paleocene-Eocene)			
<i>Wortmania otariidens</i> Cope.....	×		
<i>Psittacotherium multifragum</i> Cope.....		×	
Fam. Conoryctidae (Paleocene)			
<i>Onychodectes tisonensis</i> Cope.....	×		
“ <i>rarus</i> O. & E.....	×		
<i>Conoryctes comma</i> Cope.....		×	
Order Xenarthra (Paeanodontia, Paleocene-Eocene)			
Fam. Metacheiromyidae			
<i>Palaeonodon</i> sp. indesc.....			×
Order Condylarthra			
Fam. Phenacodontidae (Paleocene-L'r Eocene)			
<i>Tetracodon puericensis</i> Cope.....		×	
“ <i>minor</i> Matthew.....		×	
<i>Phenacodus</i> sp. div.....			×
Fam. Mioclenidae (Paleocene)			
<i>Mioclenus turgidus</i>		×	
“ <i>lydekkerianus</i>		×	
“ <i>lemuroides</i>		×	
“ <i>acolytus</i>		×	
“ <i>turgidunculus</i>	×		
“ <i>inaequidens</i>		×	
<i>Protoselene opisthacus</i>		×	
<i>Oryacodon</i> * <i>apiculatus</i> O. & E.....			
“ <i>agapetillus</i> Cope.....	×		
Order Taligrada			
Fam. Periptychidae (Paleocene)			
<i>Periptychus carinidens</i> Cope.....		×	
“ <i>rhabdodon</i> Cope.....		×	
“ <i>coarctatus</i> Cope.....	×		
<i>Ectoconus ditrigonus</i> Cope.....	×		
<i>Conacodon entoconus</i> Cope.....	×		
“ <i>cophater</i> Cope.....	×		
<i>Hemithlæus kowalevskianus</i> Cope.....	×		
<i>Anisonchus gillmanus</i> Cope.....	×		
“ <i>sectorius</i> Cope.....		×	
<i>Haploconus lineatus</i> Cope.....		×	
“ <i>corniculatus</i> Cope.....		×	
Fam. Pantolambdidae (Paleocene)			
<i>Pantolambda bathnodon</i>		×	
“ <i>cavirictus</i>		×	
Order Amblypoda			
Fam. Bathyopsidae (Up. Paleocene-L'r Eocene)			
Gen. indesc.....			×

* May be better placed under Periptychidae.

COMPARISON WITH LANCE AND BELLY RIVER FAUNAS

(1) The vertebrates of the Lance and Belly River are: (1) Horned Dinosaurs (*Ceratopsia*), (2) Duck-billed Dinosaurs (*Trachodonts*), (3) Large carnivorous Dinosaurs (*Megalosaurs*), (4) Armored Dinosaurs (*Ankylosaurs*), (5) Smaller Dinosaurs of the predentate and theropod divisions, not yet cleared up as to relationship, (6) Chelonians of the families *Baenidae*, *Dermatemydidæ*, and *Trionychidae*, (7) Crocodiles of the family *Crocodylidae*, (8) *Choristodera* (fam. *Champsosauridae*), (9) Lizards of the family? *Iguanidae* (recorded from Lance only), (10) Multituberculate mammals, (11) Trituberculate mammals (positively recorded from Lance only), some demonstrably marsupials, others of uncertain relationship, none demonstrably Placentals.

Comparing the Belly River with the Lance, we find the same groups represented throughout, exceptions in (9) and (11) being probably a matter of imperfect record, as these groups are extremely rare. Among the Dinosaurs the Belly River types appear to be more varied and less extremely specialized, the phyla which pass through being represented by more primitive stages in the Belly River. Among the mammals the multituberculate mammals are recorded in the Belly River by a single genus, apparently a more primitive stage of one of the Lance phyla. Additional specimens will be diligently searched for. The trituberculate mammals have not yet been found in the Belly River, except for a single tooth of uncertain affinities, and are rare in the Lance.⁹ Whatever their affinities, these mammals do not appear to include ancestral stages of the placental phyla of the Paleocene, certainly not of the majority, probably not of any of them. The chelonians, crocodilia, and choristodera belong to the same phyla, in large part to the same genera, in the Belly River as in the Lance, and afford little evidence of progressive evolution.

Comparing the Lance with the Paleocene, we find that none of the numerous Dinosaur phyla pass through. The entire order becomes extinct and none have been found associated with the placental mammal fauna of the Paleocene (but see Appendix A).⁷ The Chelonians, Crocodiles, and *Choristodera* pass through, represented by the same phyla and without much progressive evolution as far as known. The Multituberculata pass through, but with an appreciable amount of progressive evolution, amounting in one phylum to generic, in another to marked specific difference. The Trituberculate mammals apparently disappear, al-

⁹ It is worthy of note that the greater abundance of small mammals in the Lance as compared with the Belly River is wholly due to the presence of numerous ant-hills scattered over the exposures. Practically all the Lance mammals have been found in these ant-hills.

FIGURE 1.—Geologic Range of Land Vertebrates in typical American continental Formations of late Cretaceous and Tertiary Time

though some of them may have left descendants in the rare and little known marsupials and small insectivores of our Tertiary formations. The numerous phyla of placental mammals which take the place of the dinosaurs and mammals of the Lance are not derivatives of any part of the Lance fauna, but a new appearance.

COMPARISON WITH WASATCH (LOWER EOCENE) FAUNAS

(1) The Multituberculates disappear at the end of the Paleocene, although a few rare survivors (three specimens) have been found at the very base of the Wasatch.

(2) Some of the placental phyla disappear at the end of the Paleocene, but over half of the families survive into the Wasatch, some into the Middle or Upper Eocene (see U. S. Geological Survey Bulletin Number 361, pages 100-103).

(3) The larger part of the Eocene fauna from the base of the Wasatch up is composed of genera of Perissodactyla, Artiodactyla, Rodents, and Primates; orders not found in the Paleocene. They are not descended from known Paleocene ancestors, but represent a newly arriving fauna. In the Clark Fork beds at the top of the Paleocene we find these orders still absent, although the genera of the Paleocene orders are identical with those of the Wasatch and more advanced than those of the Torrejon.

(4) The Choristodera disappear. The crocodiles and the families Baenidae, Dermatemydidæ, and Trionychidæ among chelonians continue through with little change. The dominant groups of Tertiary chelonians, Emydidæ and Testudinidæ, first appear in the Wasatch (but not at first in great numbers) and are not derivable from known Paleocene chelonians.

CHARACTERS OF THE PASKAPOO FAUNA

A small fauna has been secured by Mr. Barnum Brown from the Paskapoo beds in Alberta. It consists wholly of mammals, no dinosaurs occurring in this formation. The mammals, according to Mr. Brown's identifications, checked by the present writer, are unmistakably those of the Lance fauna in part, but include an element which has not been found in the Lance and appears to belong to the Paleocene groups of mammals, although none of its representatives compare at all closely with any Puerco or Torrejon genera. I suspect that it will be found to compare more nearly with the Fort Union fauna. It is evident at all events that there was a considerable element of placental mammals in the fauna. But the Multituberculates are those of the Lance and some of the trituberculates appear to be identical. There is no indication of the presence of any of the Eocene orders of placentals.

? *Peratherium* sp.

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Fam. ? Epanorthidæ

Picrodus silberlingi. (Family position doubtful, as this family is unknown outside of South America. Possibly a Multituberculata of undescribed family)

Order Insectivora

Fam. incert.

Coriphagus montanus

Megapterna minuta

Fam. ? Mixodectidæ

? *Mixodectes* sp. (Not Mixodectidæ; doubtfully Insectivore)

Order Carnivora (Feræ)

Fam. Oxyclænidæ

Protochriacus sp. (Reference questionable)

? *Chriacus* sp. (Not figured; of no value in correlation)

? *Tricentes* sp.

? *Deltatherium*

Order Tæniodonta

Fam. Stylinodontidæ

Calamodon sp. (Agrees better with Psittacotherium)

Order Condylarthra

Fam. Phenacodontidæ

Euprotogonia (= Tetracænodon) sp.

Fam. Mioclænidæ

Mioclænus sp.

Order Taligrada

Fam. Pantolambdidæ

Pantolambda sp.

Fam. Periptychidæ

Anisonchus sp.

INTERPRETATION OF THE VERTEBRATE FAUNAS

The evidence of fossil vertebrates in correlation is very valuable, provided it is interpreted correctly. Owing to the complex structure of the hard parts preserved and their capacity for relatively rapid and extreme progressive and adaptive changes in these hard parts, they afford a more precise and exact measure of time than do any other animals. This is peculiarly true of the mammals; dinosaurs, perhaps, rank next; other vertebrates are much less progressive. But as they respond more quickly to the opportunities for evolution afforded by lapse of time, so also they are more sensitive to difference of environment and more subject to change of geographic range and great migration movements, conditioned by great environmental changes in other regions. Moreover, the evidence is often fragmentary, and the reference of recorded genera and species doubtful and provisional to a varying degree. Omitting this element of doubt, the difference between two vertebrate faunæ may be due to

1. Lapse of time.
2. Difference of local environment.
3. Migration movements representing a change in environment somewhere else, not necessarily in the region concerned.

Lapse of time will be represented by changes in the evolutionary stages of the phyla which pass through from one to the other. It will not bring about sudden changes in the composition of the fauna, although certain phyla may diminish, while others increase in numbers.

A difference of local environment will involve the absence of certain groups of more or less restricted habitat, whose continued existence may yet be known by their presence in both earlier and later faunæ of different facies, or may be inferred from more indirect evidence.

A migration movement may cause the sudden appearance of new groups, the disappearance or extinction of older ones, with or without any apparent change in the facies or environmental type of the faunæ compared.

In attempting to apply the vertebrate evidence to correlation of the later Cretaceous and earlier Tertiary formations, these principles must be kept in mind or the results will be misleading. If properly understood they serve to reconcile what have appeared to some authors to be contradictory statements by vertebrate paleontologists. Marsh in his description of the Lance fauna lays weight on its resemblance to the Jurassic and Lower Comanchic faunæ. This is quite correct, inasmuch as it consists of Multituberculates unknown in the Tertiary except for a few Paleocene survivors, and of Trituberculates of rather remote affinity to the Tertiary placentals and similar in several features to those of the Jurassic. Osborn, on the other hand, pointed out that the Multituberculates of the Lance were much more closely allied to their Paleocene successors than to their Jurassic ancestors, and rightly concluded that there was no wide time-gap between the Lance and the Paleocene. The evidence as presented by Marsh and Osborn is not conflicting, but it presents different aspects of relationship. The Lance mammal fauna is near to that of the Jurassic in facies; it is much nearer in time to the Paleocene faunæ.

Comparing the Belly River and Lance faunæ, we find evidence of a considerable gap in time as represented especially by the progressive evolution in the Ceratopsia and other dinosaurs. But there is no good evidence of any change in facies or of the appearance of new immigrant groups of reptilia or mammalia. The reptilian phyla one and all continue through, some with little change, others with more considerable progressive evolution. The scanty evidences of mammals from the Belly

River indicate a fauna of the same facies as the Lance, doubtfully more primitive in stage.

Comparing the Lance with the Puerco and Torrejon, we find a fauna of very different facies, but indicating no very wide gap in time. It is not very clear whether the great faunal difference is due to diverse local environments or to a great movement of faunal migration, but a combination of both seems to fit the data most exactly.

Comparing the Puerco and Torrejon with the Wasatch, we find faunæ which appear to represent similar facies, but a very marked change in the sudden appearance of new orders and families of mammals and reptiles which can best be accounted for as immigrants. The lapse of time, as measured by the change in phyla which pass through, is not very great between Torrejon and Wasatch and very slight between Clark Fork beds and Wasatch. But the close of the Paleocene is marked by a great migration movement.

Comparing the mammal fauna of the Upper Fort Union with that of the Torrejon, we find that it appears to be of the same age, as indicated by the identity of a part of the fauna. But it apparently represents a somewhat different facies, with certain points of analogy to the Lance.

Comparing the Paskapoo fauna with the Lance, it appears by the same criteria to be equivalent or only slightly later in age, while apparently older than the Puerco and presumptively older than the Upper Fort Union; but it represents a facies very different from that of the Lance, corresponding more nearly with that of the Puerco and Torrejon, and perhaps still more closely with that of the Fort Union. It throws some light on the interpretation of the break between Lance and Puerco, for it contains an element that may be regarded as ancestral to a part of the Paleocene placentals, but does not appear to be related to the major and more progressive part of them. This would indicate that the absence from the Lance of the more primitive and archaic groups of the Puerco-Torrejon fauna is a matter of facies; but that the absence of the larger, more progressive and abundant Paleocene placentals from the Lance is to be ascribed to a migration movement at its close. The evidence on this point is, however, too scanty to be of any considerable weight.

By similar methods of correlation Brown has shown that the Edmonton formation underlying the Paskapoo and overlying the Pierre and the Ojo Alamo beds, which lie unconformably beneath the Puerco, are older than the Lance and equivalent to the Belly River, and that the Hell Creek beds of Montana are equivalent in age to the typical Lance, all representing nearly the same facies, but the Canadian formations somewhat more accessible to the marine fauna, as indicated by the finding of

a Plesiosaur skeleton in the Edmonton, and by the characters of the invertebrate fauna.

FIGURE 2.—Approximate Correlations of typical Formations of the late Cretaceous and early Tertiary in Europe and western America based on their Vertebrate Faunas

RELATIONS OF THE JUDITH RIVER FAUNA

On account of the disputed age of this formation it is better to rest the vertebrate evidence on other faunæ of unquestionable stratigraphic relations. I may say, however, that the fauna described by Cope from beds which Peale regards as equivalent to the Lance is unquestionably closely allied to that of the Belly River and of approximately the same age. The attempt made by Peale to show that it is identical with that of the Lance is based chiefly on a list of fragmentary specimens which, as stated by Hatcher (American Geologist, 1903, page 374) are practi-

cally valueless for exact correlation. His attempt to show that there are any common genera among the *Ceratopsia* hinges entirely on the identification of a specimen from the Denver beds, identified by Marsh as *Ceratops montanus* or some nearly allied reptile,¹⁰ and stated by Lull¹¹ to be "too fragmentary for accurate determination."

It will be sufficient to say that the published lists of species identified from both Judith River and Lance are in large part based on material too fragmentary for exact identification and of no value in exact correlation, as has been shown in detail by Mr. Hatcher, and that all that are sufficiently characteristic and complete to be of use in this way show that the "Judith River" of Cope's localities is of practically the same age and facies as the Belly River.¹²

The age of the Judith River, like any other problem in correlation, must be settled by bringing *all* the evidence into conformity. It can not be settled by balancing conflicting evidence and assigning more weight to one than to another class of data. Doctor Peale's attempt to bring all the evidence into conformity is undoubtedly right in principle, although biassed in method. But his solution of the vertebrate evidence is impossible of acceptance, especially in view of the recent researches in the Belly River fauna.

CORRELATION WITH THE EUROPEAN SUCCESSION

GENERAL DISCUSSION

The dividing line between Cretaceous and Tertiary in England is drawn between the uppermost beds of the chalk and the littoral and "fresh-water" beds which overlie it—the Thanet sands and London clay. But between these there is known to be a very considerable gap in time. This gap is partly filled on the continent by various intermediate formations, the highest stage of the chalk, the Danian, being absent in the English succession. While this is generally recognized as Cretaceous, there appears to be a difference of opinion as to the position of the Montien of Belgium and its equivalents. De Lapparent and other writers reckon it as the latest stage of the Cretaceous, while Dollo, Rutot, and

¹⁰ Amer. Jour. Sci., vol. xxxvi, 1888, p. 477.

¹¹ *Ceratopsia* monograph, p. 183. As Doctor Peale quotes and comments on the next preceding sentence in this reference, he could hardly have missed seeing this statement, to which he makes no allusion, although it invalidates his whole argument on this point.

¹² A recent note in "Science" by Mr. C. H. Sternberg puts a new light on the evidence. If his recollection of the stratigraphy is correct, Cope's *Ceratopsia* specimens came from a formation underlying the Pierre, while most of his fragmentary material came from the typical localities which Mr. Sternberg recalls as overlying the Pierre. The evidence from fossil vertebrates would accord with this, although I do not think it in any way confirms it.

others consider it as the earliest Tertiary, equivalent in age to the Thanet sands. Here, as in our own succession, the difficulty lies in the correlation of faunas of diverse facies. Into the place of these disputed formations it will not be necessary to go. It is sufficient to state that the latest unquestioned Cretaceous stage is the Danian and the earliest unquestioned Tertiary stage the Thanetian.

THANETIAN (CERNAYSIAN), EQUIVALENT TO TORREJON

The Cernay conglomerates, Rilly sands, and the La Fère glauconites have furnished a small fauna of mammals and reptiles, comparable in facies to our Torrejon and apparently of equal age. *Arctocyon*, *Dissacus*, and *Neoplagiaulax* are very characteristic types closely allied or identical with Torrejon genera. The remainder of the fauna affords rather indecisive comparison with the Torrejon except for *Pleuraspidotherium*, which¹⁸ is singularly like certain isolated teeth from the Paskapoo. A thorough revision of this Cernaysian fauna is very much needed, but there appears to be little present prospect of it.

Whether the Cernaysian fauna corresponds with the whole of the Thanetian or only a part of it is impossible to say.

LIST OF CERNAYSIAN FAUNA

Creodonta:

<i>Arctocyon primævus</i>	}	Close to <i>Clanodon</i> sp. div.
" <i>gervaisii</i>		
" <i>ducili</i>		
<i>Hyanodictis gaudryi</i>	}	= <i>Dissacus</i>
<i>Dissacus europæus</i>		

Insectivora:

<i>Tricuspidodon</i>	}	Possibly related to <i>Palæoryctes</i>
<i>Procynictis</i>		
<i>Orthaspidotherium</i>		
<i>Pleuraspidotherium aumonieri</i>	}	Cf. ? Paskapoo fauna
" <i>delessei</i>		
<i>Plesiadapis tricuspidens</i>	}	Possibly comparable with the small species of <i>Miocænus</i>
" <i>remensis</i>		
" <i>gervaisii</i>		
<i>Adapisorex gaudryi</i>	}	
" <i>chevilloni</i>		

Adapisoriculus minimus

Protoadapis copei

A doubtful primate

Multituberculata:

<i>Neoplagiaulax eocænus</i>	}	Close to <i>Ptilodus</i> sp. div.
" <i>marshii</i>		
" <i>copei</i>		

¹⁸ Auct. Osborn's figures in his review of the Cernaysian mammalia.

SPARNACIAN AND YPRESIAN EQUIVALENT TO WASATCH

The London Clay, Argiles plastiques of the Paris basin, and equivalent formations in Belgium and elsewhere contain the *Coryphodon* fauna, which extends through our Lower Eocene or Wasatch faunæ. The older part (Sparnacian) is probably equivalent to the Gray Bull or Systemodon Zone of the Wasatch, marked by the sudden appearance of *Coryphodon*, *Palæonictis*, *Eohippus*, *Pachyæna*. The newer part (Ypresian) may be more doubtfully compared with the upper part of our Wasatch, the Lysite and Lost Cabin (Heptodon and Lambdotherium zones), the evolution of the faunæ being on divergent lines, with no new invading migrants to link them together.

THE PUERCO HAS NO CERTAIN EQUIVALENT IN EUROPE

It is arbitrarily correlated by Osborn with the Montian. But the only mammal found in the Montian is *Coryphodon* from the upper beds of that horizon, and this, if correctly identified, would indicate not Paleocene, but Eocene age of a part of the formation. On the other hand, in the Lower Landenian of later age, according to Dollo, the only recorded vertebrate of any value in exact correlation is *Champsosaurus*, a characteristic Cretaceous-Paleocene genus. Dollo, however, correlates the horizon as Lower Eocene. In view of these contradictory data, and of the doubtful character of such slight evidence and the frequent confusion due to redeposit in these scattered littoral formations, it seems better to leave the Montian problem for our European confrères to solve and content ourselves with the reasonably certain data.

THE LANCE IS EQUALLY DIFFICULT TO CORRELATE

There are no European formations of corresponding facies in the late Cretaceous. Dinosaurs are found in the later Cretacic of Europe at least as late as the Mæstrichtian (= Upper Senonian or Danian), but not sufficiently abundant or complete to afford correlation data. The Gosau formation is of similar facies to the Lance, but is much older—Lower Senonian. No dinosaurs are found in the Montian or any of the European formations that are reckoned to the Tertiary. The Lance flora is shown by Knowlton to be nearly allied to the Fort Union flora, and through this to the Paleocene floras of Gelinden and Sezannes. But, as there are no late Cretacic floras of similar type to compare it with, it is *not* thereby shown to be post-Cretacic, as Stanton has observed.

FAUNAL MIGRATIONS AND DIASTROPHISM

In the foregoing discussion of the vertebrate faunas of the late Cretacic and early Tertiary the differences in faunæ have been ascribed to three factors: (1) Lapse of time; (2) Difference of facies; (3) Wide-spread migration movements. The first affords a measure of the time interval between two formations. The second, when occurring in superposed formations, indicates a change in local conditions, often accompanied by a stratigraphic break or unconformity. The third, occurring often independently of any local changes in environment, points to changes in the conditions in some other region, usually in the center of dispersal, where the migration movements originated.

It is usually assumed by paleogeographers that these changes consisted in the union of regions formerly isolated, permitting land animals to invade areas hitherto isolated. But it has been very conclusively shown by C. Hart Merriam that the range of land mammals is limited not so much by mountain barriers or even oceanic barriers as it is by climatic zones. This is also true of land reptiles, and presumably of the land fauna generally. A change in range is therefore conditioned not merely by the land connection which permits or facilitates the migration, but by climatic change which forces the movement through the changed environment. This climatic change will be largely dependent on great and wide-spread movements of elevation or submergence. A wide-ranging migration movement resulting in the simultaneous appearance in Europe and North America of identical new types is, therefore, to be ascribed not merely to such slight changes as might serve to make a land connection, but to a great movement of upheaval of the land, affecting a large part, if not the whole, of the intervening region from which the new types are presumably derived.

These great migration movements therefore I regard as caused by diastrophism. If the evidence is properly interpreted and the migrations adequately proved, they afford, it seems to me, the most reliable and in some sense the only evidence of diastrophism; for it is not possible, save through the evidence of the paleontologic record, to prove that the movements of which the stratigraphy gives evidence were simultaneous or to correlate them exactly in different regions. The extent and amount of the stratigraphic break between the Lance and the formations of the Montana group is a matter of dispute. But were it not, I fail to see how we could correlate it with the break between the European Cretacic and Tertiary series save through the faunal evidence.

FIGURE 3.—Division between Cretaceous and Tertiary Periods, as indicated by terrestrial Vertebrate Fauna of typical western Formations

As I read the evidence from the vertebrates it is to this effect :

(1) From the Belly River to the Lance there is a considerable lapse in time, but they represent the same faunal facies and they indicate that there was no great migration movement intervening, and hence *no great upheaval*, either continental or universal. There was undoubtedly a considerable local uplift along the Rocky Mountain ridges and extensive recession of the sea from the plains to eastward of them.

(2) Between the Lance and the Paleocene there is a somewhat smaller lapse in time, but a very marked change in fauna ; but they do not represent the same facies, and while a great migration movement is probably indicated by the extinction of the Dinosaur phyla and incoming of certain groups of placental mammals (Creodonta, Condylarthra, etcetera) its extent remains a little uncertain.

(3) Between the Paleocene and Eocene a great migration movement intervenes, the progressive orders of placental mammals, of turtles, and perhaps other groups appearing simultaneously in Europe and North America. The lapse of time between the uppermost Paleocene and lowest Eocene is slight.

If, therefore, we are to use diastrophic criteria as the basis of our geologic classification, the dividing line between Cretaceous and Tertiary should be drawn either between the Lance and the Paleocene or between the Paleocene and Eocene. It should *not* be drawn between Belly River and Lance.

It is perhaps apropos to recall that the late Professor Cope was for a long time of the opinion that the Paleocene should not be included in the Tertiary, but distinguished along with the Lance and associated faunæ as post-Cretaceous. Doctor Hay has also expressed the opinion that it might be better to include the Puerco and perhaps also the Torrejon in the Cretaceous.

CONCLUSIONS

The question to my mind shapes itself thus: Does the evidence conclusively support the present classification ; and, if not, is it sufficiently conclusive to warrant our changing it? I have indicated what I regard as the weight and trend of the vertebrate evidence. Without entering into any detailed criticism of the stratigraphic and paleobotanic evidence, a task for which others are far more competent, I may say that to me it appears to be inconclusive because it does not allow for the characteristics of epicontinental formations nor for the varying facies of faunas and

floras; that the asserted magnitude of the break between Laramie and Lance rests not on evidence, but on a definition of the Laramie (see Appendix B), and that no really adequate evidence has been adduced of its relations to the Cretacic-Tertiary break in Europe. The paleobotanic argument for placing the Lance in the Tertiary is the resemblance of its flora to that of the Paleocene and its great difference from that of the true Laramie. But there is no evidence that the Lance flora was absent from Europe in the late Cretaceous, and the Laramie clearly represents a different facies from the Lance. Doctor Knowlton has insisted strongly on the entire absence of dinosaurs in the true Laramie, apparently with the idea that it showed it to be much older than the Lance. But as the same phyla of dinosaurs are present in the older Belly River and in the newer Lance, their absence from the Laramie is obviously due to a difference in environmental conditions. The facies of the fauna is different and much, if not all, of the difference in flora should be ascribed to this cause.

For these and many other reasons, the evidence summarized by Doctor Knowlton in favor of transferring the Lance and associated formations to the Tertiary appears to me inconclusive, and it is directly in conflict with the evidence from fossil vertebrates, so far as I am able to understand it. But in view of this conflict, real or apparent, I do not regard the problem as a settled one. Until all the data have been brought into conformity and the exact position of the principal diastrophic break conclusively shown from more convincing data than are at present available, it seems to me better to hold to the current classification, which is at least supported by evidence better, in my opinion, than any that has been brought forward in favor of Doctor Knowlton's views.

APPENDIX A. ALLEGED OCCURRENCES OF DINOSAURS IN TERTIARY FORMATIONS

Doctor Knowlton has asserted that dinosaurs do occur in the Fort Union formation. The evidence, as far as I am acquainted with it, is that dinosaur remains have been found some hundreds of feet above an arbitrary line taken as the line of separation between Lance and Fort Union. They have not been found associated with Paleocene vertebrates; nor are they known to be different from the dinosaurs of the Lance beds beneath them. Fossil plants if found associated would give no trustworthy evidence, since the floras of the Lance and Fort Union are almost identical, most of the species being common to the two. The obvious inference would be that the dividing line, confessedly arbitrary, was

drawn in the wrong place. A precisely parallel case is shown by Sinclair in his contribution on the Puerco-Torrejon stratigraphy. The division between these two formations was arbitrarily placed by Gardner at a certain sandstone level between the upper and lower fossiliferous beds, the upper carrying the Torrejon fauna, the lower the Puerco fauna. Subsequently Granger and Sinclair found the Torrejon fauna at a level 100 feet below Gardner's line of division. The natural conclusion was that the division line had been placed at least 100 feet too high up.

As to the alleged occurrences of Dinosaurs associated with Tertiary mammals in Patagonia, this is positively asserted by Ameghino and Roth, who, however, consider the beds Cretaceous, not Tertiary. Loomis, who has recently collected in these formations, has shown that the mammal-bearing beds occur in stream-channels and pockets in the older formations, and believes that the reports of dinosaur remains in strata "above" the mammal-bearing beds are due to errors in stratigraphy in failure to recognize these conditions of deposition. There would indeed be no *a priori* improbability in the survival of dinosaurs in the isolated continent of South America after their extinction in the northern world; but the evidence that they did so seems open to very serious question.

APPENDIX B. UNCONFORMITY BETWEEN THE LARAMIE AND THE LANCE

"The asserted magnitude of the break between Laramie and Lance rests not on evidence but on a definition of the Laramie." This remark appears to require explanation, although the subject is outside the scope of this paper. The evidence for an "unconformity of 20,000 feet" is not, as one might suppose from Knowlton's repeated references to it, derived from measurements of the strata removed beneath an angular unconformity. It is based on the occurrence in the basal conglomerates of the Lance and equivalents of pebbles derived from the older formations of (presumably) the adjoining mountains. The *assumption* is made that the Laramie, along with the rest of the underlying formations, had extended over the area of these mountains and was upheaved, swept away by erosion, and the underlying formations cut down to the Paleozoic series, from which these pebbles are derived, during the interval between Laramie and Lance. But although Lee has reported evidence for such an extension of the older Cretaceous beds in New Mexico, there is no evidence that the Laramie had the same extension, save its definition as the "latest conformable member of the Cretaceous succession." It was to this circumstance that the remark had reference. It appears to me, on the other hand, that whatever inferences may have been made from

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the definition, it is very improbable that the Laramie was coextensive with the original limits of the older Cretaceous formations. Between the Niobrara and Laramie there was a widespread and considerable uplift on the plains, probably much intensified along the mountain ridges, and the erosion due to the latter probably supplied the materials for the Laramie sedimentation, as their further uplift did for the subsequent continental formations of that region.

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