

Article XI.—TERTIARY MAMMAL HORIZONS OF NORTH AMERICA.

*Abstract of a Preliminary Study.*¹

BY HENRY FAIRFIELD OSBORN.

It appears wise to publish a preliminary outline of a fuller discussion of this subject. This outline is accompanied by some geological observations on the section between northwestern Nebraska and the Black Hills, and by preliminary Eocene-Pleistocene correlations (Figs. 1-3).

The chief authorities are:

Osborn, Correlation Papers (1899-1900).²

Matthew, Classification of the Freshwater Tertiary (1899).³

Depéret, L' évolution des Mammifères tertiaires (1905).⁴

Among earlier contributors are Hayden, Leidy, Marsh, Cope, King, Scott, and Osborn; among more recent contributors are Peall, Merrill, Matthew, Hatcher, Wortman, Darton, J. C. Merriam, Peterson, Douglass, Gidley, Granger, Sinclair, Loomis. Full acknowledgments will be made in the final paper. Chief acknowledgment is due here to Messrs. Matthew and Granger.

1. EOCENE CORRELATED SECTIONS.

The accompanying Eocene correlation (Fig. 1), chiefly the work of the writer, with the assistance of Mr. Walter Granger, is explained as follows:

(1) The combination of various Eocene sections by Hayden, Wheeler, Cope, King, Wortman, Matthew, Granger, Veatch, Osborn, in the Rocky Mountain basins gives us a total thickness of 7200 feet. (2) The only section based on a careful survey is the Bridger; the Bridger deposits prove to be largely wind- and partly water-borne volcanic materials (Sinclair), and this is probably true of other Eocene deposits. (3) The formation names are all geographical. (4) The chronological correlation of the sections is entirely faunistic or based upon our present knowledge of the

¹ Originally prepared as an address before the International Geological Congress, City of Mexico, 1906 (not delivered). Abstract presented before the National Academy of Sciences, Boston, Thursday, November 22, 1906; also before the Society of Paleontologists, New York, December 27, 1906. To be published in full in the Bulletin of the U. S. Geological Survey.

² Ann. N. Y. Acad. Sci., Vol. XIII, 1900, pp. 1-72.

³ Bull. Amer. Mus. Nat. Hist., Vol. XII, 1899, pp. 19-77.

⁴ Comptes rendus, Acad. Sci. Paris, 1905-1906.

existing stratigraphic position of characteristic mammals; to these faunal levels in different formations the faunistic names *Polymastodon*, *Pantolambda*, *Coryphodon* Beds, etc., some new, some already in use, are applied. (5) The sections and correlations are to be considered as of a preliminary and provisional character.

2. OLIGOCENE AND LOWER MIOCENE.

Geological Notes by the Writer (1906), South Dakota and Northwest Nebraska.

Fig. 2 is a graphic interpretation of the wonderful deposits of the Big Bad Lands, and represents an idealized view looking southeast from the Cheyenne River (South Dakota), over the rising levels of the Oligocene, beyond and across the White river, through the Lower Miocene, to the summit of Porcupine Butte, a conspicuous land mark which caps the Upper Rosebud on Porcupine Creek, a southern tributary of the White River.

The present interpretation¹ of this continuous Oligocene and Lower Miocene section is to divide the deposits into two contemporaneous series, namely: (1) River and channel deposits, (2) overflow finer deposits, as follows:

	A. River and channel deposits: sandstones and conglomerates.	B. Overflow deposits: fine sandstones, clays, volcanic ash.
Lower Miocene	Gering Sands and Conglomerates.	Rosebud.
Upper Oligocene	Protoceras Sandstones.	Leptauchenia, or upper Brulé.
Middle Oligocene	Metamynodon Sandstones.	Oreodon or Lower Brulé.
Lower Oligocene	Titanotherium Sandstones.	Chadron Formation.

These old river channels vary from some hundreds of feet to more than a mile in width.

3. Volcanic ash layers occur extensively in the Mountain basin deposits and as thinner layers in many of the Plains deposits.

¹ This interpretation represents the thought of several observers, especially of Matthew, Hatcher, Scott and Osborn.

OLIGOCENE & LOWER MIOCENE.

N. NEBRASKA & S. DAKOTA.

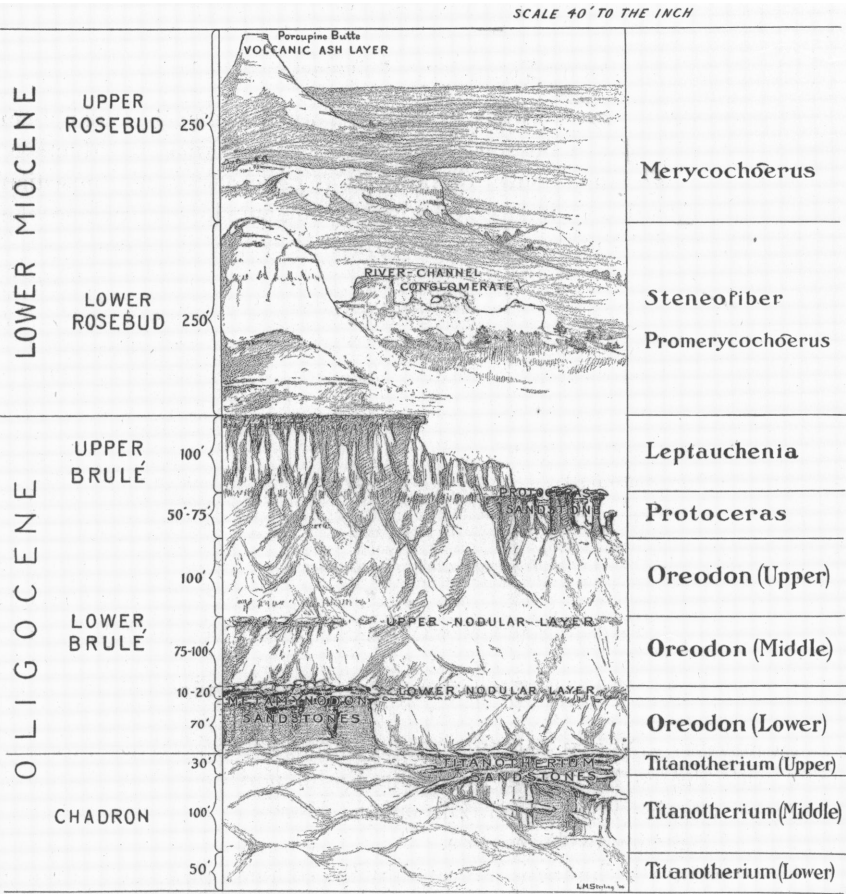


Fig. 2. Idealized birds-eye view of the great Badlands of South Dakota, looking south-east across the Cheyenne and White Rivers to Porcupine Butte, on Porcupine Creek, Pine Ridge Reservation, South Dakota.
Ancient river channels, Titanotherium Sandstones, Metamynodon Sandstones, Protoceras Sandstones, river channel conglomerates.
Clays and sandstones of the Titanotherium region, Leptauchenia and Rosebud beds.

EOCENE.

I. FIRST FAUNAL PHASE, BASAL EOCENE. ARCHAIC MESOZOIC MAMMALS
WITH PARTLY SOUTH AMERICAN, PARTLY EUROPEAN AFFINITIES.

POSTCRETACEOUS OR BASAL EOCENE.

1. Puerco Formation. Polymastodon Beds.

HOMOTAXIS. NORTH AMERICA: Puerco Formation (500 feet) San Juan Basin, New Mexico; a portion of the Fort Union Formation, Montana. S. AMERICA: A contemporary or previous (Cretaceous) land connection with South America is indicated by similar mammals occurring in the Notostylops Beds,¹ Upper Cretaceous or Basal Eocene of Patagonia.

Summary:

Archaic Triassic mammals	4 genera	6 species
“ Cretaceous “	15 “	30 “
	19 genera	36 species
Modernized or distinctively Tertiary mammals	00 “	00 “

ÉTAGE THANÉTIEN.

POSTCRETACEOUS OR BASAL EOCENE.

2. Torrejon Formation. Pantolambda Beds.

HOMOTAXIS. NORTH AMERICA: Torrejon Formation (300 feet), continuous with Puerco Formation, San Juan Basin, northwest New Mexico; a portion of the Fort Union Formation, Montana (Douglass,² Farr). EUROPE: Thanétien or Cernaysien.

Homotaxis with Europe is indicated by the common presence in France and North America of similar stages of Plagiaulacidae, Arctocyoniidae, Mesonychidae, (?) Triisodontidae. Other identifications are very uncertain.

¹ Closer comparison of the Puerco and Notostylops faunæ is very desirable. It appears probable that the affinities will prove to be very close.

² Douglass, Earl. 'A Cretaceous and Lower Tertiary Section in South Central Montana,' Proc. Amer. Phil. Soc., Vol. XLI, No. 170, pp. 207-224. Also 'New Vertebrates from the Montana Tertiary'. Ann. Carnegie Museum, Vol. II, No. 2, 1903, pp. 145-200.

Summary:

Archaic Triassic stock	4 genera	5 species
“ Cretaceous “	21 “	45 “
Total	25 genera	50 species
Modernized Tertiary stock	1 genus	1 “

II. SECOND FAUNAL PHASE, LOWER EOCENE. FIRST MODERNIZATION, INVASION OF THE ARCHAIC BY THE MODERN FAUNA. SOUTH AMERICAN LAND CONNECTION INTERRUPTED. CLOSE FAUNAL CONNECTION WITH WESTERN EUROPE. INITIAL ELIMINATION OF THE ARCHAIC FAUNA IN COMPETITION WITH THE MODERN.

ÉTAGES SPARNACIEN, YPRÉSIEN.

LOWER EOCENE.

3. Wasatch Formation. Coryphodon Beds.

HOMOTAXIS. NORTH AMERICA: Wasatch Formation, in part (1750 feet), Evanston, western Wyoming, the typical horizon; San Juan (Formation) basin of northern New Mexico (1500 feet); in the Big Horn (Formation) basin of northern Wyoming (2500 feet); in the lower portion of the Huerfano Formation near Spanish Peaks, Colorado. S. AMERICA: No South American affinities are known. EUROPE: Strong affinities with the Étage Suessonien, or Étage Sparnacien and Étage Yprésien (Londinien) of France are found in the evolution of the archaic and in the migrations of the modern mammalia of this period.

Summary:

Triassic mammals	00 genera	00 species
Other archaic mammals	23 “	51 “
Modernized mammals	18 “	47 “

III. THIRD FAUNAL PHASE, LOWER TO UPPER EOCENE. ABSENCE OF FRESH EURASIATIC OR NORTHERN MIGRATION. CONTINUATION OF SIMILAR ENVIRONMENTAL CONDITIONS. DESCENDANTS OF THE ARCHAIC AND MODERNIZED MAMMALS SLOWLY EVOLVING AND COMPETING WITH EACH OTHER DURING THE LOWER AND MIDDLE EOCENE. GRADUAL ELIMINATION OF THE ARCHAIC MAMMALS. GRADUAL DIVERGENCE FROM THE FAUNA OF WESTERN EUROPE, AND LITTLE EVIDENCE OF FAUNAL INTERCHANGE. ESTABLISHMENT OF NORTH AMERICAN UNGULATA-ARTIODACTYLA.

LOWER EOCENE.

4. Wind River Formation. Lambdotherium and Bathypsis Beds.¹

HOMOTAXIS. NORTH AMERICA: Wind River Formation of Wyoming (1200–1400 feet); Lower Huerfano Formation of Colorado, in part (300 feet). EUROPE: provisional homotaxis, Lower Wind River=Yprésien of France, in part. Upper Wind River=Lutétien inférieur of France.

The balance is now for the first time in favor of the modernized mammals, as shown in the following summary:

Archaic or Cretaceous mammals	11 genera	22 species
Modernized or Tertiary “	18 “	30 “

Preliminary Faunal Divisions.

Lower Wind River, A, 500 feet, Red Beds, Lambdotherium Beds. Containing *Coryphodon*, *Phenacodus*, *Eohippus*, *Lambdotherium* *Bathypsis*, etc.

Upper Wind River, B, 800 feet, Eotitanops Beds. Containing *Coryphodon*, *Phenacodus*, also *Eotitanops*, gen. nov. (“*Palaeosyops*”) *borealis*. This stage approximates the Lutétien inférieur of France (Argenton, older Lissieu, older Egerkingen) and Bracklesham of England.

ÉTAGES LUTÉTIEN SUPÉRIEUR, BARTONIEN.

MIDDLE EOCENE.

5. Bridger Formation. Orohippus Beds. Uintatherium Beds.

HOMOTAXIS. NORTH AMERICA: Bridger Formation of western Wyoming (1800 feet), Lower Washakie Formation (250 feet) of Wyoming in part; Upper Huerfano Formation of Colorado, in part; Lower Uinta Formation of n. Utah (1150 feet), in part. EUROPE: provisional homotaxis, Lower Bridger=Lutétien supérieur. Calcaire grossier of Paris, Issel, of France. Buchsweiler. Later fissure deposits of Lissieu and Egerkingen. Upper Bridger=Bartonien (Calcaire de Saint Ouen, Grès de Cesséras) in part.

Fauna. The whole vertebrate fauna, reptilian and mammalian, of this period is the most completely known of that of any of the Eocene phases.

 The mammalian summary is as follows:

¹ Professor F. B. Loomis has recently (Dec. 1906) completed an accurate section of the Wasatch (Big Horn) and Wind River formations, which will be available for the final report.

Archaic Cretaceous mammals	15 genera	35 species
Modernized Tertiary “	57 “	146 “
	72 “	181 “

6. Washakie Formation. Uintatherium Beds, Eobasileus¹ Beds.

HOMOTAXIS. NORTH AMERICA: Lower Washakie Formation of E. Wyoming, equivalent to the Upper Bridger Formation and Lower Uinta Formation. Upper Washakie Formation, equivalent to Middle Uinta Formation. EUROPE: Bartonien of France.

The mammalian fauna of this stage, which has long been recognized (Osborn, 1880) as in general intermediate between the Bridger and Uinta, is sparsely known. The American Museum expedition (Osborn, Granger, 1906), has very precisely fixed its age as follows:

Faunal Divisions.

B. UPPER WASHAKIE. Eobasileus Beds.

Grey and Green Beds (250 feet), Haystack Mountain, containing *Loxolophodon*, ?*Tinoceras*, *Dolichorhinus cornutus*, *Perissodactyla*-*Amynodontidae*, *Artiodactyla*-*Elotheriidae*.

A. LOWER WASHAKIE. Uintatherium Beds.

Brown Beds, (250 feet). Containing *Uintatherium*. Among *Perissodactyla*, “*Telmatherium*” *megarhinum*. Equivalent to Upper Bridger: C, D, E.

ÉTAGES BARTONIEN, IN PART, LUDIEN (LIGURIEN), IN PART.

UPPER EOCENE AND LOWER OLIGOCENE.

7. Uinta Formation. Uintatherium Beds, Eobasileus Beds, Diplacodon Beds.

HOMOTAXIS. NORTH AMERICA: Lower Uinta Formation (800 feet), equivalent to Upper Bridger Formation and Lower Washakie Formation; Middle Uinta Formation (350 feet), equivalent to Upper Washakie Forma-

¹ The name *Loxolophodon* commonly applied by Cope and others to the Dinocerata of this stage is preoccupied for a Wasatch Coryphodont, *Loxolophodon semicinctus* Cope. *Tinoceras* is equally inapplicable because first applied to a Bridger Uintathere

tion. True or Upper Uinta Formation (600 feet), closely approaching if not equivalent to the lowermost levels of the White River Oligocene. EUROPE: homotaxis is now very difficult owing to the *absolute dissimilarity* of the European and North American faunæ in these stages. It is very important to note: (1) that in the Bartonien of France, which is reckoned as Upper Eocene but not the highest stage, there appear the families Artiodactyla-Anthracotheriidae and Perissodactyla-Chalicotheriidae; (2) that in the Ludien, which is reckoned as uppermost Eocene, there appear the families Marsupialia-Didelphyidae, and Rodentia-Sciuridae. All these four families are not known to occur in North America until the Lower Oligocene Plains Formation.

Its mammalian fauna is sparsely known, as follows:

Archaic Cretaceous mammals	4 genera	5 species
Modern or Tertiary mammals	25 "	37 "

Provisional Faunal Levels.

Upper Uinta,¹ C, 600 feet. Diplacodon Beds.

Distinguished by absence of Dinocerata. Presence of Canidae.

Middle Uinta, B, 350 feet, Eobasileus Beds.

Containing ?Dinocerata, *Loxolophodon*, and especially *Dolichorhinus cornutus*. Creodonta-Mesonychidae (last appearance). Equivalent to Upper Washakie, B.

Lower Uinta, A, 800 feet, Brown Beds. ?Uintatherium Beds.

?Equivalent to Upper Bridger, C, D, and to Lower Washakie, A.

Faunistic Separation from Western Europe in beginning of the Upper Eocene.

	Families Peculiar to Europe	Families common to W. Europe and N. America	Families Peculiar to N. America.
Amblypoda			1
Insectivora	?	?	1
Creodonta		1	2
Primates	2	0	2
Rodentia	1	0	1
Carnivora	0	1	0
Artiodactyla	6	0	4
Perissodactyla	1	2	3
Cheiroptera	1	?	?
	11	4	13

Thus in the Mountain Region Upper Eocene there are only 4 to 5 families in common with Europe, in a total of 28-30 families, whereas in the Oligocene Mountain, and, Plains regions (see p. 245) there are 21 families in common with Europe in a total of 48 families.

¹ Prof. Scott suggests that C, or Upper Uinta, should be placed in the Lower Oligocene. Peterson did not observe any nonconformity between C and B.

OLIGOCENE.

IV. THE FOURTH MAMMALIAN PHASE, LOWER OLIGOCENE. SECOND MODERNIZATION. FIRST KNOWLEDGE OF THE GREAT PLAINS FAUNA. ABSENCE OF ALL ARCHAIC MAMMALS EXCEPT HYÆNODONTIDÆ. REESTABLISHMENT OF FAUNAL RESEMBLANCE WITH WESTERN EUROPE.

North America.—A second modernization, as remarkable as the first or Wasatch modernization, is shown by the first appearance of 16 families of mammals which have not as yet been recognized certainly in the Mountain Eocene Basins, namely: 6 existing families of Rodents, 4 existing families of Carnivora, 4 existing families of Insectivora, 1 existing family of Perissodactyla, 1 now extinct European family of Artiodactyla.

Europe.—A very similar modernization occurred in western Europe.¹ In the Ludien (= Lower Oligocene Lapparent, = Uppermost Eocene Depéret), Sannoisien and Stampien (= Lower Oligocene), 17 modern or still existing families appear for the first time which have not been found in earlier geological stages. Of these new families 6 appeared simultaneously in North America.

	W. European families not found in North American Oligocene.	Families common to W. Europe and N. America by contemporaneous or previous migration.	N. American Families not found in W. European Oligocene.
Edentata	1	0	0
Rodentia	5	4	3
Insectivora	1	3	2
Creodonta	0	1	0
Marsupialia	0	1	0
Carnivora	3 (sub. fam.)	3	1
Artiodactyla	5	2	4
Perissodactyla	1	7 ²	1
	16	21	11

Thus: (1) The faunal community with western Europe becomes much closer than in the Upper Eocene (see p. 244). (2) The strongest community is among the Perissodactyla. (3) The least community is among the Artiodactyla.

¹ This generalization is based upon the faunal lists of Depéret (*op. cit.*, 1905).

² The Titanotheriidae, found in central Europe, are included in this figure.

ÉTAGE SANNOISIEN (TONGRIEN INFÉRIEUR).

LOWER OLIGOCENE.

8. Chadron Formation. Titanotherium Beds.

HOMOTAXIS. NORTH AMERICA: Horizon A of Hayden and Leidy; Lower White River group, Chadron Formation (200 feet) (Darton); Titanotherium Beds (Hayden) of South Dakota and western Nebraska; Horsetail Creek Formation (Matthew) of northeast Colorado. Pipestone Creek Formation (Douglass) of Montana. Swift Current Creek, Cypress Hills, of British Columbia, etc. EUROPE, *provisional homotaxis*: Ludien, in part; Sannoisien (Tongrien Infér.); Stampien (Tongrien Supér.).

ÉTAGE STAMPIEN (TONGRIEN SUPÉRIEUR).

MIDDLE OLIGOCENE, FIRST PHASE.

9. Lower Brulé Clays (Darton). Oreodon Beds, and Metamynodon Sandstones.

HOMOTAXIS. NORTH AMERICA: Horizons B and C of Hayden and Leidy; Lower Brulé Clays (Darton), Metamynodon Sandstones (Wortman),¹ with widespread similar exposures in northeast Colorado, Cedar Creek Beds, Matthew; in southeast Wyoming; in South Dakota; in northwest Nebraska. EUROPE. Approximate homotaxis with the Stampien or Oligocène Moyen of Europe is indicated by similar stages in the evolution of Artiodactyla-Anthracotheriidae (*Hyopotamus*), of Perissodactyla-Amynodontidae (e. g. *Metamynodon*, *Cadurcotherium*), -Tapiridae, -Rhino-cerotidae, -Chalicotheriidae. Also by the disappearance in both countries of Perissodactyla-Amynodontidae, Creodonta-Hyænodontidae.

MIDDLE OLIGOCENE, SECOND PHASE.

10. Upper Brulé Clays. Leptauchenia Beds, and Protoceras Sandstones.

HOMOTAXIS. NORTH AMERICA: Upper White River Formation of South Dakota, Horizon C of the Hayden and Leidy Section; Brulé Clays (Upper part) Darton, 1897. Leptauchenia Beds (Wortman), and Protoceras Sandstones (Wortman). The sandstones contain the forest and fluviatile

¹ Wortman, J. L. On the divisions of the White River or Lower Miocene of Dakota. Bull. Amer. Mus. Nat. Hist., Vol. V, 1893, pp. 95-105.

fauna, the Leptauchenia Clays contain the plains fauna. Lower part of Cañon Formation (Matthew) of northeast Colorado. White Buttes (Martin) of North Dakota. Lower John Day Formation of Oregon (250-300 feet, tuffs).

ÉTAGE AQUITANIEN.

1. UPPER OLIGOCENE, FIRST PHASE.

Middle John Day Formation. Diceratherium Beds.

HOMOTAXIS. AMERICA: Middle John Day Formation of Oregon (Diceratherium Beds Wortman), 500 to 1000 feet, typical mountain fauna. EUROPE: Aquitanien. Homotaxis with the Aquitanien of France, typified by the Saint Gérard-le-Puy (Allier, France) fauna, is close, as indicated by similar stages in the evolution of Perissodactyla-Tapiridæ, -Diceratheriinae, -Aceratheriinae, -Chalicotheriida, and other families.

NOTES AS TO TRANSITIONAL UPPER OLIGOCENE AND LOWER MIOCENE FORMATIONS.

1. The Upper John Day Formation or Promerychochærus Beds of the Mountain Region of Oregon, and the Gering and Arikaree Formations (Darton) or Rosebud Formations (Matthew) of the Plains Region, northern Nebraska, may be regarded as transitional between the Oligocene and Miocene as these divisions are employed in France.¹ By analogy with Europe the older fauna of these beds is slightly subsequent to that of Saint-Gérard-le-Puy, that is, Upper Oligocene or Aquitanien, which, it is true, several authorities place in the Lower Miocene. The upper John Day of the Mountain Region is somewhat older than the Lower Rosebud of the Plains although both contain *Promerychochærus*.

2. Recent explorations in the upper portion of the Harrison beds (Agate Spring Quarry, Peterson²) reveal a fauna which partly resembles that of the Upper Oligocene of France; at the same time it contains *Amphicyon*, a characteristic Miocene form. Until more exact comparisons can be made this fauna should be considered transitional from the Oligocene to the Lower Miocene inclusive.

¹ Careful comparison of *Steneofiber* and other forms leads Matthew to the opinion that the Upper John Day is of *slightly* more recent age than St. Gérard-le-Puy.

² "From these discoveries it appears that the Miocene section from the Oligocene to the top of the Nebraska Beds, in this general locality, may perhaps have to be regarded as Lower Miocene." Peterson, "The Agate Spring Fossil Quarry," 1906, p. 491.

PROVISIONAL CORRELATION OF THE UPPER TERTIARY.

W D. Matthew-H. F. Osborn. - November, 1906.

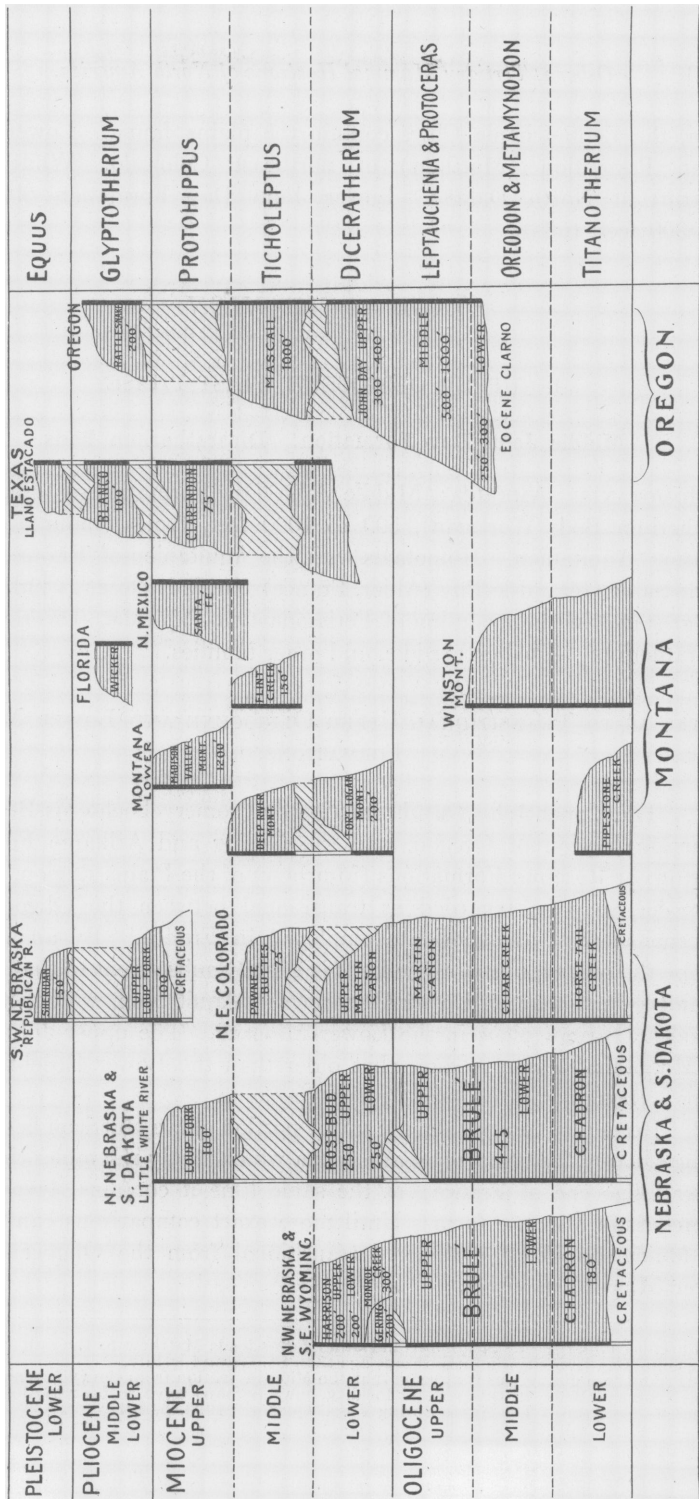


Fig. 3. Provisional correlation of the Upper Tertiary. Under each column; the line separating the Upper Oligocene from the Lower Miocene is drawn provisionally. See p. 249.

MIOCENE.

ÉTAGES AQUITANIEN, LANGHIEN.

TRANSITION: UPPER OLIGOCENE AND LOWER MIOCENE.

Arikaree Formation. Promerycochærus Beds.

HOMOTAXIS. AMERICA: EARLIER PHASE. Mountain Region, Upper John Day Formation of Oregon, Promerycochærus Beds, Wortman, 300-400 feet of tuffs.

LATER PHASE. Great Plains, Horizon D, of Hayden and Leidy. Gering Formation (Darton, 1897), (= Lower levels, local, 200 feet). Arikaree Formation (Darton) (= Middle and Upper levels, 800 feet). Monroe Creek Formation (= lower Arikaree) and Harrison Formation (= upper Arikaree, Hatcher) of northwestern Nebraska and southwestern Wyoming. Rosebud Formation (Matthew) of southern South Dakota, Martin Cañon (upper levels) of northeastern Colorado (Matthew). Fort Logan Formation (or Lower Deep River) of Montana. Cañon Ferry Formation (Douglass) of Montana.

V. FIFTH FAUNAL PHASE. FRESH MIGRATIONS VIA EURASIA. FIRST APPEARANCE OF AFRICAN PROBOSCIDEA, OF TRUE FELINÆ AMONG THE FELIDÆ, OF SHORT-LIMBED TELEOCERINÆ AMONG RHINOCEROTIDEA, OF CERVIDÆ, ANIMALS OCCURRING IN THE LOWER MIOCENE OF EUROPE. EVIDENCE OF INCREASING SUMMER DROUGHTS.

ÉTAGES LANGHIEN, HELVÉTIEN.

MIDDLE MIOCENE OR LOWER AND MIDDLE MIOCENE.

Upper Deep River Formation. Ticholeptus Beds.

HOMOTAXIS. AMERICA: CENTRAL PLAINS. Horizon E of Hayden and Leidy, 'Pawnee Creek' Formation (Matthew) of northeastern Colorado, 75 feet; immediately overlying the Harrison beds. ?Panhandle Formation (Gidley) of northwestern Texas. NORTHERN PLAINS, Upper Deep River Formation (Smith Creek) or Ticholeptus Beds of Montana; Flint Creek Beds (150 feet) of Montana; Laramie Peak of Wyoming. MOUNTAIN

REGION, Mascall Formation (1,000 feet) capping the Columbia lava (1000 feet) which in turn overlies the Upper John Day Formation (lower part). The Colorado (Matthew) and Montana (Scott, Douglass) fauna is closely similar.

ÉTAGE TORTONIEN.

UPPER MIOCENE.

Loup Fork Formation. *Protohippus* Beds.

HOMOTAXIS. NORTH AMERICA: PLAINS REGION. The typical Loup Fork (of Hayden) of South Dakota and northwestern Nebraska, near Ft. Niobrara (100 feet) renamed 'Nebraska Formation' by Scott to distinguish it from other levels; Ogallala Formation (in part) Darton of Nebraska and South Dakota; Santa Fé Marls of New Mexico; Clarendon Beds (Cummins) Llano Estacado, northwestern Texas (75 feet). NORTHERN PLAINS, Madison Valley Beds, Montana (120 feet). EUROPE: Tortonien, Grive-St.-Alban (Isère), Steinheim (Würt.). The Loup Fork mammals, although including *Hipparion*, are not quite so modernized as those of Eppelsheim and Pikermi which we regard as lower Pliocene.

PLIOCENE.

ÉTAGES MESSINIEN, PLAISANCIEN.

HOMOTAXIS. Pliocene homotaxis must be prefaced by the statement that the fauna is very sparsely and imperfectly known as yet, and that correlations with Europe are very provisional. The gaps will undoubtedly be filled in eventually.

An early phase, which may be termed the 'Republican River Formation,' is provisionally and subject to further exploration distinguishable (Matthew) from the typical Loup Fork of Hayden, and presents certain parallels with the *Lower Pliocene* of Europe, if not of more recent age. It is with difficulty distinguishable from the Loup Fork, whereas it is widely separate from a second and much later phase, represented by the Blanco Beds of northwestern Texas, which is much more recent in its fauna.

LOWER PLIOCENE OR FIRST PHASE.

Republican River Formation. Peraceras Beds.

HOMOTAXIS. AMERICA: Republican River Beds or "Upper" Loup Fork (100 feet); of northwestern Kansas Ogallala Formation (in part) Darton, of northern Nebraska; Archer Formation of Florida, in part, Rattlesnake Formation, John Day Valley, Oregon. EUROPE: Messinien, Eppelsheim in northern Europe; Pikermi in Greece. Mt. Léberon (Vaucluse).

VI. SIXTH FAUNAL PHASE, LAND CONNECTION WITH SOUTH AMERICA REESTABLISHED. INVASION OF SOUTH AMERICAN EDENTATA—GRAVI-GRADA AND—GYLPTODONTIA. MIGRATION OF NORTH AMERICAN MAMMALS TO SOUTH AMERICA.

The Blanco formation of Texas is decidedly distinct and more recent than the typical Loup Fork, the Republican River, or the Rattlesnake.

ÉTAGE ASTIEN.

MIDDLE PLIOCENE OR SECOND PHASE.

Blanco Formation. Glyptotherium Beds.

HOMOTAXIS. NORTH AMERICA: PLAINS FAUNA, Blanco Formation (Cummins and Cope) 100 feet, Llano Estacado of Texas; Ogallala Formation (Darton) northwestern Nebraska (300 feet). MOUNTAIN FAUNA, Rattlesnake Formation, John Day, Oregon (200 feet).

ÉTAGE SICILIEN.

UPPER PLIOCENE OR THIRD PHASE. UNRECOGNIZED.

Elephas Beds?

In Europe the Uppermost Pliocene is distinguished by the disappearance of *Hipparion* and the advent of *Equus* (*E. stenonis*), also of *Elephas* (*E. meridionalis*).

This phase has not been recognized in America. It is probable, however, that certain levels in Texas, Nebraska and elsewhere, now classed as Lower

Pleistocene, and containing *Elephas imperator* (an animal analogous to *E. meridionalis*), as well as *Equus* will prove to represent the American Upper Pliocene.

- VII. SEVENTH FAUNAL PHASE, PLEISTOCENE. INCREASING COLD, MOISTURE, AND FORESTATION. THIRD MODERNIZATION BY A GRADUAL EURASIATIC INVASION OF HARDY, FOREST, FLUVIATILE, MOUNTAIN (ALPINE), PLAINS, AND BARREN-GROUND FAUNA. GRADUAL EXTINCTION OF THE LARGER UNGULATA, OF THE NATIVE NORTH AMERICAN STOCKS, OF THE SOUTH AMERICAN INVADING STOCKS, OF THE MIOCENE INVADING EURASIATIC AND AFRICAN STOCKS.

PLEISTOCENE.

LOWER PLEISTOCENE. PRE-GLACIAL.

Our knowledge of the mammals in this period is still confined to the Western Plains and Mountains.

Sheridan Formation. Equus Beds.

HOMOTAXIS. NORTH AMERICA: *Plains and forest border fauna*, Sheridan Formation (Scott) or *Equus Beds*, Hay Springs, of northwestern Nebraska; Rock Creek Formation (Gidley) of Tule Cañon, Llano Estacado, Texas. Widely scattered and numerous deposits in Great Plains and Mountain Regions. EUROPE: Preglacial. Forest Beds of Norfolk (England); St. Prest (Eure-et-Loir); Durfort (Gard), containing *Elephas meridionalis* (last appearance). The European fauna of this period includes (Osborn, 1900): 12 Pliocene species, 32 Pleistocene species and races, now extinct, 17 living species, (7 Insectivora, 1 Cheiroptera).

EARLY PHASES OF THE MIDDLE PLEISTOCENE.

In the early or Glacial phases *Cervus* does not appear. The Camelidæ, Equidæ, Tapiridæ, Edentata-Gravigrada and Elephantidæ still survive. Extinct species of modern genera appear and many modern species appear.

The earliest phase, corresponding with the earliest mid-Pleistocene of Europe, is probably at present unrecognized in America.

LATE PHASES OF THE MIDDLE PLEISTOCENE.

HOMOTAXIS. AMERICA: Potter Creek Cave, Shasta County, California Silver Lake, Oregon.

Environmental conditions on the Pacific coast were different from those in the Middle and Eastern States: (1) All glaciation on the Pacific Coast was comparatively late in the Pleistocene and of the Alpine type (Sinclair). (2) It is quite possible therefore that many types of mammals (elephants, mastodons, camels, bison) survived in the comparatively mild climate of the Pacific coast after they had become extinct in more easterly regions (Sinclair).

1. Potter Creek Cave. The very rich Potter Creek Cave fauna¹ is regarded by Merriam and Sinclair² as a late phase of the Middle Pleistocene, even as late as the last quarter of the Pleistocene. It contains 5 extinct genera and 52 species of which 21 are extinct and 31 are still existing. It is chiefly a forest fauna; forest types are numerous and plains types are lacking.

LATE PHASE OF MIDDLE PLEISTOCENE.

HOMOTAXIS. AMERICA: Port Kennedy Cave, Chester County, Pennsylvania.

The Port Kennedy Cave³ contains 66 species, including 40 extinct species (fide Cope, Mercer).

¹ Sinclair, Wm. J. A Preliminary Account of the Exploration of the Potter Creek Cave. Shasta County, California. *Science*, N. S., Vol. xvii, No. 435, May 1, 1903, pp. 708-712.

² 'The Exploration of the Potter Creek Cave.' Univ. of California Publications, Vol. II, No. 1, 1904.

³ Mercer, H. C. 'The Bone Cave at Port Kennedy, Pennsylvania.' *Jour. Acad. Nat. Sci. Phila.*, Vol. XI, Pt. 2, 1899.

ROCKY MOUNTAIN BASIN DEPOSITS

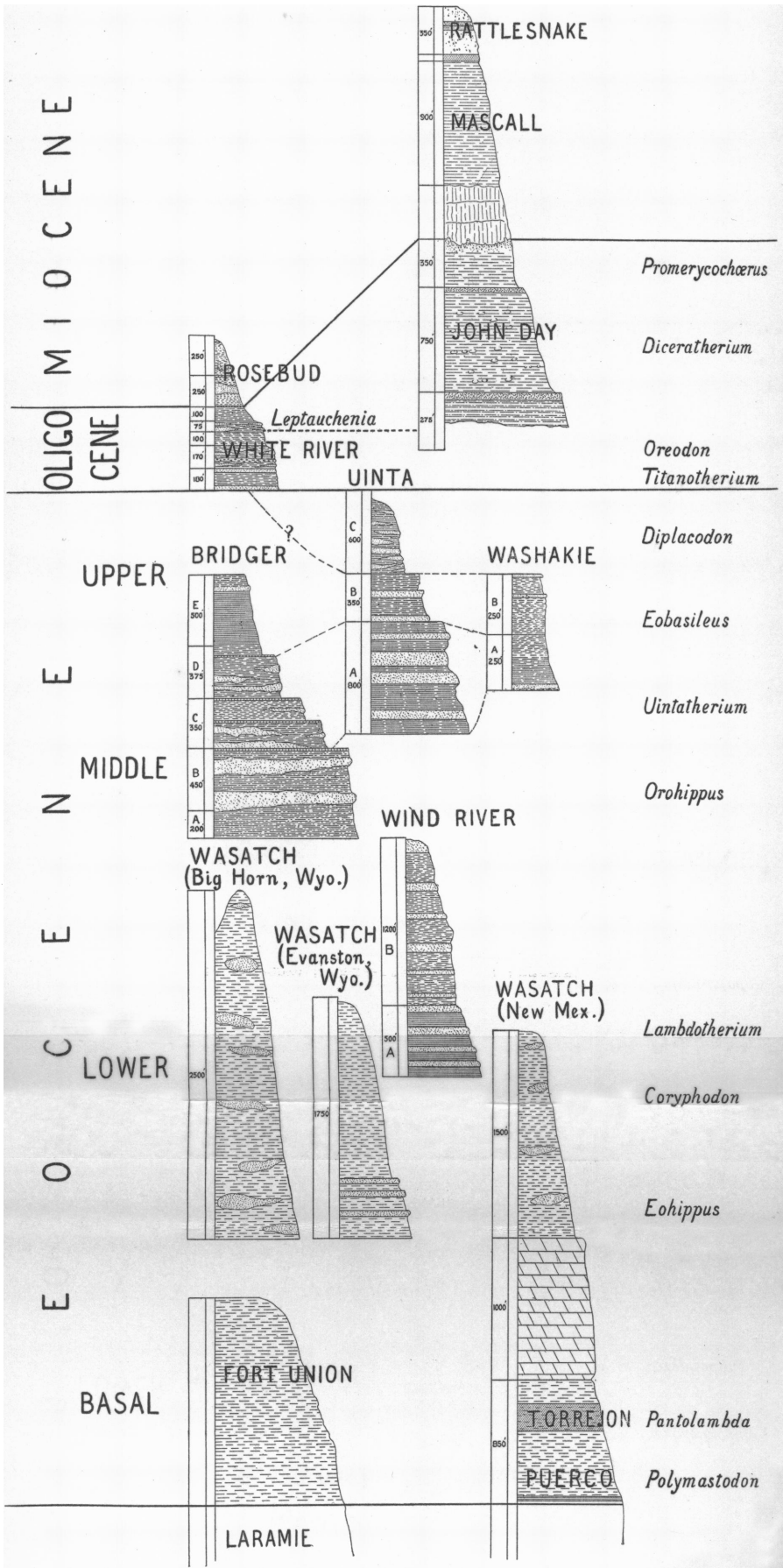


Fig. 1.—COMPOSITE SECTION OF THE EOCENE AND OLIGOCENE
Net Thickness of Eocene, 7200 ft.