THE GEOLOGICAL SURVEY OF WYOMING
S. H. KNIGHT, State Geologist

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SUMMARY OF THE LATE CRETACEOUS AND EARLY TERTIARY STRATIGRAPHY OF WYOMING

BY

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UNCOMMON SURVEY

STATE OF WYOMING

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F O R E W O R D

In view of the voluminous and widely scattered nature of the literature descriptive of the late Cretaceous and early Tertiary history of Wyoming, the following work, by Mr. Nace, is issued by the Geological Survey of Wyoming with the belief that it will be of value to workers in Wyoming geology. The information contained in the work represents investigations by many geologists extending over a period of seventy-five years. Much of the literature reviewed herein is not readily accessible to many geologists. It is thought that a survey of these data in a single publication will obviate duplication of effort and facilitate consideration of existing knowledge.

The writer of this report was assigned the problem for his Master's thesis, and it affords an example of the manner in which the graduate research work of the Department of Geology of the University of Wyoming may serve the interests of the state.

S. H. Knight
State Geologist

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SUMMARY OF THE

LATE CRETACEOUS AND EARLY TERTIARY STRATIGRAPHY OF WYOMING

by Raymond L. Nace

INTRODUCTION

Purpose. -- The establishment of the four territorial survey organizations, during the period 1867-1869, under Hayden, Powell, Wheeler and King, introduced the first systematic application of geologic science to the Rocky Mountain region. Members of these organizations named a majority of the primary stratigraphic divisions of the Rocky Mountain Cretaceous and Tertiary systems. There was, however, little co-ordination of the operations of the separate surveys, and all overlapped both in scope of work and geographic field of investigation. Many of the stratigraphic names introduced were synonyms or homonyms, and valid nomenclature was, and still is, incorrectly or loosely applied.

The work of the territorial surveys led to the establishment of the U.S. Geological Survey in 1879. The early work of this survey in Wyoming was chiefly of a reconnaissance nature, prompted in part by a need for data in the classification of the public domain. Inherent difficulties in the determination of exact age relations within limited allotments of time, often necessitated the grouping of late Cretaceous and Tertiary rocks under generalized systems of nomenclature.

Collecting by members of pioneering scientific expeditions, meanwhile, introduced additional complications by inexact or incorrect references to stratigraphic relations. It was often considered sufficient to say, for example, that a specimen had come from "the Wasatch of southern Wyoming", though the name, Wasatch, had been applied to sediments ranging from Paleocene to lower Oligocene in age. Detailed studies by later expeditions, having the primary object of obtaining paleontologic collections, have established excellent stratigraphic successions in a number of key localities.

The scattered, voluminous, and often inaccessible literature on the stratigraphy of Wyoming, needs to be summarized in a form that will provide concise information on the following phases of the late Cretaceous and early Tertiary stratigraphy: (1) present status of the nomenclature of stratigraphic units; (2) uses and misuses of nomenclatural terms; (3) age, rank, type locality, type designation, lithology, areal distribution, stratigraphic and structural relations, paleontologic distinctions, and subdivisions of each unit; (4) a reference list of pertinent publications. This paper is designed to fill these needs.

Plan of presentation. -- The material on each unit is divided into two parts. The first, titled Specific Information, lists: (1) probable age of the beds; (2) type locality; (3) quotation of the type designation; (4) restrictions or extensures of the original application of the name;

(5) synonyms and homonyms; (6) geographic distribution; (7) lithologic subdivisions; (8) important references. The second part, titled General Information, is an enlargement of the same topics and also furnishes information on stratigraphic and structural relations, paleontology, age and correlations. Minor variations of this general plan occur as adaptations to individual cases. The text consists mainly of direct and indirect quotations. Comments by the writer are chiefly explanatory.

Geologic time-terms used in the age classification. -- The term, "Post-Cretaceous", occurs occasionally in quoted passages. The term was coined during the period when the Fort Union (Paleocene) and the Laramie (Cretaceous) were often grouped together as a single formation, which was supposed to be completely transitional between the Cretaceous and Tertiary periods. "Post-Cretaceous" is not used by the writer, however, except with the strict etymological meaning of "younger than Cretaceous".

The time-term, Paleocene, as here used, is equivalent to the "basal Eocene" of many writers. It is ranked as an epoch, a time interval coordinate with the Eocene. The issues in the question of the rank of the Paleocene were summarized by W. D. Matthew in 1920 (188: 221) and discussed more in detail in 1921 (S.352: 209-227) (S.353: 27-29). He believed that the lower limit of the Paleocene is probably marked by the first appearance of placental mammals, and the upper limit by the appearance of the "principal modern orders of mammals and certain groups of reptiles". Matthew admitted, however, that plant and marine invertebrate fossils do not appear to support the distinction of the Paleocene as a separate epoch. In his paper of 1920 he conceded that the Paleocene may cover the gap between the Cretaceous and Tertiary periods, or that it may belong to the Cretaceous. Controversy over the position of the boundary between the Cretaceous and Tertiary systems has arisen both from differences of opinion of the relative weights of the distinguishing age criteria, and from inadequate or inconclusive evidence. No final conclusions are in order here, and it is sufficient for the present purpose tentatively to rank the Paleocene as an epoch of uncertain position. Paleocene, as an age designation, is herein applied to beds of uncertain age (Lance, Ferris, "Dawson arkose", Fort Union, etc.) lying stratigraphically between undisputed Upper Cretaceous and lower Eocene units. The compromise assignment of all but the uppermost Paleocene units to the upper Cretaceous series, rather than the Cenozoic, as suggested in 1921 by Schuchert (245: 45-47) and Matthew (S.353: 27-29), is, perhaps the most satisfactory practical plan adaptable to universal application. Since this suggestion has not been acted upon, however, the writer believes that confusion will be avoided by designating these strata simply as Paleocene, without committing them definitely either to the Mesozoic or Cenozoic eras.

"Terrane" is employed, as a term of convenience only, to designate units which include rocks belonging to both the undisputed Upper Cretaceous and Paleocene series, or which belong to both the Cretaceous and undisputed Tertiary. "Group" is applied, also as a term of convenience, to units including rocks belonging to two separate epochs, or to units assignable to a single epoch, but separable into distinct members of formation or member rank.

Stratigraphic and geographic scope. -- The major portion of the subject matter relates to the early Tertiary formations of Wyoming. There is, however, some material on formations of other states. This additional information is considered germane to a thorough understanding of Wyoming Tertiary stratigraphy. A few late Cretaceous formations are discussed because of their intimate stratigraphic relation to overlying strata, or because their names are involved in the synonymies of Paleocene and Eocene units. Only named stratigraphic units are discussed in detail.

Synonymies. -- No attempt was made to compile synonymy lists detailing exact usages by every writer who has ever used the names of the units considered. Available information is too incomplete for this to be possible, and such lists would, moreover, be too involved for practical application. The writer believes, however, that the lists are sufficiently complete to serve as starting points from which to approach a study of the stratigraphy of regions in Wyoming which have been discussed in the literature.

Footnotes, references to the bibliography and notations. -- Footnotes are exclusively explanatory. Their use as source indicators would be cumbersome in a work composed principally of cited or quoted material. Sources of information are indicated numerically: (75: 15). The first number is the number assigned to the reference in the appended bibliography; all numbers following the colon indicate pages in the paper cited. Bracketed numbers within direct quotations also refer to the bibliography, and indicate the source used by the author quoted. The bibliography is supplemented by a reference list. Sources in this list are indicated by numbers preceded by a capital letter "S": (S.300: 50). Dates of observations, as given, are dates of publication, not of field work. The bibliography contains many important references on later Tertiary formations not discussed in the text.

Throughout this paper an asterisk written before the name of a rock unit indicates that the name is either invalid or obsolete.

Order of arrangement. -- Discussions of rock units are arranged as nearly as possible, in the order of stratigraphic succession. Material concerning particular rock units will be found most easily with the aid of the alphabetic index of unit names.

ACKNOWLEDGEMENTS

This paper was compiled as a thesis project in partial fulfillment of the requirements for the degree of Master of Arts, at the University of Wyoming, Laramie. Research was conducted during the academic years 1934-1935 and 1935-1936, under the supervision, and with the advice, of Dr. S.H. Knight, State Geologist of Wyoming and Professor of Geology, University of Wyoming. The advice and constructive criticisms of Dr. R. H. Beckwith and Dr. H. D. Thomas, also of the Department of Geology, has been invaluable. The co-operation of the library staff of the University of Wyoming is also acknowledged.

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SECTION OF THE JUDITH RIVER FORMATION

As seen at the Mouth of the Judith River[1]

A	80 feet.	Yellow arenaceous marl passing downwards into gray grit, with seams of impure lignite; contains great numbers of a species of Ostrea, like O. subtrigonalis of the lignite basin, Cyrena occidentalis, Melania convexa, Paludina Conradi, &c. This bed caps the hills, and varies much in thickness.
B	10 feet.	Impure lignite, containing much sand; a few specimens of Ostrea like the above, with much silicified wood.
C	80 feet.	Alternations of sand and clay with particles of lignite; also reddish argillaceous concretions with a few saurian teeth and fresh water shells.
D	20 feet.	Alternate strata of sand and clay, with impure lignite and silicified wood, in a good state of preservation.
E	100 feet.	Variable bed, consisting of alternations of sand and clay, with large concretions, containing great numbers of Melania, Paludina, Helix, Planorbis, Cyclas, &c., associated with saurian remains resembling Iguanodon and Megalosaurus, and Trionyx, &c.
F	25 feet.	Alternations of impure lignite and yellowish brown clay, the latter containing great numbers of Unio, Paludina, Melania, Cyclas, and the fish remains referred by Dr. Leidy to the genus Lepidotus.
G	100 feet.	Ferruginous sand and clay, having in the upper part a seam 3 or 4 inches in thickness, composed mostly of shells of Unio. Lower part ferruginous, and coarse gray grit, with a seam near the base entirely composed of remains of Unio Danai, and U. Deweyanus, and U. subspatulatus.

[1] Copied from Hayden, F.V. (101: 129), Geological sketch of the estuary and fresh water deposits of the badlands of the Judith...: Am. Philos. Soc. Philadelphia Trans., vol. 11, new ser., 1860.

An almost identical table had been previously published by Meek and Hayden in 1857 (204: 124). Meek subsequently reproduced the table in 1876 (199: XLVIII), and entitled it, "Section of the Judith River group as seen at the mouth of Judith River".

C R E T A C E O U S U N I T S

PRINCIPAL GROUPS OF THE UPPER CRETACEOUS SERIES

GENERAL INFORMATION

During the early period of exploration in the western territories Meek and Hayden had, for convenience, given numerical designations to formations of the Upper Cretaceous series. For some years this numerical nomenclature served as the only means of designating the strata. In the discussions following there are allusions to the Upper Cretaceous formations, both by name and by number. A nomenclatural correlation between the numbers first assigned by Meek and Hayden, and the names subsequently applied to them, may be helpful to the reader. Meek and Hayden themselves gave the following correlation in 1861 (205: 419):

Lower series:	Formation No. 1 -- Dakota group
	Formation No. 2 -- Fort Benton group
	Formation No. 3 -- Niobrara Division [formation]
Upper series:	Formation No. 4 -- Fort Pierre group
	Formation No. 5 -- Fox Hills beds

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UPPER CRETACEOUS — JUDITH RIVER FORMATION

GENERAL INFORMATION

The Judith River beds, typically developed at the mouth of the Judith River in Montana, were first described by Hayden in 1860. The following passages (101: 126, 132) indicate Hayden's understanding of the Judith River beds:

"Near the mouth of the Cannon Ball River, the Lignite Tertiary beds begin to overlap the Cretaceous strata, but do not entirely conceal them along the banks of the river until we reach 'Square Buttes', about thirty miles below Fort Clarke. ... The country in the vicinity of the mouth of the Yellow Stone River is covered by the Tertiary beds of the Lignite basin alone, containing their peculiar Fauna and Flora. The Tertiary beds continue uninterrupted until we reach the mouth of Milk River, where, by a reversed dip of the strata, the Cretaceous Formation rises to the surface from beneath the Tertiary. The Tertiary beds continue to overlap the Cretaceous, gradually thinning out upon the summits of the hills, until we reach the mouth of the Muscle Shell River ...

* * *

"Again, in no portion of the Upper Missouri have we met with any disturbance of strata belonging to well known Tertiary beds. ... We have, therefore, arrived at the conclusion, that the last great convulsion that uplifted the fossiliferous rocks on the Missouri, occurred after the Cretaceous epoch and prior to the deposition of the Tertiary. The fresh water and estuary beds at the mouth of the Judith, ... are tilted at every angle, from a horizontal to a vertical position. It is also evident that the con-

vulsion was synchronous with that which uplifted the surrounding Cretaceous strata of No. 1, and that the mountains in the vicinity were raised up by the same forces that elevated the Black Hills, Laramie Mountains, &c. These facts strengthen the opinion that the deposits of the Judith basin, if not an American representation of the Wealden of Europe, are, at least in part, as old as Cretaceous." (See table, p. 4.)

In 1922 Knowlton stated (140: 77) in his summary of the "Laramie problem":

"By the time the Laramie was established by King, it had come to be generally accepted that the Judith River beds were stratigraphically and paleontologically in the proper position demanded by the definition of the Laramie, and hence we find C.A. White /319: 72/ referring to them as one of the subordinate groups or regional divisions of this group, as it was then called."

Knowlton added (p. 78) in the same paper:

"The latest and most authoritative statement is that published by C.F. Bowen in 1915 /16: 100-101, 104-153/, which presented the result of several season's work in this and adjacent areas. In general Bowen agreed with the statements of Stanton and Hatcher, namely, that the Judith River is the equivalent of the Belly River of Canada and is of Montana age.

* * *

"It therefore seems settled that the Judith River formation is not to be regarded as of Laramie age."

More complete details upon the Judith River formation are included in Knowlton's paper (140: 77-78), accumulated information is summarized, and references to important papers are given.

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UPPER CRETACEOUS BEAR RIVER FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; southwestern Wyoming, upon the bank and near the mouth of Sulphur Creek, a tributary of Bear River.

TYPE DESIGNATION. -- White said (325: 91) that the Bear River strata were discovered by Henry Engelmann in 1359, and that the "strata were generally spoken of as the Bear River estuary beds". Elsewhere (326: 15) White noted that the first published account of the Bear River "estuary beds" was contributed by Meek and Engelmann in a jointly written paper published in 1860, and that later in the same year Meek published descriptions of the characteristic fossils. These papers were not examined by the writer. In 1869 Hayden included in his Third Annual Report a paragraph which is

usually quoted as the type designation of the formation. Hayden's description (104: 191-192)[1] was as follows:

"After passing Rock Springs station, Union Pacific railroad, the next exposures of coal are at Bear River City, and at Evanston, and also at Coalville, near the entrance of Echo Creek into Weber River. ... These coal beds seem to be separated from those at Separation and Carbon, and to present some features different from those in any other portion of the West. I am in doubt as to their precise position, but I am inclined to regard them as of lower tertiary age ... On Bear River we find several species of Ostrea, both above and below the coal, and in a cut just west of Bear River City is found the greatest profusion of molluscous life that I have ever seen in any of the tertiary beds of the West. There seems here to be a mingling of fresh and brackish water fossils. At Evanston, impressions of deciduous leaves are abundant in beds above the coal. No portion of the fauna seems to be identical with anything found in other places. The flora seems also to be distinct ... I have named the group of coal strata which is exposed from beneath the middle tertiary beds by upheaval at Bear River City, Evanston, and Coalville, the Bear River group."

RESTRICTIONS. -- Hayden, and others connected with the territorial surveys, considered the Bear River formation a local phase of the "Laramie". In 1892, however, White published an article in which he stated (325: 92) it as his object to show that "the strata which have hitherto been known as Bear River Laramie are not only not referable to the Laramie formation but that they occupy a lower position" and are "overlain by marine Cretaceous strata the equivalents of which are known to underlie the true Laramie". In 1895 White again wrote on the Bear River formation. He proposed (326: 15, footnote) to impose the following restriction:

"The Bear River group, as proposed by Dr. Hayden, embraced strata now known to belong to three separate formations; I retain the name for those only which pertain to one of them; that is, for those to which the name 'Bear River' has been most generally applied."

SYNONYMY. -- Throughout the literature written prior to the publication of White's restrictions of the name Bear River, the strata were referred to as the "Bear River Laramie" and "Bear River estuary beds". White explained (326: 18) his own prior usages:

"In certain of my writings ... in 1877 and 1878 I assigned the ... Bear River formation, as well as the coal-bearing beds near Evanston, which are also found in Bear River Valley, to the great Laramie formation. Both of these assignments" were erroneous.

"Brackish water deposits on Bear River", mentioned by Meek (198: 312-313), are approximately equivalent to the Bear River formation.

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[1]The 3d Ann. Rept. was first published in 1869. It was reprinted in 1873 in a combined edition of the 1st, 2d and 3d Ann. Repts., from which the quotation was obtained.

BEAR RIVER FORMATION - Specific and General Information

SYNONYMY (cont'd).
Bear River "group" or "coal group" of Hayden (104: 92) (109: 144-145), according to Veatch (300: 60), included true Bear River plus coal-bearing strata at Bear Town, Coalville, and Evanston, which belong to the Frontier, Hilliard and Evanston formations.
Bear River "estuary beds" of Meek (in King 134: 462) are approximately equivalent to the true Bear River formation.
"Point of Rocks Group" of Powell (229: 100-101) included the Bear River.
"Laramie" of King (137) included the Bear River, according to Veatch (300: 60).
"Post-Cretaceous" and "Laramie" of Peale (in Hayden 114: 630-631) was approximately equivalent to the Bear River.

DISTRIBUTION. -- The formation extends northward in a narrow belt from the type locality, partly in Wyoming and partly in Idaho, to a northward limit about 40 miles north of the 43d parallel. There is a shorter and narrower belt lying a few miles east of, and parallel with, the main outcrop.

IMPORTANT REFERENCES. -- Hayden (104: 191-192). Meek (in King 134: 462-463). White (325: 91-97); historical summary and re-definition. Stanton (239: 98-115); stratigraphic and paleontologic description, and confirmation of White's conclusions. White (326: 13-108); historical review of controversy, with list and illustrations of all known members of invertebrate fauna. Veatch (300: 60-64); historical review and summary of stratigraphy, structure and paleontology. Mansfield and Roundy (167: 75-84); "a revision of the Beckwith and Bear River formations". Knowlton (140: 78); a summary of relations of formation to the "Laramie problem".

GENERAL INFORMATION

In 1870 Meek enumerated (in King 134: 462-463) some of the common fossils of the Bear River. He remarked that these and others were, with one or two exceptions, generically and specifically distinct from fossils in underlying marine sandstones. His conclusion was that the Bear River fauna is "such as we could only expect to find mingled together in an estuary deposit".

Hayden believed (104: 191) that the Bear River formation, as well as the supposedly equivalent Laramie, was Tertiary in age. This age assignment is not surprising in view of his statement (104: 189): "I regard all the coal beds of the West as lower tertiary." It was noted in the synonymy list (p.8) that Hayden included in the Bear River, coal-bearing strata properly belonging to younger formations. Cope, as early as 1874, detected a flaw in the customary grouping of the Bear River formation with younger strata in the Laramie (sensu lato). In his report on the vertebrate paleontology of Colorado Cope noted (in Hayden 108: 435) the distinctive character of the Bear River fauna and remarked:

"On this account, and because of the great stratigraphical differences exhibited by the Bear River and Evanston coal strata, I have followed Hayden in regarding the Bear River group on the west side of the Bridger Basin as

representing a distinct series of rocks, with present knowledge."

White and Stanton eventually settled the dispute over the age and stratigraphic position of the Bear River. In 1892 White said (325: 20) that Stanton's investigations had shown that the Bear River formation "lies beneath the greater part, if not the whole" of the Upper Cretaceous series, and that "he has determined its position as beneath the Colorado formation and above that series of Jurassic strata which ... are generally regarded as of Upper Jurassic age". It was demonstrated by Stanton in 1892 (284: 98-115) that the Bear River has no species of fossil in common either with the Laramie or with any Tertiary formations. In 1895 White (326: 24), therefore, did not hesitate "to assign the Bear River formation to the Upper Cretaceous, and to designate its position as at or near the base of that series". This assignment, White said, accorded with the reputed age of "a formation in Hungary whose fauna is more nearly like that of the Bear River formation than any other known".

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UPPER CRETACEOUS LARAMIE FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- The Laramie is now classified by the U.S. Geological Survey as a lithologic unit of formational rank. No type locality was specified in the type designation. In 1907 Veatch advocated (298: 526) the view that Carbon, Wyoming was the locality in King's mind as the type of the formation. Both Cross (47: 27-45) and Peale (226: 45-58) disagreed with this view. According to Knowlton (140: 17), Veatch's opinion has not been accepted. Application of the name Laramie is now restricted, by decision of the Committee on Geologic Names of the U.S. Geological Survey, to strata in the Denver Basin of Colorado (see Stone and Calvert 293: 746). For convenience, then, it may be considered that the type locality of the formation is in the Denver Basin region east of the Front Range of Colorado.

TYPE DESIGNATION. -- According to Knowlton (140: 12) the word Laramie, used as a formation name, first appeared in an author's proof, dated Nov. 15, 1875, of Geologic Map No. 1 of the Fortieth Parallel Survey. The map, Knowlton said, was noticed in the American Journal Science for February, 1876, but in neither place was there any definition of the name. The first printed description of the Laramie was that of Hague (in King 136: 60,61), who included an unimportant section measured on the Denver Pacific Railroad, five or six miles west of Carr station, and about 18 miles southeast of Cheyenne, Wyoming. King, in his first description, which appeared in 1878 in Volume 1 of his report, stated (137: 331):

"The great sandstone series of the Fox Hill is conformably overlaid by a continuation of the sandstones, which attain a thickness of from 1,500 to 5,000 feet, varied greatly in lithological character over different areas, but in general characterized by the frequent occurrence of workable beds of lignite and innumerable seams of carbonaceous clay."

LARAMIE FORMATION - Specific Information

Hague's description (in King 136: 64) in Volume 2 of King's report, published in the previous year, was also vague:

"The Laramie beds form the uppermost members of the great series of conformable strata that lie upturned against the Archaean mass of the Rocky Mountains; all overlying strata resting unconformably upon the older rocks."

RESTRICTIONS. -- As Laramie is now used by the U.S. Geological Survey, it complies with the original definitions of King and Hayden. The geographic application of the name, however, is restricted. Knowlton pointed out, (140: 15) that the geographic application of the name "reached its maximum extension about the year 1890"; since then, elimination and subtraction have gradually restricted the application to a comparatively small area. Knowlton remarked also (p. 81):

"It has been contended ... that the original delimitation of the Arapahoe and Denver formations from the supposedly continuous Laramie section constituted a virtual re-definition of the Laramie, but ... the essential part of King's definition -- namely, that it is the uppermost member of the conformable Cretaceous series above the Fox Hills -- is maintained."

Stone and Calvert stated (293: 746) that the unqualified name Laramie is approved by the U.S. Geological Survey for application in the Denver Basin only, and that when applied elsewhere it must be enclosed within quotation marks.

SYNONYMY. -- (See tables, pp. 13-15, 18-19, 23; also chart, pl.2.)

"Bear River Laramie" of territorial survey geologists included true Bear River and, in addition, strata stratigraphically above and below Bear River.

"Laramie" of Ward in 1886 (303: 401-555) included strata now assigned to the Mesaverde, true Laramie, Lance, Denver, Arapahoe and Fort Union.

*Point of Rocks group of Powell in 1876 (229: 47-49, 155-158), included the lower portion of Hayden's "Laramie".

*Bitter Creek group of Powell (229: 45-47, 64-66, 162-166) included the upper part of Hayden's "Laramie" ("Fort Union"; "Great Lignitic") and the whole of his Wasatch.

"Laramie" of White in 1878 (in Hayden 113) included the "Lignitic group" (Laramie and Fort Union) of Meek and Hayden, the "Laramie" of King, the *Point of Rocks group of Powell, and the lower part of Powell's *Bitter Creek group.

"Laramie group" of White (in Hayden 113) was equivalent to his "Post-Cretaceous" rocks throughout his writings.

White explained (319: 721) in 1878 that Laramie, as used by him, included all strata between the Fox Hills (below) and the Wasatch (above). He treated the Judith River, Fort Union, "Lignitic", true Laramie, *Bitter Creek, *Point of Rocks, Bear River, Lance, Medicine Bow, Ferris, Evanston and Hanna as regional divisions or subordinate members of his Laramie group. All these units had not, of course, been designated and described at the time he wrote.

"Laramie" of King (137) in 1878 was said by Veatch (300: 60) to include the Bear River formation.

LARAMIE FORMATION - Specific Information

SYNONYMY (cont'd).

"Laramie" and "Post-Cretaceous" of Peale in 1879 (in Hayden 114:630-631) was said by Veatch (300: 60) to be approximately equivalent to the Bear River formation.

"Laramie" of Endlich, in his report of 1879 on the Sweetwater district of Wyoming (in Hayden 114: 88-89) is probably mostly Fort Union.

"Laramie" mapped by Eldridge in 1894 (69: frontispiece) included the Lance and Fort Union strata exposed east of the Big Horn Mountains and around the borders of the Big Horn and Wind River basins.

"Laramie" of Darton (56: 8-9; and other papers), which he subdivided into the Piney, Kingsbury conglomerate and *De Smet formations, included the whole of the Lance and Fort Union, part of the Wasatch of Wind River, and some beds older than Lance or true Laramie.

"Laramie" of Darton in the Newcastle region (56), according to Collier (31: 87), belongs to the Lance formation.

"Laramie and associated formations" of Fisher (76: 3) in 1906 in the Bighorn Basin, according to Sinclair and Granger (277: 59), is Largely Fort Union.

"Laramie and associated formations" of Fisher, according to Lupton (165: table f.p. 166) included Fort Union, Lance and Mesaverde.

"Laramie" described by Woodruff in 1909 (334: 206) in the southwest side of the Big Horn Basin is Lance, and probably, in part, Fort Union.

"Laramie" of Washburne in 1909 (304: 169) in the northeast part of the Big Horn Basin included Lance and probably some Fort Union.

*Upper Laramie of Veatch in 1907 (299) included the Hanna formation and all but the lower 200 feet of the Ferris.

*Lower Laramie of Veatch (299) is approximately equivalent to the Medicine Bow formation.

*Upper Laramie of Ball and Stebinger (4) in 1910, in the Little Snake River coal field is equivalent to the Ferris and/or Hanna formations.

DISTRIBUTION. -- (See pl. 1.) Denver Basin, Colorado. Partially equivalent strata in southern Wyoming are called Lance or Medicine Bow. The Lance formation of northeastern Wyoming, Montana and the Dakotas is a partial equivalent.

IMPORTANT REFERENCES. -- Bowen (17: 227-231); Cross (47: 27-45); Dobbin (137: 331-339, 350-357); Knowlton (139: 325-340), (140: 1-175); Stone and Calvert (293: 746); Veatch (298: 526:549).

GENERAL INFORMATION

In 1922 Knowlton published an historical review (140: 1-79) of the "Laramie problem" to which there is little to add. The Laramie formation, as at present defined, is definitely of Cretaceous age. The following brief notes indicate the solution of the "Laramie problem" which has been generally accepted.

King early recognized the difficulties involved in the usages of the name Laramie employed by his contemporaries. He remarked (137: 333):

"... Dr. Hayden was in error in marking the lowest limit of the

LARAMIE FORMATION - General Information

Laramie by the occurrence of the sandstones and coal beds. ...since in Utah, Wyoming and southern Colorado the coal-beds are found to descend quite to the base of the Cretaceous, it is evident that no group lines can be drawn on the coal-beds, except in the most local and restricted way."

Other sample passages from King's report (137: pp. indicated) show, in a general way, his intended application of the name:

"Good exposures of the Laramie group beds may be seen along the railroad just east of Separation Station, where they show the peculiar ash-gray sandstones, containing a considerable development of argillaceous beds and a great number of coal seams." (p. 334)

* * *

"Around the irregular oval ... of the Bitter Creek uplift occurs one of the finest exposures of the Laramie series. From about six miles east of Salt Wells Station, on the Pacific Railroad, it dips at gentle angles of from 4° to 7° to a little north of east. ... A continuous series is exposed as far as Black Butte, where, upon the top of the bluff, the Cretaceous passes under the beds of the Vermilion Creek (Wasatch), with no appearance of angular unconformity. The exposure appears to be between 4,000 and 5,000 feet." (p. 355)

* * *

"Beginning at the Fox Hill summit ... four miles east of Salt Wells, the exposure up half-way to Point of Rocks consists of rapid alternations of friable rusty and light-colored sandstones, drab and gray, yellowish clays, and dark, carbonaceous clays, with important coal seams." (p. 336)

* * *

"As to the precise upper limit of the Cretaceous series ..., we prefer to draw the line on the top of Black Butte, including the Dinosaurian and plant-beds in the Cretaceous, believing also that in tracing the contact between the beds next over the Dinosaurian series and the ashy beds which overlie them we detect a slight non-conformity which, when traced north, seems ... persistent ... The Vermilion Creek series, which here rests upon the top of the Laramie in conformity, is elsewhere seen where the non-conformity is violent, the difference of angle reaching often 20° and sometimes 80°." (pp. 338-339)

Knowlton stated (140: 78-79) that in contemporary usage in the Canadian provinces, Laramie is a group term including the Edmonton formation (Lower Laramie) and the Paskapoo (Upper Laramie). The Canadian "Laramie", therefore, is not to be considered as more than approximately equivalent with the Laramie of the Denver Basin. A passage in Merrill's history of American geology (206: 592), published in 1924, indicates the tenacity of erroneous ideas concerning this formation. Merrill stated that the Laramie is "accepted as occurring in Carbon County, Wyoming, where it is 6,000 feet thick, whereas in the Denver Basin it is only about 1,200 feet thick". The thickness given by Merrill coincides with the thickness of the *Upper Laramie of Veatch (299: 527), but is 500 feet less than that of his *Lower Laramie (Medicine Bow), which apparently approximates the true Laramie most closely in age. Veatch's application of the name Laramie had been discredited by Bowen in 1918, 6 years before Merrill's book was published.

LARAMIE FORMATION - General Information

Knowlton presented (140: 60) a tabular correlation of the nomenclature of rock units in the Hanna Basin, Carbon Co., Wyoming, used by Bowen and Veatch. The section given by Knowlton, it seems to the writer, leaves certain nomenclatural ambiguities unclarified; these are indicated in the footnotes below. The following section is copied exactly from Knowlton (140: 60):

	Bowen, 1918	Veatch, 1912[a]
Tertiary	North Park formation, 0-400 feet.	North Park Tertiary, 4,500 feet.
	Unconformity	Unconformity
	Hanna formation,[b] 7,000 feet.	Fort Union formation,[c] 800-2,000 feet.
	Unconformity[d]	
Tertiary(?)	Ferris formation, 6,400 feet.	"Upper Laramie," 6,000 feet.
		Unconformity
Cretaceous	Medicine Bow formation,[e] 6,200 feet.	"Lower Laramie," 6,500 feet.
	Lewis shale	Lewis shale

The latest word on the Laramie formation, found by the writer, is that of Shimer (1934), who considered (265: 913) the Laramie equivalent to the Lance formation (see chart, pl. 1, f.p. 18).

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[a]Apparently an error. The writer has found no record of work done by Veatch in Carbon County, or of data on that area published by him, in 1912. His papers on the "Laramie problem" (298), on the coal fields of Carbon County (299) (from which the section was taken), and on the geology and geography of Lincoln County, were all published in 1907.

[b]The Hanna formation was considered by Bowen (17: 230) to represent only the upper half of Veatch's *Upper Laramie.

[c]Dobbin and his associates stated (61: 22) that the "Fort Union", placed by Veatch above his *Upper Laramie, is actually a part of his *Upper Laramie, and probably occurs "some distance below its top".

[d]This unconformity is the same as that shown by Veatch between his *Upper and *Lower Laramie. According to Dobbin and his associates (61: 22), Veatch mis-located the unconformity by 2 or 3 thousand feet and it actually occurs about the middle of his *Upper Laramie.

[e]The Medicine Bow formation does not include the upper 200 feet of Veatch's *Lower Laramie. These upper strata belong to the Ferris formation.

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Table of Correlations of Geologic Names Used for Western Colorado Strata (after Gale[1])

The horizontal arrangement is intended to indicate actual equivalency of the strata. Double lines indicate the various conclusions as to the age of the strata thus designated.

System	Hayden var. writings	King (137)	Powell (229)	White (in Hayden 113)	White (324)	Gale (79)	System
Recent					(Alluvium)	(Alluvium)	Recent
Glacial (?)			Morainal deposits	"Scattered drift"	(Local drift)	(Local drift)	Pleistocene (?)
		Wyoming conglomerate	Bishop Mountain conglomerate		Bishop Mountain conglomerate	Bishop Mountain conglomerate	
Tertiary			Browns Park	Uinta	Browns Park	Browns Park	Post-Tertiary (?)
		Uinta					Tertiary
	Bridger	UINTA: Bridger	Bridger	Bridger	Bridger	Bridger	
	Green River	UINTA: Green River	Green River	Green River	Green River	Green River	
	Wasatch	UINTA: Vermilion Creek (a)	Bitter Creek	Wasatch	Wasatch	Wasatch	
	Fort Union or Great Lignite group			(Neither unconformity nor hiatus recognized.)		Fort Union (?) (a)	
						Laramie	Cretaceous
						Lewis	
		Laramie	Point of Rocks (b)	Laramie[c]	Laramie[c]	Mesaverde	

[1]Copied from Gale, H.S. (79:.90), Coal fields of northwestern Colorado and northeastern Utah: U.S. Geol. Survey Bull. 415, 1910. The lower part of Gale's table is omitted.

[a]Unconformity. [b]Local unconformity. [c]White regarded the "Laramie" as transitional between the Tertiary and Cretaceous.

Table of Correlations of Geologic Names Used for Strata in the Big Horn Basin, Wyoming (after Lupton[1])

Fisher (76: 8), 1906		Washburne (304: 167), 1909			Lupton (165: 166), 1915		
System	Formation	Series	Formation		System or series	Formation	Thickness (feet)
Quaternary	Alluvium Later terrace gravels Early terrace gravels				Quaternary		0-50± 0-25±
Tertiary	Wasatch formation	Tertiary (Eocene)	Wasatch formation Unconformity Fort Union formation Unconformity		Tertiary and Tertiary(?)		
	Laramie and associated formations					Undifferentiated Fort Union and Lance formations	1,275±
Cretaceous		Upper Cretaceous	Laramie(?) formation[a]				
			Montana	Bearpaw Judith River Claggett Eagle[b]	Upper Cretaceous	Montana: Mesaverde formation	1,200±
	Pierre shale		Colorado shale			Cody shale	

[1] Condensed from Lupton, C.T. (165: 166), Oil and gas near Basin, Big Horn County, Wyoming: U.S. Geol. Survey Bull. 621, 1915. The lower part of Lupton's table and his column showing Hewett's classification (120: 91) are omitted.

[a] The "Laramie(?) of Washburne was called *Ilo formation by Hewett. Hewett assigned the *Ilo formation to the "Cretaceous or Tertiary" system.

General Section of Cenozoic formations Exposed in Moffat Co., Colo., and Southern Sweetwater Co., Wyo.[1]

System	Series	Group and formation		Thickness (feet)	Character
Quaternary		Alluvium; terrace gravels			Sandy clay along streams and in valley bottoms; terrace gravel on benches along rivers.
		Unconformity			
Tertiary	Miocene (?)	Browns Park formation	Bishop conglomerate	Browns Park, 1,200+; Bishop, 0-200	Browns Park is mostly soft chalk-white sandstone; beds of chert; conglomerate at base. Bishop conglomerate (in the writer's opinion equivalent to basal conglomerate of Browns Park formation) consists of water-worn and subangular pebbles and boulders embedded in finer gravel and sand matrix.
		Unconformity			
	Eocene	Bridger formation			Ash-gray and greenish clay shale; gray, buff, and blue-green sandstone; light-gray and white marl, limestone, and chert; conglomerate.
		Unconformity locally			
		Green River formation (including Laney shale member and Tipton tongue).		1,500 ±	Gray fissile shale and oil shale; gray clay shale; gray and buff sandstone and limestone; oolitic layers and alga reefs.
		Wasatch formation (including Cathedral Bluffs tongue).		3,000-5,600	Variegated clay shales; gray, buff, and pink sandstone, grit, and conglomerate; coal beds.
		Unconformity			
Tertiary (?)	Eocene (?)	Post-"Laramie" formation		0-800	Gray and brown sandstone; gray and drab shale; coal beds; conglomerate at base.
		Unconformity			
Upper Cretaceous		"Laramie" formation		1,020-2,350(?)	Sandstone, shale, and some coal.

[1]Copied from Sears' "General section of geologic formations" (260: 276), U. S. Geol. Survey Bull. 751-G, 1925. The remainder of Sears' section, which included rocks as old as pre-Cambrian, is omitted here.

Compare with tables, pp. 18-19, 22-23, and charts pls. 2, 3.

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SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; along the North Platte River at the mouth of the Medicine Bow River, in T.24 N., R.84 W., Carbon Co., Wyoming.

TYPE DESIGNATION. -- Bowen named and described (17: 229-230) the formation in 1918, in his report on the Hanna Basin:

"Above the highest marine formation -- the Lewis shale -- is a mass of continental deposits, divisible into four formations having a maximum thickness of more than 20,000 feet. For the lowest of these formations the name Medicine Bow is here proposed, because the formation is best exposed and most easily studied along both sides of North Platte River at the mouth of the Medicine Bow. The Medicine Bow formation is the equivalent of the 'Lower Laramie' as defined by Veatch. The latter term is not applicable, for the 'Upper Laramie', in the sense in which that term was originally used, is not of Laramie age. As the relation of the Medicine Bow formation to the Laramie of the Denver Basin can not be determined by field relations, and as paleontologists are not agreed as to the relation of the fossil remains found in the two formations, the use of the unqualified term 'Laramie' is not advisable, and it is thought that confusion may be avoided by the use of an entirely new name for the formation hitherto called 'Lower Laramie'.

"The Medicine Bow formation rests conformably on the Lewis and consists of an alternating succession of shale and massive to thin-bedded, ripple-marked, and cross-bedded sandstones, with several beds of coal in the lower third of the formation. The massive and thick-bedded sandstones are commonly somewhat coarser than the thin-bedded varieties and in some places contain clay balls and an occasional pebble the size of a pea.

* * *

"The Medicine Bow formation is terminated above by a conglomeratic zone taken as the base of the Ferris formation ..."

SYNONYMY. -- (See tables, pp. 13, 16, 19, 23, and pls. 1, 2, 3.)

*Lower Laramie of Veatch (299: 246, 249), and of other writers = Medicine Bow formation.

*Bitter Creek group of Powell (229: 45-47, 64-65), of White (in Hayden 113: 32-34), of Cope (40: 36), (in Hayden 108: 435-436), of Lesquereux (148: 25-26), of Meek (in Hayden 107: 456-457), (199: LI), of Ward (303: 401-555), and of others, included strata now assigned to the Medicine Bow formation.

"Laramie(?)" of Schultz (247: 263) and his "Laramie" (248: 223) (251: 23), may belong wholly or in part to the formation. These strata, which Schultz gave the economic designation "Black Buttes coal group", were believed by Osborn (224: 53) and by Dobbin (61: 23) to be of Lance age. Dobbin believed that the "coal group" included part of the upper Lewis. Because of geographic location, the strata should, perhaps, be called Medicine Bow.

"Laramie" of Sears (260: 276, 291) and Ball (3: 246, 247) is probably Medicine Bow.

DISTRIBUTION. -- South-central Wyoming. Rocks of adjacent parts of Colorado called *Lower Laramie or "Laramie" probably also belong to the Medicine Bow formation.

Geologic formations of the Rock Springs field (After Schultz).

System	Series or Group.	Formation	Economic designation	Thickness (feet)	Description
(?)	Post-Eocene	Igneous	Leucite lava	0 to 350	Dikes, flows, volcanic necks, and agglomerate.
		Bishop conglomerate.	Gravel	0 to 200	Waterworn and subangular pebbles and bowlders, many of them from 1 to 6 feet in diameter, embedded in finer gravel and sand.
		—Unconformity—			
Tertiary	Eocene series	Green River formation		0 to 630	Massive, irregularly bedded sandstone; white, yellow, and brown shaly sandstone; some limestone and interbedded shale.
			—Unconformity—		
				0 to 950	Thin-bedded shale, sandstone, and limestones (some of which are oolitic); some dark-colored bituminous shale.
		—Unconformity—			
		Wasatch formation.	[1]	0 to 800	Variegated clay, shale, and sandstone, in places slightly conglomeratic; produces highly colored escarpment of Laney Rim and Cathedral Bluffs.
			[2]	100 to 275	Thin fissile shale and sandstone; pronounced oolitic limestone, in places 20 to 50 feet thick near base; also other oolitic and concretionary beds locally resembling huge oyster shells scattered on surface
			Black Rock coal group	1,000 to 3,500	Alternating layers of white, yellow, and brown sandstones, and gray, drab, and carbonaceous shales, with coal beds and conglomerate containing granite and quartzite pebbles. Numerous bands of white concretionary sandstone, weathering in irregular shapes. Basal sandstone is conglomeratic. Sandstone hardens locally and weathers into forms resembling large log or spherical concretions. Large cross-bedded reddish sandstone forms badland topography in Red Creek valley and Fire Hole Basin.
		—Unconformity—			

Geologic formations of the Rock Springs field (After Schultz).

(Continued)

System	Series or group.	Formation	Economic designation	Thickness (feet)	Description
Tertiary	Eocene series	"Upper Laramie" formation	Knobs-Cherokee coal group	6,000 to 9,400	Alternating layers of soft yellowish brown and white sandstones and drab, brown, and black shales. Not exposed in Rock Springs dome.
		Unconformity			
Cretaceous	Montana group	"Laramie" formation	Black Buttes coal group	1,500	Massive basal bed of white and yellow sandstone showing traces of conglomerate in places; forms prominent scarp; overlain by various sandstone, clay, and coal beds. Fossils abound in places. Exposed only in the northern part of the east side of the dome and here only lower part is visible. On west side of Rawlins dome this formation is 3,900 feet thick.

[1] Copied from Schultz, A.R. (248: 222-223), The southern part of the Rock Springs coal field, Sweetwater County, Wyoming: U.S. Geol. Survey Bull. 381, pt. 2, 1910. The remainder of Schultz's section, showing the older Lewis shale, Mesaverde, and an unnamed unit, all members of the Montana group, is omitted.

In an earlier report in 1909, on the northern part of the Rock Springs field, Schultz (247: 259) showed bed [1] resting directly on the "Black Rock coal group" without the presence of the intervening bed [2]. In a later report in 1920 (251: 22-23), on the Baxter Basin gas field, Schultz assigned beds [1] and [2] to the Green River formation (see table, pp. 22-23), and called them the Cathedral Bluffs red beds and Tipton shale member, respectively, of the Green River. His assignment of the Tipton shale to the Green River is still accepted, though Sears and Bradley (263: 99) rank it as a tongue. The Cathedral Bluffs beds are said by Sears and Bradley (263: 96-97) to be an interfingered tongue of the Wasatch (see table, p. 16, and chart, pl. 4).

In a footnote to his table of 1909 (247: 259) for the northern part of the Rock Springs field, Schultz, though assigning the "Black Rock coal group" to his "Wasatch", stated that fossil plant collections had been studied by F.H. Knowlton and determined as "undoubtedly Fort Union".

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MEDICINE BOW FORMATION - References; General Information

IMPORTANT REFERENCES. -- Bowen (17: 230); Dobbin, Bowen and Hoots (61: 10, 23-24); Ferren (74: 19-20); Knowlton (138: 215-216), (140: 61-65); Powell (229: 40, 45-47, 64-66, 162-166); Osborn (224: 53); Schultz (247: 259, 263-264), (248: 219, 223, 232-234), (251: 23, chart f.p. 24); Veatch (298: 526-549), (299: 246, 249).

GENERAL INFORMATION

Distribution, lithology and stratigraphic relations. -- Dobbin, Bowen and Hoots (61: 23-24) described the formation in the Hanna and Carbon basins in 1929:

"The Medicine Bow formation ranges from 4,000 to 6,200 feet in thickness and consists of yellow, gray, and carbonaceous shale, beds of coal, and gray and brown sandstone. The lower part of the formation is made up of massive to cross-bedded brown sandstones, which usually form a conspicuous group of ledges and contain numerous beds of coal. These sandstones are overlain by ... dark-colored shales and thin-bedded fine-grained brown sandstones, with some beds of massive white sandstone. The sandstones at the top of the formation are coarse, massive, friable, and easily eroded and are interbedded with thick beds of dark-gray shale."

Dobbin and others (62: 142) reported in 1929 that in the Rock Creek field, rocks "corresponding to the Medicine Bow and Ferris formations of the Hanna and Carbon Basins may be present above the Lewis and beneath the overlapping gravel and Hanna formation in parts of the area described, but if so they are wholly concealed." Unpublished data and maps of the general region of the Rock Creek field, compiled by Knight for the Department of Geology, University of Wyoming, show the Medicine Bow formation cropping out along the Albany County line from the southern part of T.16 N., to the northern part of T. 19 N., R. 77 W., as well as in the Rock Creek field proper.

Ferren (74: 19) reported that, at the southeastern end of the Shirley Mountains in Carbon County, Wyoming, the Medicine Bow is from 4,000 to 6,000 feet thick and consists of "an alternating series of brown, gray, white, buff, and yellow massive to thin-bedded ripple-marked and cross-laminated sandstones intercalated with gray, blue, and black shales." He noted also the presence of a "few thin coal beds of minor importance" in the lower part of the formation.

The Medicine Bow formation, wherever identified, is apparently conformable with the underlying Lewis. Conformable relations were noted by Bowen (17: 230) in the type locality, by Knight (personal communication) and parties of the Geological Survey of Wyoming in southern Albany County, and by Ferren (74: 20) at the southeastern end of the Shirley Mountains. Bowen also maintained (17: 232-233) that the relation between the Medicine Bow and overlying Ferris is one of strict conformity. Ferren noted (74: 20) similar relations at the southeastern end of the Shirley Mountains.

The "Black Buttes coal group", named by Schultz in 1909, in his paper on the northern part of the Rock Springs coal field, may belong

largely to the Medicine Bow. The cola group has been assigned by some geologists to the Lance, but, because of geographic location, should perhaps be called Medicine Bow. Schultz, in his description (247: 263) of the "Black Buttes coal group", stated that along the east side of the Rock Springs dome

"the Black Buttes coal group lies conformably upon the marine Lewis shale . ... The basal member ... consists of a massive bed of yellowish-white sandstone, in places over 100 feet thick and not known to be coal bearing. This member ... forms steep hills and cliffs along the contact. The rocks above this sandstone consist of a series of variable sandstone, clay, and coal beds that lie exposed in the low hills and ridges east of the main scarp. On the west side of the dome this group is absent ..."

In the paper quoted, Schultz assigned the coal group to the Laramie(?) formation and represented a thickness of 2,371 feet, plus or minus. In his paper of 1910, on the southern part of the Rock Springs field he represented (248: 223) 1,500 feet of the coal group, again assigning it to his "Laramie" (see table p. 19). In 1920, reporting on the Baxter Basin field (251: 23), Schultz once more included the group in his "Laramie" (see table, p. 23).

Black Buttes Coal Group is a name of economic significance only, and has no valid stratigraphic rank. The beds figured in the historic "Laramie problem", and the name is partially synonymous with the *Bitter Creek group of the geologists of the territorial surveys. The beds were included in the *Bitter Creek by Meek in 1874 (in Hayden 107: 455), by Powell in 1876 (229: 40, 45-47, 64-66, 162-166), by Peale in the same year (in Hayden 109: 145), by White in 1879 (in Hayden 114: 223), and by other writers (see pl. 2). In 1922 Knowlton reviewed the controversy over their age (140: 61-65). For more detailed information on this unit see the following references: Schultz (247: 259, 263-264), (248: 219, 223, 232-234), (259: 293-294), (251: 23); Dobbin, Bowen and Hoots (61: 23-24).

Paleontology, age and correlation. -- (See pls. 1 and 3). Bowen included (17: 230) only a brief note on the paleontology of the Medicine Bow:

"The formation contains remains of fresh and brackish water invertebrates, land plants, and bones of vertebrates. The plants are regarded by F.H. Knowlton as of the same age as the plants of the Laramie of the Denver Basin. The invertebrates are considered by T.W. Stanton to belong to the fauna of the Lance formation. The bones belong in part to the ceratopsians, but no specimens have been found that are sufficiently diagnostic for even generic determination."

Dobbin, Bowen and Hoots believed (61: 23), in 1929, that the Fox Hills sandstone of eastern Wyoming is "almost certainly represented in the uppermost part of the Lewis shale, in the lower 500 feet of the Medicine Bow, and in the basal member of the Black Buttes coal group ..." They believed also that the Lance formation "is approximatley represented in the major part of the Medicine Bow formation".

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Section of Late Cretaceous and Tertiary Rocks Exposed in the Rock Springs Uplift, Sweetwater County, Wyoming (after Schultz)

Series and group	Formation and member.		Economic designation.	Thickness (feet).	Character.
	Igneous.		Leucite lava.	0-350	Dikes, flows, volcanic necks, and agglomerate.
Tertiary or Quaternary.	Bishop conglomerate.		Gravel	0-2,000	Waterworn and subangular pebbles and boulders, many of them from 1 to 6 feet in diameter, embedded in finer gravel and sand.
	Unconformity				
Eocene series	Bridger formation.		Volcanic ash.	0-2,000	Green and buff tuffaceous shales and sandstones, coarse pumiceous tuffs, marls, and shales, conglomerates, cherts, limestones, and thin beds of lignite. Red, green, and buff gypsiferous tuffs and white marls.
	Unconformity				
	Green River formation	Plant beds and Tower sandstone of Powell		0-500	Massive, irregularly bedded sandstone; white, yellow, and brown shaly sandstone; some limestone and interbedded shale.
		Unconformity			
		Laney shale member.	Upper oil shale	0-950	Thin-bedded shale, sandstone, and limestone (some of which are oolitic); some dark-colored bituminous shale.
		Unconformity			
		Cathedral Bluffs red beds member.	[1]	0-1,500	Variegated clay, shale, and sandstone; in places slightly conglomeratic; produces highly colored escarpment of Laney Rim and Cathedral Bluffs.
		Tipton shale member	[2] Lower oil shale.	100-325	Thin fissile shale and sandstone; pronounced oolitic limestone, in places 20 to 50 feet thick near base; also other oolitic and concretionary beds locally resembling huge oyster shells scattered on surface.

Section of Late Cretaceous and Tertiary Rocks Exposed in the Rock Springs Uplift[1] (Cont'd)

Series and group.	Formation and member.	Economic designation.	Thickness (feet).	Character
Eocene series	Wasatch formation	Black Rock coal group	1,000-2,500	Alternating layers of white, yellow, and brown sandstones and gray or drab and carbonaceous shales, with coal beds and conglomerate containing granite and quartzite pebbles. Numerous bands of white concretionary sandstone, weathering in irregular shapes. Basal sandstone is conglomeratic. Sandstone hardens locally and weathers into forms resembling large logs or spherical concretions. Large cross-bedded reddish sandstone forms badland topography in Red Creek valley and Fire Hole Basin.
	Unconformity			
Cretaceous (?).	Post-"Laramie" formation	Knobs-Cherokee coal group	6,000-9,400	Alternating layers of soft yellowish brown and white sandstones and drab, brown, and black shales.
	Unconformity			
Upper Cretaceous series.	"Laramie" formation	Black Buttes coal group	1,500	Massive basal bed of white and yellow sandstone, showing traces of conglomerate in places: forms prominent scarp; overlain by various sandstone, clay, and coal beds. Fossils abound in places. Exposed only in the northern part of the east side of the dome, and here only the lower part is visible. On west side of Rawlins dome this formation is 3,900 feet thick.
		Montana group (Lewis shale, etc.)		

[1] Copied from Schultz' (251: 22-23), Oil possibilities in and around Baxter Basin: U.S. Geol. Survey Bull. 702, 1920.

The remainder of Schultz' section, which shows the characters of the members of the Montana group, is omitted here. The section shows Schultz' classification of the rocks in his last report on the Rock Springs area. In an earlier report (see table, pp. 20-21) Schultz assigned beds equivalent to beds [1] and [2] to the "Wasatch" formation.

C R E T A C E O U S - T E R T I A R Y T E R R A N E S

CRETACEOUS to MIDDLE EOCENE *BITTER CREEK TERRANE

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- The unit has no valid rank. It was a terrane which included previously named, more natural, divisions, and the name Bitter Creek has been dropped. The type locality was along Bitter Creek, Sweetwater Co., Wyoming, in the vicinity of Bitter Creek and Black Buttes stations, on the Union Pacific Railroad.

TYPE DESIGNATION. -- Powell named (229: pp. indicated) the *Bitter Creek "group" in 1876:

"This group is well exposed along Bitter Creek in the vicinity of Bitter Creek and Black Buttes Stations. A fine section can be obtained by commencing at Pine Bluffs at the foot of the limestone beds and passing in a direction a little north of west until the massive gray sandstone of the next group is reached. Across this stratch of country the beds dip to the east, and their outcropping edges stand in a succession of ledges and can be well studied.

* * *

"The junction of the Bitter Creek Group with the Lower Green River can be very well seen in the escarpment at Pine Bluffs ... In like manner the junction between this group and the next lower[1] can be well seen in an escarpment east of and facing Black Butte." (pp. 45-46)

* * *

"Those beds to which the name Wasatch Group has been given ... are the western extension of the Bitter Creek beds, and hence the name Wasatch group should be dropped. The conglomerate at the bottom of what was called the Wasatch Group is represented by the conglomerates of the Bitter Creek Group on both flanks of the Uinta Mountains.

"The beds called the Washiki[2] Group are the upper part of the Bitter Creek series. I have been unable to carry any line of demarkation between these beds over such an extent of country as would warrant their separation from the Bitter Creek series, yet this may be done ..." (p. 65)

SYNONYMY. -- (See table, p. 14).

Powell's *Bitter Creek group (229: 45-47, 64-65) included the Lewis, Lance (or Medicine Bow), Ferris, Hanna, Evanston, and Wasatch, the "Black Buttes coal group" of Schultz (247) (248) (251), the upper part of the "Laramie" of his contemporaries, all of King's *Vermilion Creek group, and the *Washakie (= upper Bridger) of Hayden. In general, the same usage was followed by those of Powell's contemporaries who employed the name.

IMPORTANT REFERENCES. -- Cope (40: 36), (in Hayden 108: 435-436); Knowlton

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[1]The next lower unit was Powell's *Point of Rocks group, the upper part of which is now assigned to the Mesaverde formation.

[2]An outmoded spelling of *Washakie = upper Bridger.

*BITTER CREEK TERRANE - References; General Information

(138: 215-216), (140: 61-65); Lesquereux (148: 25-26); Meek (in Hayden 107: 456-457), (199: LI); Powell (229: 45-47, 64-66, 162-166).

GENERAL INFORMATION

The name *Bitter Creek group had come into general use some time before the publication of Powell's Uinta Mountain report in 1876. Cope, in his report of 1874 on the vertebrate paleontology of Colorado (in Hayden 108: 435-436), described the *Bitter Creek strata in the Black Buttes locality. Cope recorded the finding of the bones of Agathaumus sylvestris, associated with plant leaves at Black Buttes, just above a heavy sandstone low in the series. This dinosaur horizon, was later assigned to the "Black Buttes coal group" by Schultz, which is believed to be of either Lance or Medicine Bow age. In his work on the Cretaceous Vertebrata, Cope, in 1875 (40: 32), described the stratigraphy and paleontology of the *Bitter Creek exposures a few miles south of Black Buttes.

In 1873 Meek, in one of his paleontological papers, described (in Hayden 107: 455-457) the "group" in the general area of the type locality. He found that, near Black Butte Station, the "group" passed under strata of the *Washakie formation, from which he had difficulty in separating it. He classified the fossils as "brackish water types".

Meek again discussed the paleontology and correlation of the *Bitter Creek in 1876, and theorized (199: LI) concerning its relations to the Judith River formation. He decided:

"It would be unsafe, however, to refer these Black Butte beds positively to the horizon of the Judith River group on the evidence of a single species of Corbicula, the presence of lignite, and Dinosaurian[1] remains; but it is certainly an interesting coincidence that it should be found here at this remote locality under such similar circumstances."

Lesquereux's studies of the fossil flora of the *Bitter Creek led him to the belief (148: 25-26) in 1876 that the group was Tertiary in age.

The relations of the *Bitter Creek to the "Laramie Problem" were fully reviewed by Knowlton (140: 61-65) in 1922.

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[1] Meek and Hayden were the discoverers of the dinosaur Agathaumus sylvestris, which had been described and named by Cope.

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UPPER CRETACEOUS to LOWER EOCENE(?) *DE SMET TERRANE

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- The unit was originally defined as a formation. It has since been shown to be a terrane, has been subdivided into more natural divisions, and has been relegated to synonymy. The type locality was in the northeast quarter of the Dayton quadrangle, Sheridan County, north-central Wyoming, in the vicinity of Lake De. Smet.

TYPE DESIGNATION. -- Darton named and described the *De Smet in 1906 (56: 8):

"The great series of coal measures occupying the northeast quarter of the Dayton quadrangle consists of sandstones and shales, several thousand feet thick, for which the name De Smet formation is proposed. A typical locality is about Lake De Smet, northwest of Buffalo, where there are extensive exposures. For the greater part of its extent in the Dayton quadrangle the De Smet formation lies on the Piney formation, but farther southeast it is underlain by a thick mass of Kingsbury conglomerate ... and it is probable that this conglomerate develops out of its lower portion.

"The De Smet formation has a thickness of 4000 feet or more, for its beds dip eastward at angles ranging from 3° to 8° under a district 15 miles wide, in the northeast corner of the Dayton quadrangle."

RESTRICTIONS. -- The name has not been used since 1909, when Taff, in his paper on the Sheridan coal field, divided (295: 126-132) the *De Smet into members, which were shown by Thom and Dobbin (296: 488), and by Simpson (271: 1-12) to range from Upper Cretaceous to lower Eocene in age.

SYNONYMY. -- Darton's *De Smet included the Lance, the Lebo and Tongue River members of the Fort Union, and the Ulm formation.

In 1909 Taff (295: 126-132) separated the *De Smet of Darton into two major divisions; the lower he left unnamed, but the upper division he subdivided into the Tongue River, *Intermediate, and Ulm "coal groups".

According to Thom and Dobbin (296: 488), the lower part of Taff's lower member = Lance formation; the upper part of Taff's lower member = Lebo shale; the Tongue River "coal group" = Tongue River member of the Fort Union; the *Intermediate and Ulm "coal groups" = Wasatch. These statements of equivalence were reiterated by Baker (2: 24).

Thom and Dobbin also believed the *Intermediate coal group was in part equivalent to the Sentinel Butte shale of North Dakota and eastern Wyoming, assigned by them to the Wasatch, but classed by the U.S. Geol. Survey as Fort Union(?), and by Simpson (271: pl. f.p. 12 as upper Paleocene (see chart, p. 29).

IMPORTANT REFERENCES. -- Baker (2: 23-29); Darton (56: 8-9, 16), (57: 59-67); Gale and Wegoman (81: 141-146); Simpson (271: 1-12); Taff (295: 126-133); Thom and Dobbin (296: 481-506).

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SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- The Livingston was designated as a formation by Weed (305: 21). It has since been shown by Stone and Calvert to include (293: 763-764) both Cretaceous and Paleocene strata. It is therefore a terrane, as that term is used in this paper. The type locality is in the vicinity of the town of Livingston, Montana, north of the line of the Northern Pacific Railroad.

TYPE DESIGNATION. -- Weed proposed the name "Livingston" in 1893 (305: 21):

"Overlying the coal-bearing Laramie strata, there is a series of beds constituting a newly recognized formation, for which the name Livingston is proposed, as it is typically developed in the vicinity of Livingston, Montana. The formation consists of a series of beds, in places aggregating 7,000 feet in thickness, composed of sandstones, grits, conglomerates, and clays, made up very largely of the debris of andesitic lavas, and other volcanic rocks, and including local intercalations of volcanic agglomerates."

RESTRICTIONS. -- Stone and Calvert stated in 1910 (293: 764) that the stratigraphic interval included in the Livingston "formation", as mapped by Weed, varied from place to place, in some localities including strata as old as lower Montanan, and in others including beds as young as Fort Union. They concluded, therefore, that the Livingston "has no definite age, and no formational value except in the immediate vicinity of the type locality".

DISTRIBUTION. -- As restricted by Stone and Calvert, the Livingston terrane is confined to the type locality. The name is not applied to strata in Wyoming, though Eldridge believed in 1894 (69: 25) that he had identified it in the borders of the Big Horn Basin.

SYNONYMY. -- The "Livingston" of Weed (305: 10, 21-35) (307: 201-211) included the upper Montana, the Lance, and the Lebo member of the Fort Union.

In 1894 Eldridge applied (69: 25) the name Livingston to strata in the Big Horn Basin of Wyoming. The writer believes that he applied the name to strata most of which belong to the Fort Union. Part of the Lance may also have been included.

IMPORTANT REFERENCES. -- Eldridge (69: 25); Stone (290: 80, 81-82); Stone and Calvert (291: 551-557), (292: 652-659), (293: 741-764); Weed (305: 21-35), (307: 201-211).

GENERAL INFORMATION

Weed stated (305: 10) that the Livingston overlies the "Laramie", that it consists of "strata composed of waterlaid and assorted volcanic material" containing "intercalated beds of true volcanic agglomerate", and that it is "overlain by a great thickness of beds ... which are believed to be of Fort Union age". Weed had said (305: 21) that the Livingston unconformably overlay coal-bearing sandstone belonging to

the Laramie formation. Stone and Calvert maintained (293: 763-764) in 1910, however, that

"the coal-bearing sandstone is Eagle, or at least lower Montana in age. ... the flora of the upper part of the coal-bearing beds is similar to the Livingston flora, the greater part of which comes from within 600 feet above the coal-bearing sandstone. The coal-bearing beds are transitional into the tuffaceous beds above. Therefore, the evidence of both stratigraphy and paleobotany indicates that the Livingston beds are conformable on the under-lying coal-bearing beds.

"The Livingston formation was originally described as a lithologic unit ..., the material of which the beds are composed, and not the fossils, determining the extent of the formation. Beds of this character ... have been traced north and east around Crazy Mountain where beds of similar lithology are found in all the formations from Colorado to Fort Union, and where they feather out and merge with fresh- and brackish-water and marine deposits.

"Stratigraphic relations, marine invertebrates, and fossil leaves prove the Montana age of the lower part of the tuffaceous beds on the west side of the Crazy Mountains. Northeast of the mountains some of the strata are younger than the Bearpaw and older than the Lance, while the youngest of the andesitic deposits are Fort Union. ... it is concluded that the lithologic unit ... described as the Livingston formation has no definite age, and no formational value except in the immediate vicinity of the type locality."

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Provisional Correlation of the American Paleocene (after Simpson, 1929[1])

Age		San Juan Basin (N.M.-Colo.)	Northern Wyoming	Southern Montana		Central Alberta	Principal Characters of Vertebrate Faunas
Lower Eocene		Largo	Gray Bull etc.	—?— Ulm coal group		(Absent)	
		Almagre					
		(Absent or non-fossiliferous)	Sand Coulee				First Perissodactyls, Artiodactyls, Rodents, and Adapids.
							MARKED FAUNAL CHANGE
Paleocene	Upper	—?— Tiffany	Clark Fork —?— (No Mammals)	Fort Union	Sentinel Butte (Bear Creek Fauna)	Paskapoo —?— (Absent or non-fossiliferous.)	Last Champsosaurs Last Periptychus First Phenacodus, Meniscotheres, etc. Plesiadapis
	Middle	Torrejon			Tongue River		Ptilodus, Chriacus, Claenodon, Tetraclaenodon, Pantolambda
					Lebo (Fish Creek Fauna)		
	Lower	Puerco		Tullock (No Mammals)			First Carnivores and Ungulates. Taeniolabis, Triisodon, Ectoconus, Conacodon
							GREATEST FAUNAL CHANGE
Upper Cretaceous		(Absent	[Lance]	Hell Creek		(Absent?)	Last Dinosaurs. Mammals: Only Insectivores, Didelphids, and Multituberculates
		Ojo Alamo				Edmonton	

[1]After Simpson, G.G. (271), Third contribution to the Fort Union Fauna at Bear Creek, Montana: Am. Mus. Novitates No. 345, chart following p. 12, 1929.

PALEOCENE UNITS

LOWER PALEOCENE(?) LANCE FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- In some localities the Lance is a homogeneous unit; in other regions it is divisible into mappable members which differ both lithologically and paleontologically from each other. Hence, in some localities it is a group. The type localities are along and near Lance Creek, Converse County, Wyoming; northwestern South Dakota; southwestern North Dakota.

TYPE DESIGNATION. -- The name Lance formation was proposed and defined by T.W. Stanton (286: 172-188) in 1910, according to Knowlton, who published (140: 33) the following comments on, and quotations from, the type designation:

"Of the three areas discussed in this paper the one first considered was the Standing Rock and Cheyenne River Indian Reservation, or the region between Grand and Cannonball rivers in North and South Dakota. ...

> "'... there is a rather thin but widely distributed brackish-water bed, which contains Ostrea, Anomia, Corbicula, Melania, etc., in great abundance. The zone ... varies in thickness from 3 or 4 feet up to 40 feet and is lithologically very similar to the underlying marine beds, but its base is irregular at many places and shows channeling and other evidences of erosion. It was therefore regarded by the field geologists as the basal member of the overlying Lance formation resting unconformably on the Fox Hills. In the study of this brackish-water bed evidence was found at several localities, ... that there is a distinct transition without a break of any importance between the marine Fox Hills sandstone and the brackish-water deposit. ... distinctive Fox Hills species belonging to such marine genera as Scaphites, Lunatia, and Tancredia, /were/ found directly associated in the same bed with the brackish-water forms ...'

"The second area included the valley of the Little Missouri from Marmarth to Yule, N. Dak. The point emphasized with reference to this area was the finding of an oyster bed some 500 feet above the base of the Lance formation and above all the dinosaurs that have been found in the region.

"The Lance Creek area in Converse County, Wyo. ... was the third area considered. Of this area Stanton said:

> "' ... the marine Fox Hills deposits extend about 400 feet higher than had previously been determined, and ... nonmarine coal-forming conditions were temporarily inaugurated here before the close of Fox Hills time.'"

SYNONYMY. -- (See table, p. 15). *Lance Creek, "Hell Creek", and "Ceratops" beds were names frequently applied to the Lance. These terms, however,

were not in every case, exact synonyms of Lance, since they were most frequently applied to what is now called the Hell Creek member. Stone and Calvert (293: 746) stated that the term Lance formation had been adopted by the Committee on Geologic Names of the U.S. Geological Survey as a formation name to apply to strata which had been called "Lance Creek", "Hell Creek", and "Ceratops" beds, in Wyoming, Montana and the Dakotas.

"Laramie" of Eldridge (69: frontispiece) in 1894 in the Big Horn Basin = Lance and probably some Fort Union. It may safely be assumed, as a general rule, that any so-called Laramie beds in northern and eastern Wyoming are either wholly or partially assignable to the Lance formation.

*Lance Creek beds was proposed by Hatcher (96: 369) in 1903 as an alternative for "Ceratops beds".

"Laramie" of Ward in 1886 (303: 401-555) included the Lance.

"Laramie and associated formations" of Fisher in 1906 (76: pl. 3) included strata of the Lance.

*De Smet formation of Darton (56: 8-9; and other papers) in 1906, included the Lance, according to Baker (2: 24).

In 1909 Knowlton (138: 238) considered the Lance an integral part of the Fort Union.

"Laramie" of Washburne (304: 169) in the northeast portion of the Big Horn Basin, and of Woodruff (334: 206) in the southwest portion of the basin (both in 1909), are probably Lance plus some Fort Union.

"Lance" of Barnett (7: 65) in 1914, in the Douglas oild field of Converse Co., Wyoming, probably includes the Fort Union.

*Ilo formation of Hewett (120: 103-104) in 1914, along the Shoshone River and eastern edge of the Big Horn Basin = Lance.

In 1930 Jepsen decided (128: 475) that in the Big Horn Basin a sandstone, mapped by the U.S. Geological Survey in the upper Lance, rightfully belongs in the lower Fort Union.

DISTRIBUTION. -- Eastern, central, and north-central Wyoming; eastern and southern Montana; western part of the Dakotas. Because of geographic location the "Lance" formation, as mapped in southern Wyoming in and around the Rock Springs uplift, should, perhaps, be called Medicine Bow. The type exposures of the Medicine Bow formation are in Carbon County, almost on a direct line between the Rock Springs uplift and the type localities of the Lance.

NOMENCLATURAL DIVISIONS. -- In northeastern Wyoming and parts of Montana the Lance is divided into the Hell Creek and Tullock members. In 1934 Schlaikjer named (241: 45-47) the Torrington, a new member of the Lance in the Goshen Hole area of eastern Wyoming. In the Dakotas the formation is divided into the Ludlow lignitic and Cannonball marine members, which merge and interfinger in some localities, and a lower, unnamed, "somber" non-lignitic member.

IMPORTANT REFERENCES. -- Baker (2: 24); Brown (23: 823-845), (24: 355-380); Dobbin, Bowen and Hoots (61: 23); Dobbin and Reeside (63: 165-166), (64: 9-25); Hatcher (95: 135-144), (96: 369-375), (97: 1-300); Hewett (120: 103-104), (122: 26-30); Jepsen (128: 496); Knowlton (138: 179-238),

LANCE FORMATION - References; General Information

(140: 25-41); Lloyd and Hares (151: 523-547); Matthew (188: 221), (S.352: 209-227), (S.353: 27-29); Osborn (224: 45-53); Schlaikjer (241: 31-68); Schuchert (245: 45-47); Shimer (265: 913-915; pl. 122); Simpson (268: 1-7), (271: 1-12); Stanton (286: 172-188), (289: 127-156), (S.345: 1-9); Stone and Calvert (291: 551-557), (292: 652-669), (293: 741-764); Thom and Dobbin (296: 500-506).

Areal Distribution and Lithology

Southern and central Wyoming. -- Strata in southern Wyoming called Lance should probably be called Medicine Bow and/or Ferris (see pp. 20-21, ante).

In the Salt Creek oil field of Natrona County, central Wyoming, according to Wegemann (309: 50), the Lance is 3,200 feet thick. The Lance of the Wind River Basin was described by Bauer (11: 672) in 1934.

Big Horn Basin, Wyoming. -- The geology of the general area of the Big Horn Basin was examined and described by Eldridge in 1894 (69: 1-72), by Darton (57: 60-70) (58: 303) and Fisher (75: 311) in 1906, and by Hewett (120: 103-104) in 1914 (see synonymy of Laramie and Lance, pp. 11, 31). In all these papers, deposits of Lance age were included with other strata under the name "Laramie", except by Hewett, who called them *Ilo.

In 1917 Hewett and Lupton (123: 27-28), used the name Lance for strata in the southern part of the Big Horn Basin and defined the base of the unit as "the first massive sandstone that overlies the coal-bearing part of the Meeteetse formation west of Big Horn River and the shale east of the river". The top of the Lance was placed at the base of an unconformably overlying conglomerate, assigned to the Fort Union formation.

In 1926 Hewett described the geology of the Oregon Basin, Meeteetse and Grass Creek Basin quadrangles, where, he said (122: 26-27), sand and sandstone dominate clay and shale in the Lance. The sandstone beds, usually massive and non-laminated, occasionally "show the torrential type of cross-bedding" and range from 40 to 210 feet in thickness. Exposures in the Oregon Basin Quadrangle, Hewett said, are poor and the good outcrops are "confined to the few badland areas along the upper parts of the two branches of Dry Creek". He added:

"A characteristic feature ... is the presence of persistent beds from which numerous concretions weather out. Most of these concretions are slightly flatttened spheres that commonly range from 2 to 10 feet in diameter. ... The beds of clay and shale range from gray to light brown but commonly lack the lamination and dark color of those of the Meeteetse formation. No gravel has yet been found in the Lance, and the coarsest material appears to be less than 0.1 inch in diameter."

Hewett found that in the Meeteetse Quadrangle the thickness of the Lance ranged from 910-1,010 feet in the northwest, to 840 feet in the southeast. In the Grass Creek Basin Quadrangle, Hewett said (p. 30), the color of the Lance

LANCE FORMATION - Areal Distribution and Lithology

"ranges from buff to slightly yellowish and white. The beds of intercalated shale are generally thinner than the sandstones, and their color ranges from gray through pale drab to olive-brown and brown. The coarsest material ... consists of several rounded quartzite pebbles about 1 by 1½ by 2 inches, found associated with waterworn bones in sec. 29, T.46 N., R.97 W. ... in the same section several beds of coal, each less than 6 inches thick, occur in the uppermost 15 feet of shale ... These are the only coal beds observed in the Lance formation in the entire region."

In 1930 Jepsen (128: 496) recorded his opinion that in the Big Horn Basin the Hell Creek and the Tullock members of the Lance formation are not recognizable, and that the Lance, as mapped by the U.S. Geological Survey, included strata shown by fossil mammals to belong to the lower Fort Union.

Johnson (130: 821) stated in 1934 that, in the Cody region of the Shoshone Canyon, there are 1,800 feet of strata in the Lance formation.

Northeastern Wyoming; southeastern Montana. -- In 1922 Collier recorded (31: 87) that in the Osage oil field the Lance formation is composed of soft massive cross-bedded and irregularly bedded prolifically concretionary sandstones, and sandy shales.

The formation northward from the Osage oil field, Weston County, was described by Dobbin and Barnett (60: 8) in 1927:

"In the Gillette field ... the Lance formation is divisible into a lower member consisting of sandy shale, dark gritty clay, and massive sandstone containing dinosaur bones, and an upper member composed of fine-grained yellowish sandy shale interbedded with thin layers of hard calcareous sandstone and numerous thin carbonaceous beds. These members ... are directly traceable northward into the Hell Creek and Tullock members of the Lance formation ... in eastern Montana. The Hell Creek member is also traceable southeastward into the 'Ceratops' beds of the Lance Creek area ..."

Goshen Hole area. -- The Lance formation in the Goshen Hole of eastern Wyoming was described by Schlaikjer in 1935 (241: 31-68). He found (p. 65) that the formation can there be separated into three divisions: (1) lower; 100-200 feet of continental deposits containing ceratopsians and other reptiles; (2) middle; 80-125 feet of brackish-water deposits; (3) upper; 60-100 feet of continental deposits (Torrington member), containing Triceratops eurycephalus Schlaikjer, a new advanced species. In this region Schlaikjer said (p. 33) that the Lance as a whole consists mainly of yellow and greenish sands, yellow, green and red carbonaceous shales, lenticular beds of cross-bedded yellow and brown channel sandstones, occasional large rounded sandstone concretions, a few thin beds of lignite, black shales, and a few thin limestones.

Stratigraphic and Structural Relations

Big Horn Basin. -- In the Oregon Basin, Meeteetse and Grass Creek Basin

quadrangles Hewett recorded (122: 30) locally discernible angular unconformities between the Lance and overlying Fort Union. Concerning the Oregon Basin Quadrangle he remarked (p. 28) that in secs. 13 and 24, T.50 N., R.100 W., a sandstone in the base of the Fort Union "rests successively on the Lance and Meeteetse formations and therefore marks an angular unconformity". He noted, however (p. 29), in the Grass Creek Basin Quadrangle, that if "the unconformity at the base of the Fort Union is present in this quadrangle it is not apparent".

Jepsen (128: 496, 498), in 1930, stated that in northeastern Park County the dinosaur-bearing Lance is disconformably overlain by beds of the Fort Union which have yielded Puerco vertebrate fossils. He concluded that "this disconformity marks the greatest faunal separation in the stratigraphic column of the area".

Miscellaneous localities. -- Renick (232: 15) stated in 1929 that the Lance and underlying Bearpaw (Cretaceous) are difficult to separate in the central and southern part of Rosebud County, Montana.

Collier (31: 87) observed that in the portion of Weston County examined by hin "a casual examination suggests that the Lance formation may be unconformable with the Fox Hills sandstone. Darton and other Federal geologists, however, have regarded these formations as conformable."

Bauer (11: 672) maintained that in the Wind River Basin the contact between the Lance and Fort Union formations is strictly conformable.

Schuchert, in his paper of 1921 on the Lance and Fort Union formations, concluded (245: 45-46), from studies in the Dakotas, (1) that there is no important faunal or stratigraphic break between the Lance and the underlying Fox Hills or the overlying Fort Union, (2) that the sequence from the Pierre and Fox Hills to the top of the Fort Union is unbroken, and (3) that reported unconformities are due entirely to changes "from marine to brackish- and fresh-water deposition or to the irregularities of continental sediments". Two years later, nevertheless, Merrill stated (206: 592) that "most geologists recognize an unconformity" below the Lance, and that this unconformity in many places cuts down into the Pierre.

In 1930 Dobbin and Reeside published a systematic study of the stratigraphic relations of the Lance to underlying rocks. Among their conclusions they stated (64: 9) that

"the Laramie, Arapahoe, and Denver formations of the Denver Basin are represented in the Lance formation; that the differing thicknesses of the Fox Hills are original and not due to varying amounts of pre-Lance erosion; that each supposed angular discordance is due to some other phenomenon, such as local small faulting or cross-bedding; and finally, as a general conclusion, that there is no unconformity between the Fox Hills and Lance other than such as is found along local minor erosion planes at many horizons within both formations."

LANCE FORMATION

Paleontology, Age and Correlation

The complete known dinosaur fauna of the Lance was described by Hatcher, Marsh and Lull in 1907 (97). Brown, in 1914, pointed out that the name "Ceratops beds" was a misnomer, applied to the Lance, "because the genus Ceratops became extinct long before Lance time, and that the Lance "should be known faunally as the Triceratops zone".

Knowlton (140: 40) believed the Lance was partly synchronous with the Arapahoe, Denver, Raton and *Dawson arkose (= Monument Creek, sensu stricto). He stated that the U.S. Geological Survey had tentatively decided in 1914 to assign the Lance to the Tertiary system. Bauer had previously explained this assignment, stating (9: 298) that "the close correlation of the Lance flora with that of well-determined Tertiary formations of the Gulf coast, considered together with the mountain-making movements that are supposed to have immediately preceded the deposition of the strata", had led the survey to assign the formation to the Tertiary(?) system.

Matthew, however, disagreed strongly with this age classification. He declared (S.353: 27, 28) in 1921:

"The position of these border-line formations has been in dispute ... ever since they were first discovered. A Cretaceous vertebrate fauna was found associated with a Tertiary flora. Vertebrate palaeontologists and palaeobotanists took opposite sides; the stratigraphic geologists were divided ... This discrepancy has been maintained and confirmed by all subsequent work. It should be recognized as the fundamental difficulty. It does not help matters to misrepresent or ignore any part of the evidence, and if Dr. Cross's references to the vertebrate evidence fairly reflect the way in which the U.S. Geological Survey'considered all available evidence' ... its weight and tenor was not correctly understood.

* * *

"The Lance fauna is wholly Cretaceous in character. It is entirely a continuation and specialization of the Judith (late Cretaceous) without any new elements, but the amount of evelutionary change ... shows that it is considerably later in time."

Elsewhere (S.352: 217, 221), Matthew said in the same year:

"The Lance of Wyoming, Hell Creek of Montana, Arapahoe and Denver of Colorado contain the Triceratops fauna. The same six families of dinosaurs are found ... The same groups of turtles, crocodiles and Rhynchocephalia are present ... The mammals (chiefly from the Lance) belong mostly, probably all, to the metatherian families Plagiaulacidae and Cimolestidae, but include more specialized genera than are found in the Senonian. Detailed comparisons indicate a very considerable lapse of time as measured by the phyletic changes, but no great faunal break or change, due to the invasion of a new fauna from elsewhere.

* * *

"The position of the Edmonton as indicated by its dinosaurs is about half way between the Lance and the Judith-Belly River. It confirms

the view that the faunal change from Judith to Lance was due to time, not to migration.

"(5.) The correlation of the Lance with the latest marine Cretaceous of the American succession is very strongly supported by Dr. Stanton's Cannonball memoir."

In 1915 Bowen, from an exhaustive comparison of the faunas of the Judith River, Belly River and Lance formations, concluded (16: 153) that the evidence of both vertebrates and invertebrates "indicate a closer relationship between the Belly River and Judith River" than between either of them and the Lance, and that they both "are separated from the Lance by a marine formation which is of undoubted Cretaceous age".

Hewett and Lupton (123: 28) concluded in 1917 that, although the Lance "is usually classed in the Tertiary(?) system, the striking unconformity at its top in the Big Horn Basin inclines the writers to believe that it is more properly assignable to the Cretaceous".

In 1930 Jepsen's paleontologic observations led him to decide (128: 498) that in the Big Horn Basin, between the Lance and Fort Union, there is a time-gap which "is the only break of note within the Cretaceous-Tertiary sequence of the basin," and that he favored "placing of the Cretaceous-Tertiary boundary between the Lance and the Paleocene".

Problems in the classification of the beds lying between known Cretaceous and unquestioned Tertiary sediments were summarized by Shimer (265: 913-915) in 1934. Shimer pointed out that in these transitional beds, (1) the flora is dominantly Fort Union; (2) 75 per cent of the species of plants in the Ludlow and Hell Creek members of the Lance in the Dakotas range into the Fort Union; (3) the Cannonball marine member of the Lance is Cretaceous in age and interfingers with the Ludlow member; (4) the Fort Union is post-Cannonball and is either Danian [see pl. 1] or Paleocene in age; (5) the Raton, Arapahoe and Denver floras are younger than the Lance and older than the Eocene Wilcox flora of the Gulf coast; (6) "the presence of the majority of the species of the so-called Fort Union throughout the Danian and the Paleocene means either an unparalleled persistence of an almost entire flora or the need of more careful collecting and of a more refined discrimination of species, the necessity of a restudy of these various floras from the modern stratigraphical and botanical viewpoint"; (7) "the widespread presence of dinosaur bones in Danian and Paleocene formations in the Rocky Mountains and Great Plains region presents the problem as to how many of these reptilian remains represent redeposition from the erosion of earlier unconsolidated beds and how many were really living at the time"; (8) "until more thorough paleontological knowledge of the Rocky Mountains-Great Plains formations is obtained, their placement in either the late Cretaceous or the Paleocene must be considered as provisional"; and that (9) "in the continental deposits of Colorado, Wyoming, South and North Dakota, and Montana, Danian-Paleocene non-marine transitional deposits probably did occur."

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SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; member of the Lance formation. The type locality is in the Hell Creek region of northeastern Montana.

TYPE DESIGNATION. -- The Hell Creek member was named and described by Barnum Brown (23: 823-845) in 1907. In 1909 Knowlton (138: 184) gave the following comments on and quotations from the type description of the member:

"To the beds of this area which contain a rich dinosaur fauna he /Brown/ gave the name Hell Creek beds, and also stated that:

> "'These beds are exposed on the Yellowstone River at Sentinel Butte /Castle Butte?/ near Forsyth; at Glendive; near Eklaka; and at Hockett P.O., south of the Yellowstone. They are probably continuous with the dinosaur-bearing beds of the Little Missouri, and of the Grand and Moreau Rivers.'

"The 'Hell Creek beds', which are between 300 and 400 feet in thickness, are stated by Brown to rest unconformably on the Fox Hills, and are composed of two members, a basal massive sandstone, and an upper member of alternating dark arenaceous clays, carbonaceous shales and sandstone. Overlying the dinosaur-bearing clays ... are the so-called lignite beds, 100 feet in thickness, which are characterized by the presence of numerous beds of coal. They are referred by Brown with question to the Fort Union. Above the lignite beds without apparent break are the light-yellow sandstones and clays of the 'identified Fort Union.'"

In 1922 Knowlton, again writing on the Hell Creek member (140: 29) quoted an additional passage from Brown's description:

> "'Lithologically the Hell Creek beds of Montana are similar in almost every respect to the Ceratops beds of Converse County, Wyo. Most genera and many species of vertebrates and invertebrates are common to both deposits, while the faunal facies may be considered a unit.'"

SYNONYMY. -- (See also synonymies of the Laramie and Medicine Bow, pp. 10-11, 17. Also table, p. 15.)

Throughout the literature the strata of the Hell Creek member have been referred to as "Ceratops beds", "somber beds" and "Hell Creek beds". Also, as is indicated in the synonymies of the Laramie and Lance formations, they were often included indiscriminately in the Laramie.

Simpson, in 1929, stated (27: 6): "The 'Hell Creek member' of the Lance is the Hell Creek or Lance, sens. strict., of vertebrate paleontologists."

DISTRIBUTION. -- The member has been distinguished from the Lance proper in eastern and southern Montana, east-central and northeastern Wyoming, and the Dakotas.

IMPORTANT REFERENCES. -- Brown (23: 823-845), (24: 356); Dobbin and Barnett (60: 8-11); Dobbin and Reeside (64: 9-25); Hatcher (95: 135-144),

(96: 369-375), (97: 1-300); Knowlton (138: 179-238), (140: 25-41); Matthew (188: 221), (S.352: 209-227), (S. 353: 27-29); Rogers and Lee (236: 26-28; the member was here called "lower part of the Lance".); Schuchert (245: 45-47); Shimer (265: 913-915, pl. 122); Simpson (268: 1-7, (271: 1-12).

GENERAL INFORMATION

In 1909 Knowlton published a study (138: 179-238) of the Hell Creek beds and related units. He believed that in most areas the Hell Creek rested unconformably on the older Cretaceous rocks, that it was not synchronous with the Laramie (restricted), and that the Hell Creek beds "are stratigraphically, structurally, and paleontolgically inseparable from the Fort Union". Apparently Knowlton's "Hell Creek beds" included the Hell Creek and Tullock members of the Lance, or else the Tullock was included in the Fort Union.

Hatcher gave the following description (95: 137) of the Hell Creek member in northeastern Wyoming:

"The Ceratops beds are made up of alternating sandstones, shales, and lignites, with occasional local deposits of limestones and marls. The different strata of the series are not always continuous ... This is especially true of the upper two-thirds of the beds. ... All the deposits of the Ceratops beds of this region bear evidence of having been laid down in fresh waters.

* * *

"The sandstones largely predominate in the lower members of the beds. They are always fine grained, massive to well stratified, and marly white to yellowish brown in color. They are occasionally compact and hard, but for the most part quite soft and friable. ... almost everywhere in the sandstones are numerous concretions of varying size and shape."

Dobbin and Barnett (60: 9) recorded a thickness of about 800 feet for the Hell Creek member in northeastern Wyoming. Rogers and Lee (236: 19) described the "lower part of the Lance formation" (probably the Hell Creek member), in the Tullock Creek coal field, Rosebud and Big Horn Counties, Montana, in 1923. In 1929 Renick (232: 15) recorded a thickness of 675 feet for the Hell Creek member of the Lance in central and southern Rosebud County, Montana. In 1927 Simpson (268: 1-7) listed, described and illustrated the mammalian fauna of the Hell Creek beds of Montana. (See pl. 1, and table, p. 29.)

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LOWER PALEOCENE(?) TULLOCK MEMBER

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; member of the Lance formation. The type locality is in the valley of Tullock Creek, Rosebud and Big Horn Counties, Montana.

TULLOCK MEMBER - Specific and General Information

TYPE DESIGNATION. -- The Tullock member was named and described by Rogers and Lee in 1923 (236: 29, 30):

"The upper member of the Lance formation -- herein named Tullock member, from its exposures in the valley of Tullock Creek -- is made up of yellowish sandstone and shale and contains ten more or less lenticular coal beds. ... Although the sandstone is lithologically similar to that in the lower part of the formation, it commonly occurs in beds less than 20 feet thick. These beds, however, seem to be more persistent than the thicker ones that are common in the lower part of the Lance. Much of the sandstone and shale is more or less calcareous ... The shale is for the most part yellowish gray to brownish ... Many bands of carbonaceous shale are present in the Tullock member ...

* * *

"The thickness of the Tullock member is remarkably uniform throughout the area, despite the existence within it of a number of more or less well-marked local unconformities.

* * *

"The top of the Tullock member is marked by a thin but very persistent sandstone which everywhere weathers to a well-defined rim rock. This sandstone is overlain by the soft beds of the Lebo shale member of the Fort Union ..."

SYNONYMY. -- In the literature published prior to the description above quoted, the Tullock member was involved in the Laramie-Lance-Fort Union controversy. The Tullock member was often called "somber beds", included in the "Hell Creek beds", not differentiated from the Lance proper, or included in the Fort Union.

DISTRIBUTION. -- East-central and northeastern Wyoming; adjacent parts of South Dakota; southern Montana.

IMPORTANT REFERENCES. -- Dobbin and Barnett (60: 9); Renick (232: 14-15); Rogers and Lee (236: 19-20, 29-34); Simpson (271: 1-12).

GENERAL INFORMATION

Rogers and Lee recorded an average thickness of 300 feet for the Tullock member in the type locality. Renick (232: 15) in 1929 gave a thickness of 250 feet for the Tullock member of the Lance in central and southern Rosebud County, Montana. Dobbin and Barnett stated (60: 9) that the Tullock member, as developed in the Gillette coal field of northeastern Wyoming, "includes 400 to 600 feet of light-colored calcareous sandstone and sandy shale with numerous thin beds of coal or carbonaceous shale", with numerous beds of hard calcareous sandstone. They added the paleontologic note that the Lance formation in this area had yielded specimens of Campeloma multilineata Meek and Hayden, Goniobasis tenuicarinata Meek and Hayden, Tulotoma thompsoni White, as well as "fragmentary remains of reptiles and a considerable flora". Among the fossils which had been recorded in 1923 by Rogers and Lee from the type Tullock was a bone fragment, "identified by C.W. Gilmore as a section of the supraorbital horn core of a ceratopsian, probably Triceratops". In 1929, however, Simpson stated (271: 6) that

TULLOCK MEMBER - General Information

"No dinosaurs occur in the Tullock, and its champsosaurs, crocodilians, and turtles could be either Paleocene or older. Mammals have not yet been found in this formation. The Tullock is younger than the true Lance or so-called 'Ceratops' beds, and from its position it is probably the equivalent of the Puerco. If this proves to be the case, its continued inclusion in the Lance would be quite improper." (See chart, p.29.)

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LOWER PALEOCENE(?) CANNONBALL AND LUDLOW MEMBERS

GENERAL INFORMATION

The Cannonball marine and Ludlow lignitic members of the Lance formation are typically developed in the Dakotas. They have not been definitely identified in Wyoming. Thom and Dobbin have described (249) the Lance of Montana and the Dakotas somewhat in detail. They said that the Ludlow member of the Lance "is equivalent to the Lebo shale member of the Fort Union of Montana, plus the Tullock member of the Lance and the 'lignitic beds' of Brown". According to them the Cannonball marine member, known only in the Missouri Valley in North and South Dakota, is "stratigraphically equivalent to the Ludlow lignitic member of the Lance, into which it merges westward", and "contains an abundant marine fauna largely descended from that of the Fox Hills".

The fauna of the Cannonball member was described and illustrated by Stanton (S.355: 1-66, pls. 1-10) in 1920. Shimer believed (224: 913) that the Cannonball member is late Cretaceous, post-Montanan in age. He said that

"Forty percent of the mollusks are Cretaceous species, but Cretaceous cephalopods and Inoceramus have disappeared. There are no Tertiary species, but there is a closer generic relationship with the Tertiary of the Gulf region than with that of the Arctic or of the Pacific realms. These genera, persisting into the Tertiary, were introduced from the Montanan or earlier. The corals are all new species, some with a close affinity to Cretaceous species and others to the Tertiary. There is no known marine Tertiary within a thousand miles of the Cannonball area."

Schlaikjer believed (24: 54) that a portion of the Lance in the Goshen Hole region may correspond to a part of the Cannonball member.

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LOWER PALEOCENE(?) TORRINGTON MEMBER

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Member of the Lance formation. It is not a separately mappable unit. The type locality is along Horse Creek in the

TORRINGTON MEMBER - Specific Information

Goshen Hole area of eastern Wyoming, south of the town of Torrington, near the center of T. 22 N., R. 61 W., Goshen County.

TYPE DESIGNATION. -- Schlaikjer named and described the member in 1935; he stated (241: 45-47) that one of the best exposures occurs along Horse Creek, where a section of 150 to 200 feet is measurable, and that

"One of the most outstanding features of this section is the presence of the brackish water fossils, Corbicula, Ostrea, etc. These fossil-bearing strata are found about a mile to the east in W½, Sec. 13, T. 22 N., R. 61 W. On the south side of the Creek the Ostrea beds are fifteen to twenty feet in thickness. They are lenticular and thin out into gray sands and thin yellowish limestone, which contain Halymenites. ... About a mile and a half northeast of the town of Huntley, NW¼, Sec. 19, T. 23 N., R. 60 W., the oyster bed is about three feet in thickness ... Above the oyster layer are seven feet of ... sandy shales which are succeeded by a two-foot layer of finely bedded yellow sandstone. This sandstone contains at the bottom a four-inch layer of brackish water fossils." (p. 45-46)

* * *

"In the lower part of the uppermost twenty feet of this section /NE¼, Sec. 4, T. 22 N., R. 61 W./ the skull and some skeletal parts of a new species of Triceratops were collected. This individual ... represents the last recorded survivor of that great group of dinosaurs. The presence of this specialized Triceratops in addition to the presence of the brackish water fauna which probably is stratigraphically above the Triceratops beds of the Lance in other areas, makes it necessary to give a new name to the continental deposits above the Corbicula-Ostrea zone. I suggest that it be known as the Torrington member of the Lance formation ..." (p. 47)

SYNONYMY. -- In all previous work in this region the Torrington member had been undifferentiated from the Lance or "Laramie", as it was sometimes called.

AREAL DISTRIBUTION. -- Central portions of the Goshen Hole area.

IMPORTANT REFERENCES. -- Adams (S.344: 1-47); Schlaikjer (241: 31-68, pls. 1-6); Stanton (285: 241-293), (S.345: 1-64, pls. 1-9)

GENERAL INFORMATION

Lithology. -- The lithology of the Torrington member is illustrated in the following representative section, given by Schlaikjer (241: 45):

Section measured in NW cor., SW¼ sec. 14, T.22 N., R.61 W.	Thickness (feet)
Alluvium	
Gray finely laminated sandstone.....	1
Concretionary yellow gray limestone.....	0.5
Purplish shale.....	3
Yellow sands.....	2
Iron-stained limestone, many brackish water fossils.....	0.5

TORRINGTON MEMBER - General Information

Yellowish gray limestone, large Pelecypods.....	0.5
Purplish shale.....	2
Gray massive sandstone.....	2
Gray concretionary sandstone.....	1
Gray massive sandstone Ostrea.....	2
Gray finely-bedded sandstone Ostrea.....	1
Yellow, purple and reddish shale.....	2
Gray finely-bedded sandstone.....	1
Gray, purple, red and yellow shale.....	4
Finely-bedded gray sandstone.....	1
Yellow and purple shales.....	4
Finely-bedded gray sandstone.....	2
Massive gray sandstone.....	0.5
Finely-bedded dark gray sandstone.....	2.5
Red, purple and yellow shales.....	7
Massive gray sandstone.....	8
Finely laminated gray sandstone.....	1
Yellow platey sandstone.....	2
Yellow, purple and red shales.....	23
Concealed by water of Horse Creek	

Correlation. -- Schlaikjer (241: 51) stated his belief

"That the Torrington member is equivalent to at least part of the Arapahoe-Denver beds in the Denver Basin is indicated by the close affinity of the ceratopsians found in both. This is additional evidence for considering the Torrington as an upper-most member of the Lance."

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LOWER PALEOCENE(?) EVANSTON FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation. The type locality extends from a point in the bluffs on the east side of Bear River just north of Evanston, to a point about 7 miles north of Evanston, Uinta Co., southwestern Wyoming.

TYPE DESIGNATION. -- Evanston was used for the first time as a formation name of definite significance by Veatch (S.346: 332) in 1906. At that time he made no formal definition of the formation but included it in his stratigraphic column with brief notes on the lithology, distribution, thickness (1500 feet) and economic value. In the following year Veatch (300: 76-77) gave the following formal description:

"The Evanston formation is typically exposed in the vicinity of Almy. ... It is regarded as separated from the lower Laramie, represented by the upper part of the Adaville formation, by a pronounced period of faulting and erosion, which is inferred on stratigraphic grounds, not by contact of the two formations. In lithologic aspect it is very similar to the Adaville, consisting of yellow, gray, and black carbonaceous shales and irregular brown and yellow sandstone beds, but differs from the

Adaville in containing pronounced conglomerate beds below the upper coals. ... The coals are much dirtier and less persistent than those found in the Adaville beds. The upper limit of the Evanston is fixed by the pronounced sandstones and conglomerates which mark the base of the Almy. ... The Evanston is characterized by coal and by dark-colored clays and by a relatively small proportion of sandy and conglomeratic material, while the Almy is more predominantly arenaceous and conglomeratic, and in places shows a reddish tinge not seen in the Evanston."

SYNONYMY. -- "Evanston group" of Lesquereux in various writings on southwestern Wyoming = Evanston formation.
"Bear River coal group" of Hayden in 1873 (104: 92, 144-145) included beds of the Evanston formation, according to Veatch (300: 60).
*Bitter Creek group of Powell in 1876 (229: 45-47, 64-66) included the Evanston formation or its equivalents.
"Evanston beds" of Emmons in 1877 (in King 136: 337) included by him in the Laramie = Evanston formation.
"Evanston coal series" of White in 1878 (319: 721) and 1879 (in Hayden 114: 240), included by him in his "Laramie" = Evanston formation.
"Evanston coal-bearing strata" of Bannister in 1879 (5: 244) = Evanston formation.
"Wasatch" of White in 1886 (323: 9-12) and Stanton in 1892 (284: 113), included the Evanston formation.

DISTRIBUTION. -- Vicinity of the town of Evanston, Uinta Co., Wyoming; central and northern Lincoln Co., Wyoming.

IMPORTANT REFERENCES. -- Bowen (17: 230-235); Dobbin, Bowen and Hoots (61: 10, 23, 24-25); Knowlton (140: 66-68); Osborn (224: 33); Schultz (246: 366), (250: 68-71); Veatch (S.346: 332), (300: 76-87, pl. 3).

GENERAL INFORMATION

Areal distribution and Lithology. -- Veatch said (300: 80) that the greatest thickness of the typical Evanston occurs in the Almy region "along the section running east from the southeast corner of sec. 13, T. 16 N., R. 121 W.", and that

"In the bed of the river at this point there are several impure carbonaceous beds of Evanston age, and between these and the Almy conglomerates 1,600 feet of strata occur. North of this the Evanston beds are observed in contact with the Bear River formation. ... The difference between the Almy and Evanston beds is not very marked just east of this Bear River outcrop; the conglomerates of the Almy largely disappear and a conglomeratic layer shows in the Evanston below the coal horizon. The thick coal beds of the Almy mines are much thinner in this section and apparently die out entirely a short distance to the north. ... The Evanston is 600 feet thinner in the center of sec. 18 than half a mile to the south, and it is inferred that it gradually pinches out along the Bear River outcrop ... On the north end of this Bear River outcrop pronounced reddish beds, apparently the middle Almy, rest directly on Bear River strata, indicating that the pinching out is progressing along this line and affects the Evanston and Almy beds alike."

EVANSTON FORMATION - General Information

In 1908 Schultz (246) described the geology of the Labarge oil field "of central Uinta County", Wyoming. In 1912, however, county lines in southwestern Wyoming were re-drawn and the Labarge field is now in east-central Lincoln County. At this time Schultz assigned (p. 366) a thickness of 9,500 feet to the Evanston, but stated that the upper limit of the formation was not seen. In a later paper (1914) on central Lincoln County, Schultz made similar observations (250: 68-69) on Evanston outcrops in the Fall River Basin, and on the east of Hoback Range in the northeastern part of Lincoln County. Schultz stated (p. 69) that in this general area the Evanston strata

"consist chiefly of clay, carbonaceous shale, shaly sandstone, and brown, gray, yellow, and white sandstone. Associated with these rocks are some coal beds, but owing to the extensive talus cover, to their ready weathering and to the lack of prospecting it is not possible to state how thick or numerous they are. Probably they contain nearly as much coal as the Adaville formation east of Labarge Ridge."

Stratigraphic and structural relations. -- Lesquereux (148: 19), Bannister (in Hayden 107: 541), Cope (in Hayden 108: 441), Emmons (in King 136: 330) and King (137: 373) believed that the relation of the Evanston and overlying Almy is one of strict conformability. Veatch (S.346: 332)(300:81-83) and Schultz (246: 366) (250: 70) also considered them to be conformable.

Veatch, on the other hand, found that the Evanston lies in pronounced unconformity on older beds. His analysis (p. 81) of the structural and stratigraphic relations of the Evanston to the Bear River and Beckwith formations convinced him that the exposures he had examined "are regarded as strongly suggestive of a marked time interval between the Adaville and Evanston and as indicating an essentially unconformable relation between the Evanston and the known Cretaceous series". Elsewhere, in his paper on the "Laramie problem", Veatch has said (298: 549, footnote) that there is an unconformity both at the top and base of the Evanston.

At various points in the area studied Veatch recorded dips in the Evanston formation ranging from 12° to 16° and noted (p. 83) that at the south end of Medicine Butte the Evanston beds are cut by a fault with a displacement of 5,000 feet, with the upthrown block of the fault on the east.

Schultz, in his paper on the Labarge oil field, also found (246: 366) the Evanston unconformable on the Adaville formation. In his Lincoln County report Schultz said (250: 70)

"The Evanston formation is overlain by ... the Almy formation of Uinta County. These two formations are separated from the overlying Knight formation by an unconformity which represents a period of minor folding and faulting and erosion amounting to several thousand feet. Thus a series of beds over 12,000 feet thick, apparently conformable and certainly nowhere so greatly disturbed as those that preceded or succeeded them, is separated from the rest of the section by unconformities due to pronounced orographic movements and erosion. The great break occurs between the Evanston formation and the known Cretaceous."

EVANSTON FORMATION - General Information

Schultz also stated (250: 69) that in the Fall River basin the Evanston "lies unconformably upon Weber quartzite and later Carboniferous, Triassic, and Jurassic beds, involving an unconformity of more than 20,000 feet." In this area, he said, the Evanston dips from 15° - 45° E., and the dips increase westward.

Paleontology, age and correlation. -- Veatch (300: 84-86, pl. 15) listed and illustrated the principal members of the Evanston flora. Among the invertebrates collected from the Evanston he listed (p. 86) the following:

Pisidium saginatum White
Sphaerium formosum M. and H.
Planorbis cf. convolutus M. and H.
Bulinus longiusculus M. and H.
Bulinus disjunctus White
Helix evanstonensis White
Goniobasis tenuicarinata M. and H.
Macrocyclis spatiosa(?) M. and H.
Columna teres M. and H.(Meek ?).
Hydrobia recta White
Cypris _____?
Goniobasis nebrascensis M. and H.
Helix (Patula) sepulta White
Campeloma multilineata M. and H.

Veatch concluded (p. 87) his discussion of the age of the Evanston with the statement:

"Dr. T.W. Stanton regards the invertebrates as Laramie or Fort Union ... The paleontologic collections made at this locality do not prove conclusively that the beds are Upper Cretaceous, or, on the other hand, show that they are basal Eocene. If a final study of the fauna shows conclusively that these beds are of the same age as the Denver beds, the weight of evidence afforded by the dinosaurian remains found in the Denver beds, which Marsh regarded as proving their Cretaceous age, must be considered. The stratigraphic evidence strongly suggests that the line between the Eocene and the Cretaceous should be drawn at the base of the Evanston, and certainly shows no reason for drawing it between the Evanston and the Almy. On the whole, the Evanston formation may be tentatively regarded as Eocene."

In 1918 Bowen considered various lines of evidence (17: 233) and offered the following reasons for his belief that the Evanston formation "should be correlated with the Hanna":

"(1) The flora of the Evanston is said to correspond to that obtained from the old town of Carbon, which in all probability came chiefly if not entirely from the Hanna formation and therefore tends to support the correlation of the Evanston with that formation; (2) the Evanston is conformable with the overlying Wasatch, a relation which is not known to exist between the Wasatch and older rocks in any other place in Southern Wyoming; (3) the relation of the Evanston to the Adaville ('Lower Laramie') is largely a matter of inference, for it nowhere rests on the Adaville, and some of those most familiar with the Evanston section now believe that the Adaville formation, formerly thought to represent the 'Lower Laramie' is really Mesaverde."

EVANSTON FORMATION - Paleontology, Age and Correlation

Concerning these lines of evidence it may be pointed out that the first is entirely theoretical. The second involves the assumption that Hanna and Wasatch are essentially different in age, an assumption which, as will be shown in the discussions of the formations, is unwarranted. The force of Bowen's second point is considerably mitigated by his own statement in the same paper (p. 235) that the Hanna formation "is the equivalent of the Wasatch of the Great Divide Basin and Rock Springs fields". The third point, the writer presumes, implies that the unconformity at the base of the Evanston excludes the possibility of correlation with the Ferris, because the type Ferris is believed by Bowen to be conformable with the underlying Medicine Bow. This reasoning, of course, must be weighed in the light of Bowen's statement (pp. 233-234) that "a considerable unconformity near the margin of the ancient land mass from which the sediments were derived may give place to apparent conformable relations at a considerable distance from that place".

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LOWER PALEOCENE (?) FERRIS FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation. The type locality is southwest of the North Platte River in the southwestern portion of T. 23 N., R. 84 W., in the Hanna Basin of central Carbon Co., Wyoming.

TYPE DESIGNATION. -- The Ferris was described and named by Bowen (17: 230) in 1918:

"The Medicine Bow formation is terminated above by a conglomeratic zone taken as the base of the Ferris formation ... As defined the Ferris formation is approximately equivalent to the lower half of the 'Upper Laramie' of Veatch [299]. The conglomerate at the base of the Ferris formation ranges through an interval of about 1,000 feet, in which massive sandstone, more or less conglomeratic, alternates with non-conglomeratic sandstone and shale. The conglomerate is sparingly developed at the base of the zone but increases in amount upward. It is succeeded by an alternating series of sandstone and shale containing numerous beds of coal. The maximum thickness of the formation is about 6,500 feet.

"Both the matrix and the pebbles of the conglomerate consist of materials of the same kind as make up the sandstone of the underlying Medicine Bow formation. ... (1) it is made up of only the most resistant kinds of rock; (2) it is lacking in several kinds of rock now exposed in the surrounding mountains ...; (3) it contains materials that seem to be foreign to this region ..."

SYNONYMY. -- (See table and notes, p. 13)
"Laramie" of territorial survey geologists and of most writers on south-central Wyoming, in publications earlier than 1906, included the Ferris.

FERRIS FORMATION - Specific and General Information

SYNONYMY (cont'd).

*Bitter Creek group of Powell (229: 45-47, 64-66, 162-166), and of others, included the Ferris.

"Great Lignitic" and "Fort Union" of Hayden in southern Wyoming included the Ferris.

"Upper Laramie" of Veatch (229: 246, 250) in 1907 in eastern Carbon Co., Wyoming = Ferris plus Hanna.

"Upper Laramie" of Veatch in 1906 (S.346: 332) and 1907 (300: 76-87, pl. 3) in Uinta Co., Wyoming, which he named the Evanston formation, may be equivalent to the Ferris formation.

"Knobs-Cherokee coal group" of Schultz (248: 233, 234-236) (251: 23) in the Rock Springs uplift, probably = Ferris or Evanston.

"Upper coal group" of Ball (3: 246, 247-249) appears to include the Ferris and possibly Hanna also, although he noted no unconformity within the "upper coal group".

Bowen intimated (17: 233) that the *Upper Laramie of Ball and Stebinger (4: 190, 193-198) in the eastern part of the Little Snake River coal field, Carbon and Sweetwater counties, Wyoming, and Routt Co., Colorado, belongs to the Ferris formation.

"Undifferentiated Tertiary" of Smith (279: 224, 233, 239) was believed by Bowen (17: 233) to belong to the Ferris formation.

"Post-'Laramie'" of Sears (260: 276, 291-292) may be Ferris, but more probably = Hanna.

DISTRIBUTION. -- Borders of the Hanna and Carbon basins, and southern end of the Shirley Mountains, Carbon Co., Wyoming; Great Divide Basin coal field and Rock Springs uplift, Sweetwater Co., Wyoming; Little Snake River coal field, Sweetwater Co., Wyoming, and Moffat Co., Colorado.

IMPORTANT REFERENCES. -- Ball (3: 246, 247-249); Ball and Stebinger (4: 190, 193-198); Bowen (17: 230-234); Dobbin, Bowen and Hoots (61: 24-25); Ferren (74: 20); Smith (279: 224, 233, 239); Veatch (299: 246, 249-250).

GENERAL INFORMATION

Areal distribution and lithology. -- "Knobs-Cherokee coal group" (see synonymy above) was the economic designation given by Schultz (248: 234) to beds which he called "Upper Laramie" in 1910, and to which he assigned a thickness of from 6,000 to 9,400 feet. He stated that the base of the "group" consists of non coal-bearing beds of soft shale and brown conglomeratic sandstone. He said that coal-beds are present in the "group" on the west side of the Rawlins dome, and probably also on the east side of the Rock Springs dome. In 1909 Smith had described (279: 233) similar characteristics of the "group" in the Great Divide Basin coal field, but Schultz said that in this region both upper and lower portions are coal-bearing.

In 1929 Dobbin and his associates described (61: 24-25) the Ferris in the Hanna and Carbon basins in similar terminology. According to them the Ferris there consists, from the base upward,

of 300 feet of dark shale and coarse yellow sandstone "containing small scattered pebbles and irregular thin beds of conglomerate"; 800 feet of sandstone containing pockets, lenses and thin beds of conglomerate irregularly distributed throughout, the conglomerate predominating; 5,400 feet of "gray, brown, and yellow sandstones interstratified with numerous thick beds of coal". The sandstones are very irregular and lenticular, and are commonly ripple-marked and cross-bedded.

Ferren identified (74: 20) the Ferris formation in 1935 in the southeastern portion of the Shirley Mountains, in which locality he noted the same absence of locally derived material as had been described by Bowen in the region farther south and west. Ferren stated (p. 20), that in his locality the basal portion of the Ferris is a conglomerate with a maximum thickness of 1,000 feet and consists of "pebbles of chert, quartz, quartzite, porphyries and rhyolites". The upper part he reported to be covered by "Quaternary alluvium and terrace gravels".

Rocks in the Little Snake River coal field, described by Ball and Stebinger in 1910 as "Upper Laramie", were considered by Bowen (17: 233) to be equivalent to the Ferris formation. Ball and Stebinger (4: 193-195) separated the *Upper Laramie into three lithologic members, the lowest of which is composed of gray and brown sandstone with intercalated gray, brown and drab shale and coal beds, overlying a massive cross-bedded ferruginous, conglomeratic basal sandstone. The middle member consists of non coal-bearing clay shale, sandy clay, and a small amont of massive or thin-bedded soft sandstone. It was noted that this middle member varied markedly in thickness, from place to place. The upper member is coal-bearing and is composed of gray and brown sandstone and interbedded shales. Ball and Stebinger stated that their "Upper Laramie" "is the equivalent of the *Upper Laramie of Veatch in the Hanna field". The relations to Veatch's section, however, are not fully explained (see table, p. 13). An unconformity occurs near the middle of Veatch's *Upper Laramie, and only the beds below the unconformity belong to the Ferris. Ball and Stebinger showed no unconformity within their *Upper Laramie, although the extreme variability of the thickness of the middle member, and the presence of "coarse cherty conglomerates" suggest that one may be present. It is possible, therefore, that the upper part of their *Upper Laramie may be Hanna in age.

Stratigraphic and structural relations. -- Bowen studied the relations of the Ferris to the underlying Medicine Bow in some detail. His observations led him to decide (17: 232-233) that "the existence of a conglomerate is not positive proof of a great unconformity", particularly when the conglomerate occurs "in the midst of a great mass of continental deposits that have the same lithologic character throughout". His conclusions (p. 233) were that the field relations of the Ferris conglomerate and the underlying Medicine Bow formation show

"(1) that the two have been equally deformed; (2) that there is no angular discordance between them ...; (3) that the Ferris formation is nowhere known to transgress the Medicine Bow formation and overlap older rocks; (4) that ... the conglomerate seems to have been derived from the

same source as the Medicine Bow; (5) that there appears to be a gradual transition from the Medicine Bow formation to the Ferris formation. The contact between the two is not sharply defined, coarse sandstone of the Medicine Bow formation being followed by grits in which a few small pebbles occur, and these giving place higher up to pockets, lenses, and thin beds of conglomerate, which are finally succeeded by thick beds of sandstone that are conglomeratic throughout. Interbedded in this transition zone are several beds of dark-gray shale, some of which attain a thickness of 30 feet.

"This transition zone is very significant, occurring in all areas where both the Medicine Bow and Ferris formations or their equivalents are present. In the southern part of the Great Divide Basin it is, according to Smith, 800 feet thick and consists chiefly of clay with interbedded thin rusty-brown sandstone, which becomes increasingly conglomeratic toward the top. ...

"Similar conditions in the Little Snake River field are described by Ball and Stebinger.

"This thick transition zone ... seems to the writer to be a fatal objection to the idea of an unconformity. It is difficult to conceive of a basal conglomerate occurring several hundred feet above the base it is assumed to represent."

Paleontology, age and correlation. -- Bowen found (17: 230-231) in the Ferris specimens of fresh-water invertebrates and land plants which were "regarded as of Fort Union age, whereas the vertebrate remains, thus far found only in the conglomeratic zone, consist of bones of turtles, indeterminable fragments of ceratopsians, and a few specimens that have been identified by C.W. Gilmore as Triceratops". He interpreted the presence of Triceratops to point to a correlation of the Ferris with "the Lance of Wyoming and Montana and the Denver formation of the Denver Basin". This opinion was repeated by Dobbin, Bowen and Hoots (61: 25) in 1929.

The formation is probably also represented, at least in part in the Monument Creek formation (sensu strictu; = *Dawson arkose of many writers), which is known to interfinger with the Denver and Arapahoe formations, and which is said by Lee (145: 531-534) to contain dinosaur bones in association with Paleocene mammals. The upper part of the Ferris may correlate with the Tullock member of the Lance in northeastern Wyoming, and with all or part of the Evanston formation of southwestern Wyoming. In 1924 Reeside (S.354: pl. 4) correlated the Ferris with the whole of the Lance and Fort Union in all other areas, with the top of the Ferris representing a part of the hiatus between the Fort Union and overlying Eocene rocks. He did not, however, make a detailed statement of his reasons for these unusual representations. Ferren, without discussing evidence of the age of the Ferris assigned (74: 20) it to the Eocene(?). The U.S. Geological Survey classifies it as Tertiary(?).

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PALEOCENE(?) SHOSHONE "GROUP"

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- The Shoshone is a "group" in that it is a collective name applied to supposedly equivalent units in separated areas. Cross, who proposed the name, stated (47: 34) that it "refers to no typical locality or district but rather to a province".

TYPE DESIGNATION. -- Cross defined the group in 1909; he stated (47: 32, 33-34):

"In 1892 I ... advocated: --

"'The restriction of the term Laramie, in accordance with its original definition, to the series of conformable beds succeeding the marine Montana Cretaceous, and the grouping of the post-Laramie lake beds described, with their demonstrated equivalents, in another series to which a comprehensive name shall eventually be given.'

* * *

"Succeeding or in part synchronous with the Rocky Mountain uplift there was erosion and resultant deposition in many basins or on the slopes of the rising land. For such of these more or less distinctly local deposits as may now be preserved it is proposed to provide a group name.

* * *

" ... it is proposed to apply the term Shoshone Group to the deposits which unconformably succeed the Laramie and to their equivalents, and which are overlain by the Fort Union of Wasatch beds, when they are present."

RESTRICTIONS. -- None. Gale stated in 1910 (79: 80) that, by decision of the committee on geologic names of the U.S. Geological Survey, Shoshone had been adopted "as a general time term" to apply in the same sense in which Cross had defined the name.

SYNONYMY. -- Cross stated (47: 38) his intention that the name should apply to beds which, previously, had been commonly called "Post-" and "Upper Laramie".

NOMENCLATURAL DIVISIONS. -- Cross (47: 38) stated his opinion that the Shoshone group includes the Arapahoe, Denver, Middle Park, and Animas formations of Colorado; the "Carbon and Evanston beds" (now known as the Evanston formation; see pp. 42-46) of Wyoming, the "Ceratops beds" and "Hell Creek beds" of Wyoming and Montana (now called Hell Creek member of the Lance; see pp. 37-38), and the Livingston "formation" of Montana. The Livingston is a terrane including strata from Cretaceous to Fort Union in age (see pp. 27-28). The Lance formation (see pp. 30-42) seems to be partially equivalent to the Laramie formation of the Denver Basin. The entire Lance cannot, therefore, belong to the Shoshone "group".

Gale (79: 80) assigned his *Upper Laramie to the Shoshone "group", stating that the name may perhaps "signify the beds which overlie the true Laramie of the Yampa River field [northwestern Colorado], or ... the

whole Green River Basin", which are overlain by the "typical Wasatch". Knowlton believed (138: 216) that the lower part (Ferris) of the *Upper Laramie of Veatch (229: 246) may belong to the Shoshone group.

IMPORTANT REFERENCES. -- Cross (47: 27-45); Knowlton (138: 216), (140: 80-81).

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MIDDLE PALEOCENE HANNA FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation. The type locality is west and north of the town of Hanna, Carbon County, Wyoming.

TYPE DESIGNATION. -- Bowen (17: 231) described and named the formation in 1918:

"For the upper part of the 'Upper Laramie' as defined by Veatch the name Hanna formation is proposed, because the formation is well exposed to the west and north of the town of Hanna and yields all the coal mined at that place. The Hanna formation rests unconformably on the Ferris formation. A conglomeratic sandstone marks its base, above which conglomerate, sandstone, shale, and coal beds alternate to the top of the formation, some 7,000 feet above its base.

"This formation differs from the Ferris in being highly feldspathic, in being conglomeratic throughout, and in the fact that the conglomerate contains an abundance of local material, notably granite, Mowry shale, and Cloverly conglomerate."

SYNONYMY. -- (See tables, pp. 13, 14, 16, 18-19, 23.)

*Bitter Creek group of Powell (229: 45-47, 64-66), and others, included the Hanna formation.

In 1876 King (135: Map 2) mapped the Hanna equivalent ("Black Rock coal group") in the Rock Springs coal field as *Vermilion Creek.

"Great Lignitic", "Fort Union", "post-Cretaceous", "Laramie", "post-Laramie", and *Upper Laramie of Hayden and other geologists prior to 1918, many times included the Hanna or its equivalents.

*Upper Laramie of Veatch (299: 246, 250) = Hanna plus Ferris.

"Fort Union" of Veatch (299: 246, 250) = most of the Hanna.

"Black Rock coal group" of Schultz (247: 259, 264, 267) (248: 222-223, 236-239) (249: 294-295) (251: 22, 24-31), which he included in the lower part of his "Wasatch", probably = Hanna.

"Wasatch" of Gale (79: 69-80) and of Sears (260: 292-293) probably included all or part of the Hanna.

"Hanna" formation of Dobbin and his associates (62: 142-143), in the Rock Creek field, Carbon and Albany counties, included Wind River.

DISTRIBUTION. -- Central portions of the Hanna and Carbon basins, Carbon County; southeastern portion of the Red Desert and borders of the Rock

HANNA FORMATION - Specific and General Information

Springs uplift, Sweetwater County; east- and west-central borders of the Rock Creek dome, Carbon and Albany counties; northern end of the Medicine Bow Mountains, Carbon County; all in Wyoming. Probably also in the Little Snake River coal field of Sweetwater County, Wyoming, and Moffat County, Colorado.

IMPORTANT REFERENCES. -- Bowen (17: 231-235); Dobbin, Bowen and Hoots (61: 23); Dobbin, Hoots, Dane and Hancock (62: 142-143); Knowlton (138: 215-216), (140: 61-65); Neely (210: 7-9); Schultz (247: 259, 264, 267), (248: 222-223, 236-239), (249: 294-295), (251: 22, 24-31).

GENERAL INFORMATION

Areal distribution and lithology. -- The Hanna formation is largely a conglomerate composed of materials derived from older local rocks, and the relative abundance of different constituents varies from place to place in accordance with the character of the surrounding older rocks, as Bowen pointed out in his description of the formation in the type locality.

In the Hanna and Carbon basins, according to Dobbin, Bowen and Hoots (61: 23), the Hanna formation "consists of alternating conglomerate, sandstone, shale, and coal beds, and its base is marked by a thick conglomeratic sandstone and locally massive conglomerate". They found that the Hanna sandstones "range from coarse-grained massive or thick-bedded varieties to fine-grained thin-bedded sandstones"; the latter, when weathered, tend to split into thin slabs. The coarse-grained varieties are conglomeratic and highly feldspathic.

It was noted by Dobbin and other collaborators in 1929 (62: 142-143) that the Hanna formation crops out in the Rock Creek field, Carbon and Albany counties, where it consists of yellowish-brown sandstone, yellowish-green sandy shale, coarse conglomerate, coal beds and variegated shales, the latter of which, they said, "resemble the variegated beds which elsewhere in Wyoming have been mapped as Wasatch". It is shown on subsequent pages of the present paper that these variegated beds actually are Wind River in age and do not belong in the Hanna formation.

Schultz (247: 264), in a paper on the northern part of the Rock Springs coal field, Sweetwater County, applied the economic designation Black Rock coal group to approximately the lower three-fourths of his "Wasatch" formation. He represented 1,200 to 2,650 feet as the thickness of the "group", and described it as "prolifically coal-bearing, some of the coal beds reaching a thickness of 25 feet". In a second paper, on the southern part of the Rock Springs field, Schultz (248: 222-223) again used the economic name "Black Rock coal group", represented a thickness of 1,000 to 3,500 feet, and again assigned it to the "Wasatch" (see table, p. 18). In 1920 Schultz reported on the Baxter Basin gas field in the Rock Springs uplift, again used the name, assigned the "group" a thickness of from 1,000 to 2,500 feet, and still included it in the "Wasatch" (see table, p. 23).

HANNA FORMATION - General Information

Knowlton has said (138: 215-216) that the "Black Rock coal group" had been mapped by King (135: Map 2) in 1878 as *Vermilion Creek, which is usually considered an exact synonym of Hayden's typical "Wasatch". Schultz, although he repeatedly assigned the "Black Rock coal group" to the "Wasatch", believed it to be of Fort Union age and stated (247: 259, footnote) that "an abundant collection of plants" had been obtained from the lower third of the "Wasatch" and had been determined by Knowlton "as undoubtedly Fort Union". It was the opinion of Dobbin, Bowen and Hoots (61: 23) that the "coal group" is equivalent to the typical Hanna formation.

In addition to the outcrops mentioned, the writer has observed extensive exposures of gray and somber-colored sandstones and carbonaceous shales, lignite beds, and red clinker, in the Great Divide Basin in the eastern portion of the Red Desert. These exposures, which the writer believes are of Hanna age, begin about forty miles west of the type locality of the Hanna formation near the town of Hanna, and extend westward on both sides of the Lincoln Highway past Wamsutter. The exact areal extent of the exposures was not determined, but they were traced 25 miles north of Wamsutter into the desert, where sediments of Green River age cover the surface. Almost the entire area mentioned was mapped by Smith in 1909 (279: pl. 12) as "Wasatch", a name which has been too loosely applied to convey the exact stratigraphic meaning demanded by contemporary stratigraphy. The red clinker beds of the Hanna(?) formation in this region are conspicuous in long, low scarps and ridges, which are in some places capped by Cathedral Bluffs (Wind River?) sediments.

The Hanna formation was also identified by Neely in the region at the north end of the Medicine Bow Mountains, Carbon County, where, he said (210: 7-8), it consists of heavy locally-derived boulder conglomerates, yellow arkosic sands, gray and yellow shales, and a few carbonaceous shales.

Stratigraphic and structural relations. -- Wherever observed the Hanna formation has been found to rest disconformably, or in angular unconformity, on older rocks ranging from Upper Cretaceous to pre-Cambrian in age. King had observed an unconformity between the lower part of his *Vermilion Creek group (including the "Black Rock coal group" or Hanna) and the underlying "Laramie" (= "Black Buttes coal group" or Medicine Bow) in, and southward from, the vicinity of Black Buttes, Wyoming. The same relations in this region were noted by Knowlton (138: 215-216) and Schultz (247: 259, 264) in 1909, and again by Schultz in 1910 (248: 223, 236) and 1920 (251: 23). Bowen (17: 231) stated that in the type locality of the Hanna formation,

"All the rocks up to and including the Ferris formation seem to have been equally deformed and were folded, faulted, and deeply eroded before the deposition of the Hanna formation. After the deposition of this formation there was another disturbance, which followed chiefly the lines of the earlier movements ... By this disturbance the Hanna

formation was tilted in some places into a vertical position and was locally faulted."

Bowen said (p. 234), moreover, that the "unconformity between the Fort Union and Wasatch is the most widespread and significant break that had been produced up to that time since the beginning of the Cretaceous period." On a subsequent page, he included in his summary the statements (p. 235) that "the great break, as indicated by structural and field relations, occurs at the base of the Hanna formation", and that "this formation is the equivalent of the Wasatch of the Great Divide Basin and Rock Springs fields".

Paleontology, age and correlation. -- Bowen summarized (17: 231) the scanty paleontologic data obtained from the typical Hanna formation as follows:

"This formation contains an abundance of plant remains, all of which are referred to the Fort Union by Mr. Knowlton. The invertebrates are also regarded by Mr. Stanton as chiefly indicative of Fort Union age, though species found near the top are said to resemble the Wasatch fauna. Only a few fragmentary remains of vertebrates have thus far been found in this formation. They include fish scales, fragments of turtle shells, and a fragmentary mammalian jaw identified by J.W. Gidley as a creodont, probably Claenodon, which may belong to either the Fort Union or Wasatch."

Dobbin, Bowen and Hoots (61: 23) considered that the "Hanna formation probably represents the Black Rock coal group, of Wasatch age of the Rock Springs field." In another paper Dobbin and other collaborators (62: 142-143) stated that "the entire Hanna formation is regarded in the light of present evidence as of Wasatch (Eocene) age."

In all of these statements as well as those quoted above from Bowen's analysis of unconformities, there appears to be a profound inconsistency: treatment of "Wasatch" and Hanna as something of distinctly different age in some discussions, and treatment of them as synchronous deposits in other discussions. There is strong evidence, (1) that the lower two members (Almy and Fowkes) of the Wasatch of the type locality in southwestern Wyoming are of Fort Union age; (2) that the typical Hanna formation is synchronous with all or part of the lower type Wasatch; (3) that the type Hanna is therefore of Fort Union age; that (4) Bowen's statements that the most profound stratigraphic breaks occur between the Fort Union and Wasatch on the one hand, and at the base of the Hanna on the other hand, are therefore inconsistent; (5) that the upper part of the Hanna in the Rock Creek field, described by Dobbin and others (62: 142-143) is of Wind River age and hence approximately corresponds to the Knight (upper) member of the typical Wasatch.

The "excellent exposures of variegated shale" mentioned by Dobbin (62: 142) as occurring "in the bluff of Cooper Creek in sec. 8, T.18 N., R.76 W., and vicinity", are the remnant of a continuation of extensive

exposures of variegated beds in Cooper Lake Basin, about 10 miles east of the Rock Creek field, from which Knight and parties of the Geological Survey of Wyoming have obtained typical vertebrate index fossils characteristic of the Wind River formation of the Big Horn Basin, and the Knight formation of southwestern Wyoming.

The writer finds it difficult to reconcile the statements of Bowen: that (17: 231) the greatest break in the geologic section of southwest Wyoming occurs "between the Fort Union and Wasatch"; that (17: 233) the Evanston formation (which underlies the oldest type Wasatch in southwestern Wyoming) "should be correlated with the Hanna"; that (17: 235) the Hanna formation "is the equivalent of the Wasatch of the Great Divide Basin and Rock Springs fields".

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Divisions of the Fresh-Water Tertiary of the West (after Matthew[1])

Periods		Formations	Thickness	Faunal Divisions	Lake Basins
Pleistocene		Sheridan	100	Equus	Silver Lake and other localities in Oregon, Nevada, and elsewhere.
Pliocene		Blanco	150	Pliauchenia	
				Hippidium	Great Plains (Niobrara Basin)
Miocene	Upper	Loup Fork	400	Procamelus	
	Upper	Deep River	150	Cyclopidius	Deep River, Montana
	Middle				
	Lower	John Day	1000	Diceratherium	John Day, Oregon
Oligocene		White River	800	Protoceras	
				Oreodon	Great Plains, (Sioux Lake)
				Titanotherium	
Eocene	Upper	Uinta	800	Diplacodon	Uinta, Utah
				Telmatotherium	
	Middle	Bridger	2000	Uintatherium	Upper Green River, Wyoming Huerfano, Colorado
	Lower	Wind River	800	Bathyopsis	Wind River, Wyoming
		Wasatch	2000	Coryphodon	Big Horn, Wyoming
	Basal	Torrejon	300	Pantolambda	San Juan, New Mexico
		Puerco	500	Polymastodon	

[1] Copied from Matthew, W.D. (177: 20), A provisional classification of the fresh-water Tertiary of the west: Am. Mus. Nat. History Bull., vol. 12, 1899.

Epochs of sedimentation and Life Zones from Basal Eocene to Early Oligocene Time in Basins of the Rocky Mountain Region (after Osborn[1])

Physiographic Epochs	Life Zones
6. Lower Oligocene, represented by Chadron formation. Flood plains east of the Rocky Mountains. Sedimentation extremely slow. Moderate rainfall. Warm temperate climate.	17. Titanotherium-Mesohippus 16. Theoretic zone. No fauna known.
5. Latest upper Eocene, represented by Uinta formation (Uinta C). Flood-plain basins south of the Uinta Mountains. Sedimentation relatively rapid; fine material. Heavy rainfall, diminishing.	15. Diplacodon-Protitanotherium-Epihippus
4. Upper Eocene, represented by contemporaneous deposits in Washakie and Uinta basins (Horizons Washakie B and Uinta B) and probably by uppermost part of the Bridger formation (Bridger E). Violent river and stream action from the north and south sides of the Uinta Mountains. Eruptions of volcanic dust; coarse material. Heavy rainfall.	14. Eobasileus-Dolichorhinus 13. Metarhinus
3. Middle Eocene, represented by Bridger formation (Horizons Bridger A,B,C,D). More quiescent floodplain conditions in the Bridger Basin: eruptions of volcanic dust; intervals of evaporation. Sediments composed in part of eroded material, generally laid down on lacustrine deposits.	12. Uintatherium-Manteoceras-Mesatirhinus 11. Palaeosyops paludosus-Orohippus 10. Eometarhinus-Trogosus-Palaeosyops fontinalis
2. Lower Eocene, represented by Wasatch, Wind River, and Green River formations. Warm temperate climate of the Green River Lake period, and evidently arid conditions in the contemporaneous Wind River sediments. Alternation of arid and fluviatile conditions characteristic of Wind River and Wasatch time. Evidence of open country favorable to cursorial animals.	9. Lambdotherium-Eotitanops-Coryphodon 8. Heptodon-Coryphodon-Eohippus 7. Systemodon-Coryphodon-Eohippus 6. Eohippus-Coryphodon
1. Basal Eocene, represented by the Puerco, Torrejon, and Fort Union formations. Forests, base-leveled areas, flood plains, and swamps widespread. Evidence of somewhat cooler climate.	5. Phenacodus-Nothodectes-Coryphodon 4. Pantolambda 3. Deltatherium 2. Polymastodon 1. Ectoconus

[1] After Osborn, H.F., (224: 9) Titanotheres of Ancient Wyoming, Dakota, and Nebraska: U.S. Geol. Survey Mon. 55, vol. 1, 1929.

Generalized Section of the Nacimiento Group
in the
Puerco River Region, New Mexico (after Gardner [1])

Formation		Lithology	Thickness (feet)
Wasatch			1,000
		Unconformity	
Nacimiento Group	Torrejon	Shale, variegated	20
		Sandstone, brown	3
		Shale, gray	15
		Sandstone, gray	3
		Shale, gray and soft sandstone	40
		Sandstone, massive, tan-colored	15
		Shale, yellowish	15
		Sandstone, massive, soft, coarse, tan-colored	120
		Shale, gray	20
		Sandstone, massive, soft, tan-colored	30
		Total thickness of Torrejon formation	281[a]
		Unconformity	
	Puerco	Shale and soft sandstone	30
		Shale, dark, carbonaceous	10
		Shale, gray	10
		Sandstone, massive, yellowish, lenticular	10
		Shale, variegated	25
		Shale, dark, carbonaceous	4
		Shale, chiefly yellowish	80
		Sandstone, massive, brown, lenticular	10
		Shale, variegated, and soft, gray sandstone	200
		Sandstone, massive, and coarse-grained, brown	40
		Shale, gray, and soft sandstone	45
		Shale, very dark, local coal streaks	4
		Shale, and soft sandstone of gray and tan colors	90
		Total thickness of Puerco formation	558
		Unconformity	
Upper Cretaceous		("Laramie formation")	900

[1] Modified after Gardner (83: 717), The Puerco and Torrejon formations of the Nacimiento group: Jour. Geol., vol. 18, 1910.

[a] Gardner gave a sum of 276 feet for the figures listed.

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- The unit is a group as that term is used in this paper. Matthew (186: 382) considered it a terrane, in the sense of a stratigraphic unit which includes two sequences of sediments, each of which contains a distinctive fauna, with no species in common with the other. The type locality of the Nacimiento group is at the foot of the Nacimiento Mountains near Nacimiento, New Mexico. (The town of Nacimiento is commonly known by the name of Cuba.) The type locality of Cope's "Puerco marls" was in the "Eocene Plateau" of the San Juan Basin, west of the Sierra Nacimiento Mountains.

TYPE DESIGNATION. -- Nacimiento group was proposed by Gardner in 1910 (83: 75) as a collective name for the Puerco and Torrejon formations. These had been earlier designated by Wortman in 1897 (in Matthew S.356: 852) who restricted the name Puerco to the lower part of the "Puerco marls" of Cope, and proposed the name Torrejon for the upper portion.

"In view of the fact that the Puerco was restricted to the lower formation when the name Torrejon was proposed, and since it is very necessary to adopt a group name in order to properly discuss the relationship of the two formations, the writer proposes the name Nacimiento group for the two formations collectively." (See Gardner 83: 75).

Nacimiento group is thus an exact synonym of the original "Puerco marls", the character of which is indicated in the following excerpts (41: 16-17) from Cope's lengthy and detailed description in 1877[1]:

"Below the sandstones which form the portals of the Cañoncito de las Yeguas, another stratum of marls shows itself ... in the sage-brush plain that separates them from the Cretaceous hog-backs. They are soft and of mixed black and dark-green colors near the locality in question, and capped by light and yellowish sandstones. These conform to the beds of the Eocene, and I traced them for forty miles to the south ... Farther south, this marl is represented by low hills of generally lighter color. Near Nacimiento ... it rises both to the east and south. The valley of the Upper Puerco is excavated in it for some distance ... At a point on the river about six miles below the village of Nacimiento, the lower sandstone of the Eocene forms a perpendicular bluff, which terminates in an escarpment of 500 feet elevation facing the south. The red-striped marls, having acquired a gentle northern dip, disappear from view some miles to the north ...

" ... During the days of my examination of the region, heavy showers of rain fell ... It became slippery, resembling soap in consistence ... The material is so easily transported that ... the Puerco River becomes the receptacle of great quantities of slimy-looking mud. Its unctuous

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[1]The description in this report had been previously printed in Ann. Rept. of the Chief of Engineers to the Sec'y of War for the year 1875, pt. 2, Appendix Gl, pp. 1008-1017.

appearance resembles strongly soft-soap, hence the name Puerco, grease. These soft marls cover a belt of some miles in width, and continue at the foot of another line of sandstone, which bound the immediate valley of the Puerco to a point eighteen miles below Nacimiento. Here the sandstone again turns to the westward, presenting a southern escarpment of 500 to 1,000 feet elevation. This forms the southern boundary of the Eocene basin.

* * *

"The soapy marls, or, as they may be called, the Puerco marls, have their principal development at this locality."

SYNONYMY. -- Puerco "group" or "marls" of Cope (41: 16-18) and other papers = Nacimiento group.
"Puerco beds" of Osborn and Earle (225: 1-70) = Nacimiento group.
"Puerco" of Endlich (in Hayden 111: 189-190) in 1877, in the San Juan Basin of Colorado = Animas formation.
"Puerco" of Holmes (in Hayden 111: 247-248) in 1877, in the Pinyon Mesa Region of New Mexico, probably = "Wasatch".

DISTRIBUTION. -- Confined to the San Juan Basin, New Mexico and Colorado

NOMENCLATURAL DIVISIONS. -- The Nacimiento group is subdivided into the Puerco and Torrejon members. These are usually ranked as formations and there is definite evidence of a marked faunal change from Puerco to Torrejon time. The lithologic distinctions between them, however, are not marked and they have not been separately mapped.

IMPORTANT REFERENCES. -- Cope (41: 13-20, 37-282), (44: 4-6, 49-741), (45: 985-986), (46: 298-361); Gardner (82: 337-340), (83: 702-741); Granger (88: 201-207), (89: 821-830); Matthew (176: 259-326), (S.352: 209-227), (S.356: 852); Osborn (219: 33-36, 91-92), (224: 58-64); Osborn and Earle (225: 1-70); Reeside (S.354: 35-44); Sinclair and Granger (278: 297-316).

GENERAL INFORMATION

Areal distribution and lithology. -- Cope stated (41: 18) that the "Puerco marls" are occasionally black in color, "due to a small amount of carbonaceous matter", but contain no lignite or coal. At that ime he gave (p. 19) the toal thickness as 500 feet, consisting of "green and black marls." In a later (1884) paper he stated (44: 4-5) that the southernmost locality at which he had observed the "marls" was west of the "Jemez and Nacimiento Mountains, in New Mexico, at the sources of the Puerco River. At this place its outcrop is about 500 feet in thickness, and has an extent of several miles on both sides of the river". In 1890 Cope said (46: 298) that on the San Juan River its thickness is 800 or 900 feet.

In 1877 Endlich described (in Hayden 111: 189-190) 1,000-1,200 feet of strata in southwest Colorado, which he called "Puerco" (sensu lato). In the same volume of Hayden's report Holmes (pp. 247-248) assigned strata in the Pinyon Mesa region of New Mexico, near the San Juan River, to the

"Puerco" (s.l.). According to Gardner (83: 710-711) the "Puerco" of Endlich belongs to the Animas formation, and the "Puerco" of Holmes may be Puerco in age, but is probably "Wasatch".

In 1910 Gardner assigned (83: 717) a thickness of 834 feet to the Nacimiento group along the Puerco River south and west of Nacimiento.

Bauer observed (10: 277) in 1916 that the Puerco "is confined, so far as is known, to the San Juan Basin in New Mexico", and that

"It is very lenticular and irregular in bedding and, like the underlying beds, is of fluviatile origin. It consists of clay, sandy shale, easily weathered sandstone, and resistant sandstones. The striking feature of the Puerco formation, aside from its mammalian fauna, is its color, which is predominantly bluish gray and gray-white, but banded with lemon-yellow sand and wine-red clay. It contains also lenses and concretions of resistant sandstone ... which are almost black in contrast to the other strata of the region."

Reeside described the group in 1924 (S.354: 35-44) and summarized the most important previous work. He said that

"The Puerco formation as defined by its fauna is now known only in a small area extending from Escavada Wash to the head of the west fork of Gallego Arroyo, in southeastern San Juan County, N. Mex. The distance along the outcrop is about 35 miles. No fossils are known from the section on Puerco River near Cuba ... and only Torrejon fossils from the beds on Arroyo Torrejon ... It is purely an assumption to apply either Puerco or Torrejon to the barren interval between the fossiliferous zones of the Puerco and Torrejon or to the lateral extension of the beds in this interval into localities where Puerco fossils are not known."

* * *

"The Torrejon formation, as defined by its fauna, is known to extend from Arroyo Torrejon in Sandoval County, N. Mex., across the southern and western parts of the San Juan Basin almost to the Colorado-New Mexico boundary. The beds that contain the fossils near Cedar Hill, in northern San Juan County, N. Mex., have been traced by continuous exposures along the Animas Valley about 12 miles into Colorado, where they rest directly upon the Animas formation. They represent, however, only the upper 300 to 400 feet of the Torrejon formation as fully exposed in New Mexico, these upper beds having overlapped the lower beds, which along Animas River below Cedar Hill are about 1,000 feet thick. The Torrejon formation has been traced also from New Mexico into the valley of McDermott Arroyo, in the southern part of the Red Mesa quadrangle, 8 or 10 miles west of Animas River. Mammalian fossils have not yet been found in the Torrejon formation in Colorado and its identification is dependent chiefly on the unquestioned tracing of continuous outcrops."

Stratigraphic and structural relations. — Cope had said in various writings, that the "Puerco" (sensu lato) rests on the "Laramie" formation. His "Laramie", according to Osborn (224: 60), has since been divided into the Ojo Alamo sandstone, Kirtland shale, and Fruitland formation, "all probably of Montana age". In 1924 Reeside (S.354: pl. 4) represented an unconformity both at the base and top of the Nacimiento group. Similar observations had been made by Gardner (83: 711) in 1910. Osborn (224: 60)

expressed the opinion that the four successive changes in the archaic faunas of the Nacimiento group "occurred during a period of continuous sedimentation, for no unconformity has been observed between the Puerco and Torrejon". Wortman also had been unable to detect any evidence of unconformity between the two formations. Gardner, however, pointed out (83: 712) that "it is especially difficult to recognize an unconformity in badland topography in the absence of abundant fossils and especially so without detailed, continuous mapping".

Paleontology, age and correlation. -- (See tables, pp. 56, 57, 64.) In 1930 Jepsen (128: 475, 481-486) applied the names "Puerco sandstone" and "Torrejon" division to portions of the Fort Union formation of the northeast part of the Big Horn Basin, Wyoming. He used the terms, however, as indicators of age equivalence, not as formation names. The writer knows of no instance in which the names Puerco and Torrejon have been applied as formation names in Wyoming. It is not essential, therefore, to devote space to a detailed discussion of the Nacimiento group. Since, however, it includes important correlation horizons, a few general notes are pertinent. Matthew, in several articles, has proffered information and opinions. He remarked (176: 262) as early as 1897:

"The difference between the Puerco and Torrejon faunas appears to be mainly in the poverty of the former in families. This, however, is not due to any scarcity of specimens or of species ... It points to a large immigration at the beginning of the Torrejon. Another considerable immigration must have taken place before the beginning of the Wasatch."

In 1921 Matthew stated (S.353: 28):

"2. The earliest placental mammals appear in the Puerco 'Lower Paleocene' which may be as old as the Lance or older ... The Torrejon and Fort Union faunas, Upper Paleocene, are not much later than the Lance, and the phyletic evolution indicates that they are considerably later than the Puerco. ...

"3. The Paleocene placentals are of primitive and archaic aspect. Although some of their phyla survive into the Eocene, they are as a whole not nearly related to the characteristic and dominant Tertiary Mammalia, and much more primitive. The metatherian mammals (multituberculates and marsupials), a minor but considerable element in the Paleocene faunas, are of distinctly Mesozoic aspect and closely related to those of the Judith and Lance. The reptiles are all Cretaceous families continued from the Judith."

In the same year Matthew said elsewhere (S.352: 220):

"(2.) The Torrejon and Fort Union are Upper Paleocene, correlated by the Palaeobotanists with the Lower Thanetian of Europe (Gelinden and Sezanne).

"(3.) The Puerco, Lower Paleocene, is post-Senonian but may be as old as the Lance or older. The fauna shows it to be considerably earlier than the Torrejon-Fort Union and the near relations in stratigraphy

and flora between Lance and Fort Union are strongly against intercalating between them the very wide time gap which is involved by placing the Puerco as later than the Lance. If so, we must conclude that the latest dinosaur faunas were contemporary with the older Paleocene mammalian fauna, and that it is owing to some imperfectly known differences in facies that they are not found associated. Some indirect evidence in support of this view is afforded by the Paskapoo, in which Lance mammals and Paleocene placentals are found associated."

* * *

"It has been suggested that the Puerco = Lower Fort Union. But there is not the slightest evidence in favor of this, and against it, in addition to the considerations I have cited, is a small amount of very fragmentary evidence indicatingthat the Fort Union carries the same mammal fauna from bottom to top."

* * *

"The placentals of the Paleocene are to my mind essentially Cretaceous ... They belong--except the Carnivora--to extinct orders. They are related only to a minor and disappearing element of the typical Tertiary placentals. And--also with the exception of the Carnivora--they show both in the Torrejon and Puerco a certain fixity of types in species, and limitations in their specializations, that are characteristic of long established groups moving toward extinction, rather than of newly appeared and flourishing groups. In essentials they have the aspect of the last Cretaceous mammals rather than the first Tertiary mammals--a concept long ago recognized by Osborn in his division of the placental orders into Mesoplacentals and Caenoplacentals. The Carnivora are an exception. They appear as forerunners of the Eocene placental invasion ... In a Cretaceous fauna their position would be that of a progressive element which was later to expand and displace the rest ...

"The reptiles of the Paleocene are also Cretaceous types, every one of them. As with the mammals, some groups disappear at the end of the Paleocene, others survive to the end of the Eocene, and some still exist precariously; the soft-shell turtles alone are flourishing."

Cockerell and Henderson (29: 229) listed the land mollusc Helix nacimientensis White (= Lysinoë nacimientensis (White)) from the Torrejon beds, Rio Torrejon, seventy miles west of Nacimiento, New Mexico; they commented that the species "was described from the Puerco, at a time when the Torrejon had not been given a separate name, and that probably "all the Puerco mollusca recorded by White in the Bulletin cited [323: 11-12] come from the Torrejon." The "Puerco" fossils listed by White were Unio rectoides?, Helix nacimientensis White, H. adapis White, Pupa leidyi? Meek.

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Correlation of Lower Eocene Life Zones of Wyoming and New Mexico (from Osborn[1], after Granger[2])

EPOCH	NEW MEXICO (WASATCH - "LARGO" AND "ALMAGRE")	EVANSTON (TYPICAL WASATCH)	WIND RIVER BASIN (TYPICAL WIND RIVER)	BIG HORN AND CLARK FORK BASINS	REMARKS
LOWER EOCENE		Green River	Lambdotherium zone ("Lost Cabin"; typical) Hyrachyus, Eotitanops, Lambdotherium, Heptodon, Eohippus, Meniscotherium	Lambdotherium zone ("Lost Cabin"). Lambdotherium, Heptodon, Eohippus, Ambloctomus	End of lower Eocene First titanotheres appear
	"Largo" (typical) Eohippus, Meniscotherium, Ambloctonus	?			
		Knight (typical) Heptodon Eohippus	Heptodon zone ("Lysite"; typical) Heptodon, Eohippus	Heptodon ("Lysite") Heptodon, Eohippus, Anacodon	First lophiodonts appear
	"Almagre" (typical) Eohippus, Anacodon			Systemodon zone ("Gray Bull"; typical) Systemodon, Eohippus	First tapirs appear
	Unconformity between Wasatch and Torrejon. In southern Colorado "Tiffany (typical). No perissodactyls.			Eohippus zone ("Sand Coulee"; typical). Eohippus (abundant). First artiodactyls, rodents and primates.	First horses appear Arrival of modernized mammals
BASAL EOCENE				?	
	Torrejon. No perissodactyls. Fauna more primitive than in "Clark Fork".			Phenacodus zone ("Clark Fork"; typical) No perissodactyls, artiodactyls, rodents or primates. Fauna more advanced than in Torrejon.	End of Basal Eocene Archaic mammals only

[1]After Osborn, H.F. (224: 67), The titanotheres of ancient Wyoming, Dakota, and Nebraska: U.S. Geol. Survey Mon. 55, vol. 1, 1929.

[2]The correlations were modified by Osborn after Granger (88: 207), On the names of the lower Eocene mammal horizons of northern New Mexico and southern Colorado: Am. Mus. Nat. History Bull., vol. 37, art. 32, 1917.

Subdivisions of the Tertiary Rocks of Nebraska Territory
(after Meek and Hayden[1])

Names	Subdivisions	Thickness	Localities	Age
Loup River Beds	Fine loose sand with some layers of limestone,--contains bones of Canis, Felis, Castor, Equus, Mastodon, Testudo, &c., some of which are scarcely distinguishable from living species. Also Helix, Physa succinea, probably of recent species. All fresh water and land types.	300 to 400 feet	On Loup fork of Platte River: extending north to Niobrara River, and south to an unknown distance beyond the Platte.	Pliocene
White River Group	White and light drab clays, with some beds sandstone, and local layers limestone. Fossils Oreodon, Titanotherium, Choeropotamus, Rhinoceras, Anchitherium, Hyaenonodon, Machairodus, Trionyx, Testudo, Helix, Planorbis, Limnaea, Petrified wood, &c.&c. All extinct. No brackish water or marine remains.	1,000 feet or more	Bad Lands of White River; under the Loup River beds, on Niobrara, and across the country to the Platte.	Miocene
Wind River Deposits	Light gray and ash colored sandstones, with more or less argillaceous layers. Fossils,--fragments of Trionyx, Testudo, with large Helix, Vivipara, Petrified wood, &c. No marine or brackish water types.	1,500 to 2,000 feet	Wind River Valley. Also west of Wind River Mountains.	?
Fort Union or Great Lignite Group	Beds of clay and sand, with round ferruginous concretions, and numerous beds, seams and local deposits of Lignite; great numbers of dicotyledonous leaves, stems, &c. of the genera Platanus, Acer, Ulmus, Populus, &c., with very large leaves of true fan Palms. Also, Helix, Melania, Vivipara, Corbicula, Unio, Ostrea, Potamomya, and scales of Lepidotus, with bones of Trionyx, Emys, Compsemys, Crocodilus, &c.	2,000 feet or more	Occupies the whole country around Fort Union,--extending north into the British possessions, to unknown distances; also southward to Fort Clark. Seen under the White River Group on North Platte River above Fort Laramie. Also on west side Wind River Mountains.	Eocene ?

[1] Copied from Meek, F.B. and Hayden, F.V. (215: 433), Descriptions of new ... fossils collected in Nebraska ...: Acad. Nat. Sci. Philadelphia Proc., vol. 13, 1861.

This table contains the type designations of the four Tertiary divisions shown.

MIDDLE AND UPPER PALEOCENE FORT UNION FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation or group. The type locality is around the mouth of the Yellowstone River on the Missouri River, near the Montana-North Dakota boundary. The formation was named after old Fort Union, which was subsequently called Fort Buford, and is now the town of Buford, North Dakota.

TYPE DESIGNATION. -- (See table, p. 65). The Fort Union was named by Meek and Hayden (205: 433) in 1861, in their "General section of the Tertiary rocks of Nebraska", which is reproduced on the preceding page. Their discussion of the generalized section included (pp. 433-434) the additional note that

"The Fort Union, or Great Lignite Group, occupies extensive areas of country in Nebraska[1], and has been seen beneath the White River Group at several distant localities. It was evidently deposited in large bodies of water, which were at first brackish, and then gradually became fresh. The great number of fossil leaves, and numerous beds of lignite contained in it, clearly show that the shores of these ancient estuaries, lakes &c, in which this formation was deposited, supported dense forests of large trees, and a growth of other vegetation ..."

RESTRICTIONS. -- The name Fort Union was very loosely used by all early stratigraphers. The present application of the name to sediments of Paleocene age, stratigraphically between the Lance and the lower Eocene, has grown out of usage rather than formal redefinition.

SYNONYMY. -- (See tables, pp. 13, 14, 15; also pl. 2.)

"Laramie", "Fort Union", "Great Lignite Group", were used interchangeably by Meek, Hayden and Lesquereux in their writings. These divisions included strata now assigned to the Laramie (restricted), Lance, Denver, Arapahoe, true Fort Union, Lewis, Medicine Bow, Ferris, Evanston and Hanna. The following synonymy list is by no means complete; it is intended to be merely illustrative.

"Great Lignite formation" of Newberry in 1869 (211: 524-532) included Fort Union.

"Laramie" of Lesquereux in 1876 (148: 1-366) included the Fort Union.

*Bitter Creek group of Powell in 1876 (229: 45-47, 64-66) has been said to include the Fort Union. In contemporary stratigraphy, however, "Fort Union" is not applied to rocks in southwestern Wyoming.

"Post-Cretaceous" of White, in various papers of 1877 and thereafter, included the Fort Union with the "Laramie".

"Laramie" of White was extended by him in 1878 (319: 721) to include the Fort Union.

"Laramie Group" of Endlich in 1879 (in Hayden 114: 88-89) included Fort Union.

"Wasatch" of Cope in 1884 in the Big Horn Basin (44: 9) included Fort Union.

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[1] "Nebraska", throughout the paper cited, means the old Territory of Nebraska, not the present state of that name.

FORT UNION FORMATION - Specific Information

SYNONYMY (cont'd).

"Laramie" of Ward in 1886 (303: 401-555) included the Fort Union. His "Laramie flora" is said to be mainly from the Fort Union.

"Wahsatch" of Wortman in 1892 in the Big Horn Basin and Big Horn Mountains (338: 139-144) included the Fort Union.

"Laramie" of Eldridge in 1894 (69: 24-25) in the Big Horn Basin may have included some Fort Union.

"Livingston formation" of Eldridge (69: 25) in the Big Horn Basin probably is largely Fort Union.

*De Smet formation of Darton (56: 8-9) (57: 62-67) (58: 303) in 1906, and of Gale and Wegemann (81: 143-146) in 1910 = Fort Union plus the Lance and Ulm formations.

"Laramie and associated formations" of Fisher (76 : pl. 3) in 1906 included all of the Fort Union of the Big Horn Basin.

"Laramie" of Woodruff in 1909 in the Big Horn Basin (334: 202, 205) = Lance, and perhaps the lower part of the Fort Union.

Jepsen, in 1930, maintained (128: 463) that the upper part of the "Lance", as shown in the U.S. Geol. Survey's 1925 geologic map of Wyoming, includes lower Fort Union in the Big Horn Basin.

"Fort Union(?)" of Shaw in 1909 (264: 155-156), in the Glenrock coal field of the Powder River Basin, probably includes Lance, Fort Union and Ulm formations.

DISTRIBUTION. -- Central Wyoming; Big Horn and Wind River basins, Wyoming; northeastern and east-central Wyoming; southern and eastern Montana; the Dakotas.

NOMENCLATURAL DIVISIONS. -- In northeastern Wyoming, southern Montana and the Dakotas the Fort Union is divided into the Lebo shale and Tongue River members. The Tullock member of the Lance is also sometimes assigned to the Fort Union. The Kingsbury conglomerate of Johnson Co., Wyo., and Sentinel Butte shale of the Powder River Basin, Wyoming, and of southern Montana, may be members of the Fort Union. Thom and Dobbin believed that the Kingsbury is merely a coarse phase of the Sentinel Butte shale, which they call Wasatch, but which the U.S. Geological Survey calls Fort Union(?). In the Fort Union of Big Horn Basin, Wyoming, Jepsen (128: 463-528) established five faunal zones: two lower ones which he considered equivalents of the Puerco and Torrejon formations of New Mexico; one which he named "Princeton Quarry level", or "Tiffany-Bear Creek faunal equivalent", and an upper member which had been previously named the Clark Fork member of the "Big Horn Wasatch", but which he considered the top of the Paleocene and therefore included in the Fort Union.

IMPORTANT REFERENCES. -- Berry (14: 30-31); Cope (in Hayden 108: 432-435), (40: 25-41); Douglass (66: 216-224); Hayden (104: 192); Henderson (119: 36-44); Hewett (120: 104-109), (122: 30-40); Jepsen (128: 463-528); King (137: 333-334); Lesquereux (in Hayden 107: 358-370), (148: 1-366), (150: 109-238); Knowlton (138: 179-238), (140: 1-79); Matthew (S.352: 209-227), (S.353: 27-29); Meek and Hayden (202: 111-126), (205: 432-434); Osborn (224: 48, 60-66); Schuchert (245: 45-47); Simpson (269: 1-15), (271: 1-12), (S.357: 115-122); Ward (303: 401-555); Wegemann (309: 50-54), (312: 23-24), (313: 59-60).

Hayden's Section of the "Great Lignitic Group"

Vertical Section, Exhibiting a Portion of the Strata of the Great Lignite Basin, near Fort Clarke, on Missouri.			
A	30 ft.	Furruginous sandy marl, passing downwards into variegated argillaceous grits: contains Paludina Leai, P. retusa, P. Leidyi, P. trochiformis.	Fort Union, Yellow Stone, Red Spring, ten miles above Fort Clarke.
B	2 in.	Seam of impure reddish lignite.	Red Spring to Fort Union.
C	10 to 12 ft.	Yellowish gray, friable grit, with numerous argillaceous concretions in horizontal layers, containing beautiful impressions of leaves of the genera, Platanus, Acer, Ulmus, and Ferns.	Best developed and most fossiliferous at Red Spring, ten miles above Fort Clarke. It occurs also along the Missouri to Fort Union, where it contains fine impressions of Ferns as well as Dicotyledonous leaves.
D	3 in.	Seam of lignite, very much mixed with clay and sand.	Red Spring and up the Missouri.
E	10 ft.	Yellowish gray grit, very friable, and containing layers of argillo-calcareous concretions, charged with leaves of the same species of plants, as in bed C.	Red Spring, &c.
F	3 in.	Seam of earthy lignite.	Red Spring, &c.
G	15 ft.	Yellow and drab clay and friable sandstone, containing argillaceous concretions, with impressions of leaves like those in beds C. and E.	Red Spring to Fort Union.
H	4 in.	Dark reddish, earthy lignite.	Red Spring, &c.
I	20 ft.	Yellow arenaceous grit, very friable, with some small Paludinas, Corbulas, &c.	Red Spring.
J	15 ft.	Alternations of lignite and clay. This bed is variable in thickness as well as in the proportions of the materials at different localities; contains large quantities of fresh water shells.	Fort Clarke, Red Spring, and other localities along the Missouri.

Hayden's Section of the "Great Lignitic Group" (cont'd)

K	40 ft.	Heavy bedded gray and ferruginous friable sandstone, with great numbers of fossils, forming seams of shell marl; Melania nebrascensis, Paludina multilineata, P. peculiaris, Bulimus limnaeiformis, Corbula mactriformis, with numerous impressions of dicotyledonous leaves in argillo-calcareous concretions.	Very largely developed at Fort Clarke, Red Spring; is also seen where the Tertiary beds are exposed along Missouri and Yellowstone.
L	2 ft.	Seam of impure lignite, probably local.	Red Spring; not seen at many localities.
M	4 ft.	Gray argillaceous friable grit, usually passing downwards into a dark brown carbonaceous clay.	Fort Clarke, Red Spring, and along Missouri.
N	2 ft.	Lignite, purest in the section.	Fort Clarke to Fort Berthold, to Fort Union.
O	6 ft.	Very dark carbonaceous clay passing down into very bluish gray arenaceous clay; contains at Fort Berthold a species of Paludina, also Planorbis fragilis, and a few impressions of leaves, petrified wood, &c.	Fort Clarke, Red Spring, Fort Berthold and Fort Union. It is also seen above Fort Union along the Missouri.
P	2 ft.	Rather pure lignite. This bed is local.	About 70 miles below Fort Clarke, near the point where the Tertiary beds first appear in ascending the Missouri.
Q	40 to 60 ft.	Gray compact or somewhat friable concretionary sandstone; contains Cyrena moreauensis, C. intermedia, Thespesius occidentalis, Compsemys victus, &c.	Near Long Lake on the Missouri. On Moreau River and Cherry Creek.

[1]Copied from Hayden, F.V. (101: 135), Geological sketch of the estuary and fresh-water deposits of the bad lands of the Judith ...: Am. Philos. Soc. Philadelphia Trans., new ser., vol. 11, 1860.

FORT UNION FORMATION

GENERAL INFORMATION

Areal Distribution and Lithology

Historic notes; general distribution. -- In 1856 Meek and Hayden (202: 111-112) gave a brief resumé of early observations on the Fort Union ("Great Lignitic") formation, beginning with records of an investigation by Dr. John Evans in 1849. According to Meek and Hayden, he had "traced a great lignite formation from below Fort Clark along the Missouri to a point 20 miles below the mouth of the Yellowstone River". Thaddeus A. Culbertson, they said, also "saw the formation at two or three points above Fort Union". Meek and Hayden remarked also that, on both sides of the Yellowstone River, "only Tertiary strata are seen from near the mouth of Powder River as far up as the mouth of the Big Horn".

In 1869 Hayden's understanding of the Fort Union formation was little changed, as shown by an almost verbatim repetition (104: 192) of his type description of 1861. He made the additional observation, however, that it "also extends along the eastern flanks of the Mountains, probably to Denver, Colorado, and perhaps further".

Lesquereux, in his report of 1873 on the "Lignitic formation and Fossil Flora" (in Hayden 107: 358-370), presented an historic review of the study of the "formation to which the name of Great Lignite is fittingly applied", together with a summaryof its areal distribution and thickness, as he understood it. The historic review began with comments on observations made by members of the Lewis and Clarke expedition of 1804.

In 1876 Hayden (109: 20) stated that the areal extent of the Fort Union formation in the upper Missouri country "cannot be less than one hundred thousand square miles, and extends far north ... into the British possessions". In the same year Lesquereux (148: 8) corroborated these observations. Their accuracy, however, is considerably depreciated by the fact that the "Great Lignitic" or Fort Union of Hayden and Lesquereux included beds now assigned to older formations, as indicated by Hayden's statement (109: 20) that the "group everywhere rests upon well-defined Cretaceous beds, which ... have received the name of the Fox Hills group ..." Obviously, Hayden's "Fort Union" included the Laramie, Lance, and equivalent strata.

Meek (199: LVIII - LIX), in 1876, recorded his opinion that the "group" extends southward "in a broad belt across the Yellowstone, between the Black Hills and Big Horn Mountains, to where it was found by Dr. Hayden passing beneath the White River group about sixty miles north of Fort Laramie".

Hayden (116: 975-976) offered the opinion in 1879 that the Fort Union "will yet be found to cover a greater or less area on both sides of the main 'divide' of the Rocky Mountains, from the Arctic Sea to the Isthmus of Darien".

FORT UNION FORMATION - Distribution and Lithology

Central Wyoming. -- Wegemann has contributed two papers on the Salt Creek oil field, Natrona Co., Wyoming. In the first of these, published in 1911, he stated (309: 50) that the Fort Union formation is 4,500 feet thick, and can be differentiated into several lithologic types: at the base, 2,000 feet of "white shaly sandstone containing here and there red ferruginous beds"; above the sandstone, "one or more coal beds"; above them, "a great series of sandstone and shale, for the most part light in color". The information in the first paper was embodied in a second paper, published in 1918. His later description of the Fort Union, however, was radically different. He said (312: 24) that

"The Fort Union formation as defined by the writer in this region consists of about 2,000 feet of fine-grained bluish-white sandstone and gray shale containing at many horizons beds of ferruginous shale only a few inches thick. Its outcrop forms a prominent pine-covered ridge, which can be seen for many miles and is referred to in the region as Pine Ridge."

The definition referred to in the quotation occurs in Wegemann's paper of 1917 on the Powder River Basin, Wyoming (313: 57-60). In this paper, 2,400 feet of coals and sandstone overlying the 2,000 feet of white sandstone, were referred to the "Wasatch" because of the presence of Coryphodon and Eohippus in the upper beds. The validity of this alteration is discussed in detail on later pages of the present paper in the section on the lithology and distribution of the "Wasatch" formation. The general conclusion is there reached that Wegemann's "Wasatch" may include the Tongue River member of the Fort Union and/or the Sentinel Butte shale member(?) of the Fort Union.

In 1909 Shaw described the geology of the Glenrock coal field, Converse and Natrona counties, in the southwest portion of the Powder River Basin, Wyoming. He assigned a great mass of strata, of unstated thickness, to the Fort Union(?) formation (264: 155-156), which he found directly overlying the Montana "without apparent break". He found that the Fort Union(?) is separable "into three members--a lower one of white to brown sandstone, already described, which is best exposed near Glenrock and on Cole Creek near Big Muddy; a middle member, which underlies a large area north and northwest of Douglas and is made up of dark shale and sandstone; and an upper member of bluish shale which weathers white and outcrops in a small area on the north side of the Glenrock field". If Wegemann's descriptions of the geologic succession farther north may be accepted, it is possible that Shaw's "Fort Union(?)" contains representatives of three formations--Lance; Fort Union and Wasatch(?).

Bauer described the Fort Union formation of the Wind River Basin in 1934 (11: 672) as follows:

"It was measured on the northeast flank of Dutton Dome in T.34 N., R.90 W., about fifteen miles south of Moneta. It is exposed also on the northeast flank of Rattlesnake Mountains, but not exposed elsewhere in the basin except on Muddy Creek, a few miles east of Maverick Springs.

FORT UNION FORMATION - Distribution and Lithology

It is quite certain there is no Fort Union in the portion of Wind River basin south and west of Riverton. If the outcrops on Muddy Creek, which the writer thinks may be Fort Union, prove to be this age, then the syncline along Dry Cottonwood and between Badwater Creek and the south slope of the Bridger Mountains probably contains a full section of Fort Union strata.

"Considerable search failed to reveal coarse materials in the Fort Union of this area."

Borders of the Big Horn Basin. -- In 1909 Woodruff described the geology of the west and southwest sides of the Big Horn Basin, where he measured a thickness of 3,100 feet in the Fort Union (334: 202). He said (pp. 205-206) that along the Shoshone River east of Cody it consists of three members: at the base, "about 1,000 feet of gray massive sandstone and green shale with coaly layers" and conglomerate; next, "1,700 feet of soft sandstone and somber-colored shale in alternating layers, some of which contain coal beds"; at the top, "400 feet of gray sandy shale with local beds of sandstone". Woodruff added, however, that plants collected from sandstone in the underlying "Laramie" (= Lance) formation, below an apparent unconformity, had been assigned by Knowlton to the Fort Union and that "if further study confirms this opinion, the Fort Union probably includes several hundred feet of beds which are considered Laramie in this report".

In 1914 Hewett (120: 91) assigned a thickness of 5,592 feet to the Fort Union formation in the Shoshone River section on the west side of the Big Horn Basin. He stated (p. 105) that the lower strata of the Fort Union are, in general, compact and well-consolidated, and form high persistent ridges in the region south of Shoshone River. He noted several beds of conglomerate, and found that the lowest group of conglomerates contains six zones from 5 to 20 feet thick in a stratigraphic distance of about 250 feet. Each of these zones is composed of smaller zones or beds of conglomerate, which range from 2 to 10 feet in thickness. The dip section is well exposed and shows the single beds to be relatively persistent, but lenticular and characteristically anastomosing ... The pebbles are mostly subangular to rounded ... Most of the pebbles are gray to black chert, from half an inch to 2 inches in diameter. There are a few pebbles of vein quartz and igneous rocks are conspicuously absent."

Hewett (pp. 105-106) also said that higher conglomerate beds were thinner and differed lithologically from those below. He found that "quartizites are more abundant than chert, and there are fair proportions of quartz schist and pink granite pebbles not represented in the lower beds". His lithologic section (p. 106) shows that the Fort Union is composed largely of red and gray clays, massive gray and buff sandstones, and a few gray shales. At the top of the section is a 20-foot bed of massive buff sandstone.

In 1934 Johnson (130: 821) assigned a thickness of 5,600 feet to the Fort Union formation in the Cody region of Shoshone Canyon.

FORT UNION FORMATION - Distribution and Lithology

Woodruff wrote (335: 176) on the Fort Union of the southeastern portion of the Big Horn Basin in 1910. He differentiated two unnamed members of the formation, a lower coal-bearing member of yellowish sandy shale and rusty sandstone, about 755 feet thick, which rests unconformably on the "undifferentiated Montana"; and an upper non coal-bearing member of gray and grayish-drab sandy shales and lenticular yellow sandstones, 225 to 600 feet thick.

In 1917 Hewett and Lupton, in their paper on the southern part of the Big Horn Basin, observed (123: 29):

"On the east side of the Big Horn Basin the Fort Union formation ranges in thickness from about 1,200 feet near Kirby to about 2,000 feet on Greybull River, about 4 miles above its mouth.

"The formation is largely composed of white, buff, and drab sandstones with gray, olive, and red shale. On the west side of the basin, the basal bed is generally conglomeratic and there are also several higher persistent beds of conglomerate. The pebbles of the conglomerate are largely white and red quartzite ... The formation contains important but lenticular beds of coal at 100 to 150 and at 480 feet above the base on the west side of the basin. ... Thin beds of coal and carbonaceous shale are known near the top of the formation on Antelope Creek, about 3 miles southwest of the town of Basin.".

Hewett later (1926) described the Fort Union of the southern part of the Big Horn Basin in detail. In his report, which covered the Oregon Basin, Meetseetse and Grass Creek Basin quadrangles, he stated (122: 30) that 60 to 70 per cent of the formation is sandstone or conglomerate, that the basal sandstone varies in character, and that

"In the region of unconformity neither this sandstone nor those higher in the formation contain any sediment more than an inch in diameter, and most of the material is less than 0.1 inch. ... the basal as well as higher beds contain thick lenses of conglomerate that are made up largely of material more than an inch in diameter.

"The thickness of the exposed part of the Fort Union formation in this region depends on the position of the Wasatch beds which overlap it. The maximum thickness of 3,140 feet is found in T. 46 N., R.97 W. ...

* * *

"In the region of unconformity the formation contains only traces of coal, whereas farther southeast, in the region of apparent conformity with the Lance formation, one to four important beds are present."

In 1909 Washburne described the Fort Union formation of the northeast part of the Big Horn Basin. He said (304: 169) that the formation consists mainly of dark shale and thick lenticular masses of sandstone. The sandstone beds, some of which are more than 100 feet thick, are most abundant in the lower part of the formation. Washburne added that

"West of Sheep Mountain there is over 1,200 feet of white conglomeratic sandstone at the base of the Fort Union, but this is exceptional.

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The lenticular sandstones in the formation contain many ferruginous concretions, which reach 40 feet or more in diameter. The shale contains smaller, hard, dense, ferruginous concretions, weathering yellow and brown. ... Coal occurs locally in all parts of the Fort Union formation. The coal beds mined southwest of Basin, near Manderson, are about 700 feet above its base."

Other descriptions of the north portion of the Big Horn Basin followed. Among the most detailed of these was that of Jepsen, in 1930, in his paper on northeastern Park County. Jepsen (128: 475) discovered typical Puerco mammal fossils in a sandstone mapped by the U.S. Geological Survey as Lance, and believed that this sandstone properly, therefore, belonged to the Fort Union. He said (pp. indicated) that the bottom of the "Puerco" sandstone is marked by a thin, irregular coal bed in the top of the Lance and that

"the first fifteen or twenty feet of the Puerco sandstone seems to be a stratigraphic unit that extends, with but little variation in thickness, throughout the area studied in Polecat Basin ... It is continuous above with the rest of the sandstone member which has a total thickness of 130 feet, but the upper reaches are separable into 'beds' and include thin shale layers. The lowest part of the sandstone varies from moderately coarse to coarse texture, and is composed chiefly of very angular quartz fragments ... The yellow color of the sandstone ... increases in prominence downward toward the base until the very contact is nearly everywhere a deep brown.

" ... where the coal is not present ... the basal sandstone assumes the nature of a torrential debris accumulation ... In some hand specimens of the sandstone, small flattened clay pebbles or galls make up most of the mass ... The sandstone itself is of vast variation in grain-size, from fine material to a conglomerate ..." (pp. 481-482)

* * *

"Above this basal unit, the Puerco sandstone varies only slightly in texture and color, and encloses thin lenses of sandy shale ... Toward the top there are many concretions which erode out as spheres and 'logs' and weather to a deep brown color.

* * *

"The uppermost surface has a relief variation of several feet. Imperfect ripple marks and some plant remains were observed at the very top where the sandstone assumed a deep purplish-brown color and is of an unusual hardness due to oxides of iron." (pp. 483-484)

Overlying the "Puerco sandstone" member of the Fort Union, Jepsen found a sequence of strata which, he said (pp. 484-486), consists of "somber intercalated shales and sandstones", and that

"At a distance which was not measured above the "Puerco sandstone," in T.57 N., R.99 W., Section 25, there appears a shale level which contains many flat ovoid siderite concretions ...

* * *

"Fifty feet above the Puerco sandstone occurs a bed about a foot

thick, which was mistaken in the field for an andesitic ash ...

* * *

"Next above these beds are a coal bed about two feet thick, capped by somber shales about 15 feet thick, which in turn are overlain by from 9 to 31 feet of sandstone containing Torrejon age mammals ...

"Impressive characters of this sandstone are its slight horizontal extent, its irregular truncation of the underlying shales, its massive, distorted bedding, and the great variation in thickness. At the base, the sandstone is white in color and contains many flattened blue clay-galls; but the white color grades upward into a brown phase which has very few clay inclusions ..."

Stratigraphic and Structural Relations

General relations; historic considerations. -- It was noted in the synonymy list that Meek and Hayden made no distinction between the Fort Union and "Laramie" formations. Thus, they stated in 1861 (205: 434) that wherever the Fort Union is seen in contact with the Cretaceous, "the two have been found to be conformable ..., while at the junction there seems to be a complete mingling of sediments". Meek and Hayden declared that "no important member of either system is wanting" between the "Fort Union" and the "well-defined Cretaceous". In 1876 Meek again asserted (199: LV), with similar confidence, that the Fort Union is everywhere strictly conformable to "the well-marked Cretaceous". In 1879 Hayden (116: 974-975) wrote again in a similar vein, concerning outcrops along the Wind River, Big Horn, Wasatch and Green River Mountains.

In 1870 King (134 : 115) had declared with certainty that

"Whatever may be the relations of these beds in other places, it is absolutely certain that within the region lying between the Green River and the Wasatch, and bounded on the south by the Uinta Range, there is no single instance of conformity between the coal beds /"Fort Union"/ and the horizontal fresh-water strata above them /"Wasatch"/.

King was opposed in this view by Hayden and others, but subsequent work has born out his conclusions. In southwest Wyoming, however, the names Fort Union and Laramie are no longer employed (see pp. 10, 12, 51).

Available data afford no adequate basis for any but the broadest generalizations concerning the relations of the Fort Union to older systems, and it is undoubtedly true that conformable relations in some localities give place to unconformities in others. In the Powder River Basin according to Wegemann (313: 60),

"we find in the region southeast of the Big Horn Mountains three fresh-water formations above the marine sandstone of the Fox Hills; the lowest of these is Lance, the highest Wasatch, and the intermediate formation may reasonably be considered to be Fort Union. A local unconformity is known to exist in the vicinity of Buffalo between the Wasatch and Fort Union, and there is evidence to indicate that this unconformity is present

although less evident in other parts of the Powder River Basin."

Bauer said (11: 672), in 1934, that there is no stratigraphic break between the Fort Union and underlying Lance in the Wind River Basin.

In 1910 Woodruff wrote (335: 176) that in the southeast part of the Big Horn Basin the Fort Union is divisible into two lithologic units, the lower of which rests unconformably on the "undifferentiated Montana", while the upper is unconformably overlain by the "Wasatch".

In 1926, however, Hewett wrote on the Oregon Basin, Meeteetse and Grass Creek Basin quadrangles in the southern part of the Big Horn Basin, where he found (122: pp. indicated) that the base of the Fort Union is at

"an angular unconformity that separates the lower group of beds which persistently yield a fauna assigned to the Lance formation from overlying beds whose flora is considered to belong to the Fort Union formation. The extent of the unconformity is indicated by the fact that in a distance of 3 miles along the strike as much as 1,800 feet of beds has been eroded. However, the basal beds have been traced southeastward in a region of folds for a distance of 60 miles without the detection of additional evidence of unconformity ...

* * *

"The maximum thickness of 3,140 feet is found in T.46 N., R.97 W., and although there is apparent conformity between it and the Wasatch beds, other evidence indicates unconformity ... The formation is nearly 5,600 feet thick on Shoshone River. In the Hole in the Ground, at the head of Fifteenmile Creek, in T.48 N., R.99 W., where it is apparently conformable with the Wasatch beds, 2,000 feet was measured. A few miles west of this area, in T.51 N., R.100 W., the formation is completely concealed by Wasatch beds. These relations show clearly that a profound unconformity separates the two formations in this region--an unconformity that indicates much more widespread uplift and erosion than that which locally separates the Fort Union from the underlying Lance formation." (p. 30)

* * *

"One feature of the pebbles of the Fort Union was useful in determining the base of the Wasatch formation in this part of the region. Many of the Fort Union pebbles ... show percussion marks from which numerous cracks radiate. The cracked pebbles are more abundant where the beds have been steeply folded, but percussion marks are common even where the beds have a flat dip." (p. 39)

In 1930 Jepsen, writing on the Fort Union of the northern part of the Big Horn Basin, said (128: 463):

"From an erosional disconformity at the top of the Lance upward through the Paleocene to the locally angular unconformity between the 'Clark Fork' and the Gray Bull, no pronounced structural or stratigraphic break has been observed."

Later, in the same reference (p. 468) he continued:

" ... the Paleocene and Eocene sediments seem conformable, and if the two series are separated by a hiatus, it is not revealed by an angular discordance. A few miles south, however, at the southwest base of McCullough Peaks, and also along the eastern margin of the basin west of the town named Basin, the edges of the Fort Union strata (Paleocene) are truncated by overlying Eocene beds which dip less steeply toward the structural center of the basin."

Paleontology, Age and Correlation

In 1857, before the Fort Union formation was named, Hayden remarked (100: 115) that the "Fort Union" invertebrate fauna "possesses the mixed character of a fresh water and estuary deposit", and that it "cannot be older than the Miocene period". Hayden (104: 189) again expressed his opinion in 1873:

"Proceeding southward from Cheyenne we pass over the coal formations of the tertiary period, which have already been called, on the Upper Missouri, the Fort Union group. This group I regard as marking the dawn of the tertiary age in the west.

"I do not think that such terms as eocene, miocene, pliocene, &c., are at all applicable to the tertiary deposits of the West, and I therefore designate them as lower, middle, and upper tertiary. I regard all the coal beds of the West as lower tertiary."

Lesquereux, in his report of 1873 on "The Lignitic formation and fossil flora" (in Hayden 107: 339-340), was fully in accord with the views expressed by Hayden. Unfortunately the "Lignitic" formation included strata ranging from Lewis to Hanna and/or Wasatch in age.

In 1874, Cope attempted to give a systematic statement of the evidence of the age of the "lignitic" strata. His summary (in Hayden 108: 432) was as follows:

"That the period of their deposit was one of transition from marine to lacustrine conditions is evident, and that a succession of conformities in position of beds may be traced from the lowest to the highest of them, and with the Tertiary strata above them at distinct localities, beginning at the south and extending to the north, is also proved by Hayden and others. It appears impossible, therefore, to draw the line satisfactorily without the aid of paleontology; but here, while evidence of interruption is clear from the relations of the plants and vertebrate animals, it is not identical in the two cases, but discrepant ... I am aware that the combination I shall make is of a highly inflammable character, because it not only relates to the most combustible deposits of the West, but also to the 'partie honteuse' of contemporary geologists and paleontologists."

Cope then stated that Hayden had enumerated the Fort Union, among

other formations, "as distinct epochs of transitional character", and had referred them to the Tertiary period. Proceeding to a discussion of the Fort Union "group", Cope tabulated (pp. 433-434) a list of references, with a brief statement of the age assignment made by the writer in each. He expressed his own opinion, however, that there is no doubt of the "Cretaceous and Mesozoic character" of the Fort Union fauna. In 1875 Cope (40: 40) reached the conclusion that, in the Fort Union group "a Tertiary flora was contemporaneous with a Cretaceous fauna, establishing an uninterrupted succession of life across what is generally regarded as one of the greatest breaks in geologic time". Cope added the footnote:

"The circumstance of the discovery of a Mesozoic Dinosaur, Agathaumus sylvestris, with the cavities of, and between, his bones stuffed full of leaves of Eocene plants (Lesquereux), would prove this proposition to be true, had no other fossils of either kind ever been discovered elsewhere!"

Meanwhile, Lesquereux wrote (108: pp. indicated):

"The locality where the discussion on the relation of fossil remains may be made with the most advantage is that of the Bitter Creek series, where there is an abundance of vegetable remains represented, at Black Butte, especially, and of animal fossils, saurians, shells, &c., also found in profusion in the strata of this series from Black Buttes to Rock Springs. In the whole series, neither Professor Meek nor his assistant have found any shells truly characteristic of Cretaceous age; and Professor Meek says himself 'that although partly committed to the opinion that this formation belongs to the Cretaceous, and still viewing it as most probably such,' he does not wish to disguise or conceal the fact that the evidence favoring this conclusion, to be derived from the mollusks alone, as now known, is by no means strong and convincing!" (pp. 371-372)

* * *

"What shall be the name of this formation; is it Cretaceous on account of the saurian bones, or is it Tertiary on account of the fossil plants in which the skeleton /Agathaumus sylvestris/ is entombed, and which are found in the same relation all over the Lignitic formations ...? No geologist, I think, will hesitate a moment in pronouncing it, from its land-character, a Tertiary formation ..." (pp. 373-374)

In 1876 Hayden said (109: 20) that he regarded "the Lignitic group proper as transitional or Lower Eocene", but in the following year Cope apparently still considered the Fort Union to be of Cretaceous age, as evidenced by a passage (41: 13) in which he referred to the "Fort Union Lignite Cretaceous".

In 1878 King (137: 353-354) offered some pertinent observations:

"Cope, in the introduction to his volume on the Cretaceous, cites Dinosaurians as coming from the Fort Union, from which he refers the fauna

to the Mesozoic series. On the other hand, the characteristic plant-life of the country differs entirely from that described by Lesquereux ... [148: 1-366]. It is noticeable that he nowhere describes in that volume any of the plants from the classic Fort Union locality, a series which has been studied by Newberry, and which contains not only a general resemblance, but some actual species identical with the Miocene flora of Greenland and northern Europe. It is mentioned by Meek that the flora of Miocene facies from Fort Union come from higher beds than the Dinosaurians, while the correlation of the Dinosaurian beds, which occur far down at Fort Union, with the Black Butte Laramie horizons, as made by Cope, seems undoubtedly warranted."

Quotations could be added ad infinitum from papers written during the "Laramie"-Fort Union controversy, over a period of three-quarters of a century. The writer believes it is rather generally conceded that "Fort Union flora" will be of little value in exact stratigraphy until it is more closely studied and more finely discriminated with the aid of carefully collected new material. During the 20th century closer stratigraphic paleontologic methods are demanded. Berry, one of the most prolific of contemporary contributors to the literature on North American Tertiary floras, pointed out in 1930 (15: 55) that it is impossible to check certain correlations by means of fossil plants because "those collected from the Wasatch have been confused with the Fort Union".

In 1902 Douglass published a paper on the Fort Union of south-central Montana. He mentioned finding in it (66: 217-218) two fresh-water pelecypods, Unio couesi White and U. cf. U. endlichi White, and included the following list of fossil plant specimens, identified by Knowlton:

Pterospermites cupanoides (Newberry)
Populus speciosa Ward
Populus amblyrhyncha Ward
Ulmus orbicularis? Ward
Vitis xantholithensis Ward
Populus daphnozenoides Ward
Populus arctica? Heer
Platanus aceroides Göpp.
Celastrus sp.
Grewia crenata (Ung.) Heer
Viburnum asperum? Newberry
Populus cuneata Newberry
Platanus nobilis Newberry
Platanus basilobata Ward
Viburnum sp.
Paliurus sp.
Grewiopsis viburnifolia Ward
Populus? n. sp.

According to Davis (S.361: 426) in 1912, the undifferentiated "Fort Union" of the Little Powder River coal field, Campbell County, Wyoming, yielded the following fossil plants, identified by Knowlton and referred to the Fort Union:

Glyptostrobus ungeri Heer
Glyptostrobus europaeus Heer
Populus amblyrhyncha Ward
Populus cuneata Newberry
Populus daphnozenoides Ward
Taxodium occidentale Newb.
Leguminosites arachioides Lesq.
Dicotyledon, probably new
Corylus rostrata Ait.
Celastrus curvinervis Ward
Celastrinites sp.?
Sequoia langsdorfii? Brogniart
Sequoia nordenskioldi Heer
Sapindus grandifolius Ward
Onoclea sensibilis fossilis Newb.
Viburnum sp.

FORT UNION FORMATION - Paleontology, Age and Correlation

Davis also listed the following invertebrates, identified and referred to the Fort Union by Stanton:

Unio priscus Meek and Hayden
Sphaerium formosum
Viviparus trochiformis M. and H.
Viviparus leidyi M. and H.
Viviparus leidyi var. formosus M. and H.
Campeloma producta White
Goniobasis tenuicarinata M. and H.
Goniobasis sp.?
Limnaea tenuicostata M. and H.
Hydrobia? sp.

Dobbin and Barnett recorded in 1927 (60: 11) that among the most abundant invertebrates of the Fort Union of northeastern Wyoming were Acroloxis minutus Meek and Hayden, Goniobasis aff. G. tenera (Hall), and Viviparus raynoldsianus Meek and Hayden

In 1930, Jepsen gave a list (128: 489) of invertebrates from sediments lying stratigraphically between the two Fort Union zones of the Big Horn Basin which he called "Torrejon" and "Tiffany-Bear Creek" faunal equivalents. His list included the following species:

Unio danae Meek and Hayden?
*Unio wasatchensis Cockerell?
Unio sp.
Vivipara retusa (Meek and Hayden)
*Vivipara paludinaeiformis (Hall)
Goniobasis tenuicarinata (M. and H.)
*Vivipara, new species
Lioplax nebrascensis (M. and H.)
Lioplax nebrascensis var. producta (White)
Lioplax limnaeiformis (M. and H.)

The three species marked by an asterisk had not been previously recorded from the Fort Union. Jepsen said that of these, Unio wasatchensis occurs in the Greybull, and Vivipara paludinaeiformis is known in the Knight formation of southwestern Wyoming.

Henderson (119: 40) has listed the following invertebrates from the "Fort Union Paleocene, Park County, Wyoming:

Unio sp. undet
Unio wasatchensis Cockerell?
Campeloma limnaeiformis (Meek and Hayden).
Campeloma nebrascensis reticulata Russell
Goniobasis tenuicarinata (M. and H.)
Viviparus retusus (M. and H.)
Viviparus paludinaeformis (M. and H.)
Lioplax nebrascensis (M. and H.)

In addition to the above, Henderson (pp. 42-44) has furnished locality lists of the Fort Union in Montana and the Dakotas. Although the above list was obtained by Henderson from Russell (S.360), similarities to the faunal list of Jepsen will be noted.

In his paper of 1902 on the Fort Union of southern Montana, Douglass stated that the mammalian fauna, though not large, was "sufficient to show that the beds are of nearly the same age as the Torrejon of New

Mexico". His list included the (66: 217) following fossil mammals:

Mioclaenus acolytus (Cope)	Euprotogonia puercensis (Cope)
Anisoconchus, very near to A. sectorius Cope	Pantolambda caviricrtis(?)
	Pantolambda(?), a small species

In 1929 Simpson published a paper in which he discussed various previously described Fort Union faunas. The discussion dealt principally with the Tiffany, Clark Fork and Bear Creek facies, but included a very concise summary of the stratigraphy and paleontology of the Fort Union as a whole. Simpson said (271: 6):

"The term 'Fort Union' has been very loosely used and it is still uncertain just how much of any given series it should properly include. Its subdivision and correlation have rested largely on stratigraphic data which, in general, are unsatisfactory. The best recent treatment, and one which may form a basis for future work, is that of Thom and Dobbin [296: 481-506]."

Jepsen's work in the Fort Union of the Big Horn Basin, Wyoming, showed that the formation there contains representatives of all the Paleocene mammal faunas that had theretofore been described from North America. The faunal zones established by Jepsen in the Big Horn Basin constitute what is perhaps the most useful standard correlation section that has yet been worked out in the continental Paleocene of the Rocky Mountain region. Jepsen stated (128: 496-497):

"The 'Fort Union' of the Bighorn Basin may not be exactly isochronous with the Fort Union of other localities, but it contains genera which are held to be diagnostic of these horizons:

Clark Fork (type locality)	Torrejon
Tiffany-Bear Creek	Puerco

"The Puerco fauna is too limited to permit more than a general correlation with the only other known occurrence, that of the type area in New Mexico."

Concerning the "Puerco sandstone" portion of the Fort Union section, Jepsen stated (pp. 482-483) that fragmentary jaws, maxillae and single teeth, most of which came from within a few inches of the base of the sandstone, included the following forms:

Eucosmodon gratus Jepsen (new sp., described p. 499)
Loxolophus nordicus Jepsen (new sp., described p. 501)
Loxolophus sp.; Eoconodon sp.; Oxyacodon sp.; Conacodon sp.

Jepsen remarked that all except Eucosmodon are typical "Puerco genera, heretofore found only in the limited area of the Puerco zone of New Mexico".

Jepsen's assignment of this "Puerco sandstone" to the Fort Union, rather than the Lance, is somewhat arbitrary. In 1929 Simpson (271: pl.

f.p. 12), while placing the Puerco in the lower Paleocene, correlated it with the Tullock member of the Lance and placed both below the Fort Union of southern Montana. He stated (p. 6), however, that the Tullock is sometimes included in the Fort Union, and (p. 7) that "There is no direct faunal evidence as yet that the Tullock is of Puerco age". In view of these uncertainties, it would seem best to keep the "Puerco equivalent" separate from the Fort Union, because of the wide time-gap indicated by the faunal differences of the typical Puerco and Torrejon formations, and because of the looseness with which "Fort Union" has elsewhere been applied. The following passages and notes indicate the most common usage of "Fort Union" among vertebrate paleontologists, and the uncertainties involved in the use of the term "Puerco age".

In 1892 Wortman headed an American Museum expedition to the Puerco region in the San Juan Basin of New Mexico. Three years later Osborn and Earle published a paper (225: 1-70) in which they summarized the results of Wortman's collecting expedition. In this paper they quoted notes from Wortman's field books, in which he said that the thickness of the "Puerco marls" (sensu lato)

> "'is roughly estimated at 800 to 1,000 feet, and as far as can be observed they lie conformably upon the Laramie. At no place examined by us can fossils be said to be abundant, but on the contrary most of the exposures are entirely barren. For convenience they are divided into Upper and Lower Beds, but ... it is only the extreme upper and lower strata that are productive; the great intermediate part we found to be singularly barren.
>
> "'The lower fossil-bearing strata occur in two layers, the lower-most of which lies within ten or fifteen feet of the base of the formation. This is succeeded after an interval of about thirty feet by a second stratum in which no fossils are found, and this appeared to be by far the richer of the two. Both of these strata are of red clay, and at no place did we find them more than a few feet in thickness.
>
> "'The lower horizon we found exposed in two places, viz.: the head of the Coal Creek or Piña Verta Cañon, and some of the upper tributaries of the Chaco Cañon. It is especially and sharply distinguished by the occurrence of the remains of Polymastodon ...'"

According to Osborn and Earle, Wortman said that, on the other hand, the upper fossil zone, near the top of the "Puerco marls", contains Chirox and Pantolambda, which are not found in the lower beds.

In 1897 Matthew published a careful study of the "Puerco marls" (176: 259-326). He, also, separated the mammalian fauna into two distinct levels, emphasizing the fact that not a single species passed from the lower zone to the upper, and that no genus passed through without modifications of at least sub-generic value. The distinctness of the upper and lower faunas led to the proposal of the names Puerco and Torrejon for the two zones. The notes of Gary Calkins (in Matthew S.356: 852), secretary of the biology section of the New York Academy of Sciences, for the Nov. 8, 1897 meeting, contain the following passage:

FORT UNION FORMATION - Paleontology, Age and Correlation

"A review of the Puerco fauna, based on Dr. Wortman's geological observations in the field and the records kept by the American Museum Collecting parties, shows that the Upper and Lower Puerco beds do not contain a species in common, and only three or four genera pass through. The two faunas are entirely distinct. Dr. Wortman proposes to call the upper beds the Torrejon formation, retaining the name Puerco for the lower beds."

In 1914 Sinclair and Granger (278) distinguished two faunal levels within the Puerco [sensu stricto]. the lower of which is characterized by Ectoconus ditrigonus, and the upper by Oxyclaenus cuspidatus and Polymastodon taöensis. Two faunal levels were also distinguished within the Torrejon. Sinclair and Granger found the lower Torrejon level to be characterized by Haploconus lineatus, Miocclaenus turgidus and Deltatherium fundaminis, while the upper level contained Tetraclaenodon puercensis, Claenodon ferox and Pantolambda cavirictus.

Matthew, in 1921, published a short paper on the question of the position of the boundary between the Cretaceous and Tertiary systems. The fact that "Fort Union" did not, in his opinion, include a Puerco equivalent, is illustrated in the following paragraph (S.353: 28):

"The Puerco 'Lower Paleocene' may be as old as the Lance or older, although usually regarded as later. The Torrejon and Fort Union faunas, Upper Paleocene, are not much later than the Lance, and the phyletic evolution indicates that they are considerably later than the Puerco."

In another paper, published a few months later, Matthew said (S.352: 218) that

"In the San Juan Basin, New Mexico, the Puerco formation overlies (unconformably) the Ojo Alamo = Judith River. It contains a large mammal fauna which is wholly unknown elsewhere. Multitiberculates form a considerable element but the major part is archaic placentals. There are no dinosaurs; but the crocodiles, rhynchocephalians and turtles are of the same groups as those of the Judith and Lance, and not perceptibly more advanced.

* * *

"The Torrejon overlies the Puerco conformably, and contains the same and some additional families of archaic mammals, both multituberculates and placentals. Some of the Puerco phyla can be followed through, apparently as direct descendants, and in these there is evidence of considerable evolutionary change, representing a considerable lapse of time.

* * *

"Close above the Lance and Hell Creek lie the Fort Union beds, devoid of dinosaurs, but not separated by any stratigraphic break, and containing a flora very closely allied to that of the Lance and to the upper Paleocene floras of Western Europe. A considerable mammal fauna has also been found in the Fort Union, correlated, as above noted, with the better known Torrejon fauna, or perhaps intermediate between this and the Cernaysian, in any event Upper Paleocene.

* * *

FORT UNION FORMATION - Paleontology, Age and Correlation

"The Torrejon and Fort Union are Upper Paleocene[1], correlated by the paleobotanists with the lower Thanetian of Europe (Gelinden and Sezanne).

"The Puerco, Lower Paleocene, is post-Senonian but may be as old as the Lance or older. The fauna shows it to be considerably earlier than the Torrejon-Fort Union, and the near relations in stratigraphy and flora between Lance and Fort Union are strongly against intercalating between them the very wide time gap which is involved by placing the Puerco as later than the Lance. If so, we must conclude that the latest dinosaur faunas were contemporary with the older Paleocene mammalian fauna, and that it is owing to some imperfectly known differences in facies that they are not found associated. Some indirect evidence in support of this view is afforded by the Paskapoo, in which Lance mammals and Paleocene placentals are found associated."

In 1929 Osborn (224: 60, 63) stated his opinion that

"As the mammals distributed through 4,000 feet of the northern part of the Fort Union deposits correspond chiefly with those of the Torrejon, it appears possible that the underlying Puerco fauna may belong in part in upper Lance time.

* * *

"On comparing the life of the Puerco with that of the Lance we find a mammalian fauna that indicates no very wide gap in time -- a fauna that is somewhat more ancient than the Torrejon and known Fort Union, also more ancient than the Cernaysian and upper Thanetian of France. It is therefore probable that the Puerco corresponds with the lower Thanetian of France, but its life has no known equivalent either in Europe or in this country."

It appears, then, that Jepsen's assignment of the "Puerco sandstone" of the Big Horn Basin to the Fort Union formation is at variance with a somewhat different usage of Fort Union, widely accepted among vertebrate paleontologists. Jepsen stated, however, that he made this assignment without attempting to evaluate the evidence of those who would question his procedure.

Jepsen's Torrejon equivalent in the Big Horn Basin is, he said (128: 486-487), characterized by the presence of the mammals:

Ptilodus sp.	Claenodon sp.
Palaeosinopa sp.	Tetraclaenodon sp.
Chriacus sp.	Plesiolestes problematicus Jepsen (gen. et sp. nov.; described p. 505)
Tricentes sp.	

Jepsen commented that this "appears to be a Torrejon assemblage, in which Claenodon, Tetraclaenodon, Chriacus and Ptilodus are the commonest elements".

---

[1]Eight years later (1929) Simpson (271: table f.p. 12) assigned the Fort Union (including Sentinel Butte shale) to the middle and upper Paleocene, and the Torrejon to the middle Paleocene only.

FORT UNION FORMATION - Paleontology, Age and Correlation

Osborn had previously stated (224: 64) that the mammals of the New Mexico Torrejon "show very close affinities to the Fort Union mammals of Montana and some affinity to the Cernaysian forms discovered in the conglomerat de Cernay, near Rheims, France", and that the upper boundary of the Torrejon is marked by the presence of Tetraclaenodon (ancestor of Phenacodus) and of two amblypods, Periptychus rhabdodon and Pantolambda.

The third faunal zone established in the Big Horn Basin Paleocene section by Jepsen, was called by him the "Princeton Quarry level", or "Tiffany-Bear Creek faunal equivalent". He did not give the stratigraphic distance of this zone above the "Torrejon sandstone". He stated (128: 474-475) that the exposures are poor below the Clark Fork horizon, but,

"Farther northeast, however, lower beds are well exposed in limited badlands, and here was discovered a layer which produced a microfauna abundantly along a few yards of exposure ...

"Quarrying revealed, among other material, specimens referable to the genera Carpolestes, Leptacodon and Ectypodus, which show the level to be contemporary in part with the Bear Creek facies of Montana and the Tiffany of Colorado, both Upper Paleocene in age. In the absence of any local geographic name which would be apropos and unconfusing, the excavation will be called 'Princeton Quarry'."

On subsequent pages Jepsen remarked (pp. indicated):

"Although no pronounced stratigraphic break was observed above the Torrejon sandstone, there appears to be a rather sudden vertebrate faunal change near the middle of T. 57 N., R. 100 W., ... Princeton Quarry level.

* * *

"The bones, dissociated and somewhat broken and water-worn, are not confined to a layer, but are dispersed through a vertical thickness of about two feet. Most of them, as well as the teeth, are now black." (p. 491)

* * *

"If the 'Princeton Quarry' level genus Phenacodaptes, herein described, proves to belong to the Artiodactyla, then the appearance of this order antedates the beginning of the Eocene epoch." (p. 494)

Jepsen listed (pp. 490-491) the following mammals from the Princeton Quarry level:

Microcosmodon conus Jepsen (gen. et sp. nov.; described p. 508)
Ectypodus sp.; Parectypodus sp.; Ptilodus sp.
Diacodon minutus Jepsen (new sp.; described p. 511)
Leptacodon packi Jepsen (new sp.; described p. 510)
Litolestes ignotus Jepsen (gen. et sp. nov.; described p. 513)
Plesiadapis fodinatus Jepsen (new sp.; described p. 516)
Phenacolemur pagei Jepsen (new sp.; described p. 514)
Phenacodus sp.; Ectocion sp.
Phenacodaptes sabulosus Jepsen (gen. et sp. nov.; described p. 517)
Carpolestes dubius Jepsen (new sp.; described p. 520)

FORT UNION FORMATION - Paleontology, Age and Correlation

The fourth faunal zone distinguished by Jepsen is the Clark Fork horizon. This zone had been previously named by parties from the American Museum, and, since it has figured largely in the literature and is sometimes considered lower Eocene, rather than Paleocene in age, it will be discussed separately from the Fort Union.

In 1921, Schuchert, in a short paper (245: 45-47) on the age of the Lance formation, proposed, as a compromise solution of the controversy over the position of the boundary between the Cretaceous and Tertiary systems, that both the Lance and Fort Union be assigned to the Mesozoic era. Much of his evidence was based on Stanton's study (S.345: 1-64) of the marine fauna of the Cannonball member of the Lance. Of the 71 forms of invertebrates in the Cannonball, Schuchert said (p. 45), "but a single bivalve passes upward into the Fort Union fresh-water beds (Corbula mactriformis), while 24 forms occur below in the marine Fox Hills or older Cretaceous formations". He stated, moreover, that there are 41 forms in the fauna that are not found in older formations of the same region, but the fauna "is not distinctively Cenozoic, but consists of types that are elsewhere found in the Cretaceous." Schuchert concluded his paper with the statement (p. 47) that

"the evidence relating to the field relations and stratigraphy, the orogeny and paleogeography, and the invertebrate and vertebrate fossils of the Montana series and the Fox Hills and Lance formations is now well enough in hand to conclude that all are unmistakeably of Mesozoic time. Furthermore, as the Lance and Fort Union are continuous formations, have wholly archaic mammal faunas, and are broken by a period of orogeny and lack of deposition from the succeeding Eocene deposits with their wholly different and modernized mammal faunas, the line separating the Mesozoic from the Cenozoic apparently lies between the Fort Union and the Wasatch, and not between the Fox Hills and the Lance."

Matthew (S.353: 29) commented on Schuchert's suggestion:

"It appears to me that the compromise indicated by Schuchert has the best elements for universal acceptance. It is in accord with the historic and universal European usage, including the Thanetian in the Tertiary, but none of the chalk succession. It conforms to the insistence of the paleobotanists that the Lance and Fort Union should be kept together. It gives a satisfactory practical base for the stratigrapher in the widespread and characteristic Wasatch formations. It places all the dinosaur formations and the bulk of the 'Paleocene' faunas in the Cretaceous where the former certainly and the latter in my opinion properly belong; but the uppermost Paleocene faunas are placed in the Tertiary. The replacement of the Cretaceous by the Tertiary vertebrate fauna would thus be a little later, of the Upper Cretaceous by the Tertiary flora a little earlier than the line agreed upon."

In another paper, published a few months later Matthew said (S.352: 225), after reviewing the paleontologic evidence:

FORT UNION FORMATION - Paleontology, Age and Correlation

"It appears that the base of the true Eocene is the proper dividing line on both theoretical and practical grounds between Cretaceous and Tertiary; that the Paleocene and the latest dinosaur faunas are best regarded as the uppermost Cretaceous. They might be referred to a distinct post-Cretaceous system as advocated by Cope, if the evidence of a widespread stratigraphic break between them and the Judith be regarded as sufficient. But the vertebrate fauna lends no support to the view that there was a distinct post-Cretaceous period. In any event, they are not true Tertiary, and to call them Eocene is to confuse two widely different faunae, one of Mesozoic and the other of Cenozoic type.

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PALEOCENE LEBO SHALE

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; member of the Fort Union group or formation. The type locality is along the course of Lebo Creek on the northern flank of the Crazy Mountains, Montana.

TYPE DESIGNATION. -- In 1910 Stone and Calvert (293: pp. indicated) in the third of their series of papers on the "Livingston formation" of Montana, named and defined the Lebo shale:

" ... there are along the northern flank of the Crazy Mountains two groups of strata of decided Livingston aspect. The older of these occurs between the Bearpaw shale and the Lance formation, and the second, which was described by Stone [290: 82; in 1909] as the Livingston formation, lies between the Lance and Fort Union. The name Lennep sandstone is here applied for the first time to the beds at the base of the Lance formation. ... The younger andesitic beds belong to the Fort Union formation and to them the name Lebo andesitic member is given. Lebo is the name of a creek in whose upper course these andesitic beds are exposed. The Lebo member is composed of 450-2,000 feet of dark-colored beds lying between the Lance formation and the massive gray sandstone of the Fort Union formation. ... They are composed in part of volcanic material." (pp. 746-747)

* * *

"The upper, dark-colored beds occurring between the Lance and the massive sandstone of the Fort Union of the section in the Musselshell Valley, and described by Stone as the Livingston formation, will be called here the Lebo andesitic member of the Fort Union formation. The Lebo sediments are believed to be correlated stratigraphically with the upper part of the Livingston formation at the type locality ..." (pp. 752-753)

SYNONYMY. -- "Livingston" of Weed (305: 10, 21-35) (307: 201-211) included the Lebo shale.
"Livingston" of Stone (290: 80, 81-82) included the Lebo shale.

LEBO SHALE MEMBER - Specific and General Information

SYNONYMY (cont'd)

"Livingston" of Eldridge (69: 25) probably = mostly Fort Union (undifferentiated).

*De Smet formation of Darton (56: 8-9, 16) (57: 59-67), and of Knowlton (138: 210), in the region east of the Big Horn Mountains, included the Lebo shale.

Taff's "lower member" (295: 126-132) of Darton's *De Smet included the Lebo shale.

"Fort Union" and *De Smet of Gale and Wegemann (81: 144-145) included the Lebo shale.

Undifferentiated Fort Union of various writers, in areas where the Lebo shale is now distinguished, included Lebo shale.

"Fort Union" of Wegemann in the Powder River Basin (309: 50) (310: 446-447) (311: 269-270), 1911-13, is probably a development of the Lebo shale, plus the Tongue River member, and, in some regions, the Sentinel Butte shale also.

DISTRIBUTION. -- North flank of the Crazy Mountains, Montana; Rosebud and Big Horn Counties, Montana; eastern Montana; parts of the Dakotas; northeast and east-central Wyoming.

IMPORTANT REFERENCES. -- Baker (2: 23-29); Dobbin and Barnett (60: 9); Rogers and Lee (236: 35-40); Stone (290: 80, 81-82); Stone and Calvert (291: 551-557), (292: 652-669), (293: 741-764); Simpson (271: 4-8); Thom and Dobbin (296: 488-494).

GENERAL INFORMATION

Areal distribution and lithology; stratigraphic relations. -- In 1924 Thom and Dobbin (296: 488-489) tabulated the thicknesses of exposures of the Lebo shale in various regions. The tabulation was as follows:

Tullock Creek field, Montana	135-170	feet
Crow Reservation, Montana	400-2100	"
NE of Crazy Mountains, Montana	400-2100	"
Sheridan-Buffalo, Wyoming	800-1000	"
Little Powder River-Gillette area, Wyo. ...	100-200	"
Pumpkin Butte area, Wyoming	2000	"

Thom and Dobbin (p. 494) found that the Lebo shale is

"well developed west of Miles City and south of the Yellowstone, growing thicker and more evenly bedded as it is traced southward into the upper part of the lower member of the Sheridan field, eventually developing into the Great Pine Ridge sandstone fan of the Pumpkin Butte area of Wyoming, which Wegemann calls Fort Union ..."

Rogers and Lee (236: 35, 36) described the Lebo member in the Tullock Creek coal field region, Big Horn and Rosebud counties, Montana in 1923 as follows:

LEBO SHALE MEMBER - General Information

"The Lebo shale member ... consists of dark-gray to olive-gray and drab shale interbedded with a few beds of gray or yellow sandstone. ... there are two horizons at which coal occurs in beds over 18 inches in thickness. Some of the sandstone beds are fairly resistant ..., but the member as a whole is soft and suffers rapid erosion. Some of the beds carry brown ironstone nodules in great abundance ... The member as a whole has a dark and somber aspect

* * *

"The top of the Lebo apparently is not marked by any very conspicuous stratum though the character of the material changes sharply within a vertical distance of 25 to 30 feet. In some districts the color contrast and the character of the topography are the chief guides. In most localities, however, the lowest stratum of the upper division of the Fort Union is a thick massive sandstone, and the base of this sandstone is considered the top of the Lebo.

* * *

"The Lebo is made up very largely of shale and fine sandy shale with generally lenticular beds of fine arkosic sandstone. Except for the numerous irregular and discontinuous layers of hard ferruginous concretions ... and for a few thin sandstones, these beds are soft and practically incoherent."

Dobbin and Barnett (60: 9) stated in 1929 that in Campbell County, Wyoming, in the Gillette field

"the Lebo shale member consists of 250 to 400 feet of soft gray to black clay and shale with numerous but non-resistant beds of ferruginous concretions and of impure coal and carbonaceous shale. This member crops out in a belt of relatively low relief at the base of the escarpment formed by the Tongue River member, and along the main drainage lines it has been dissected into almost impassable badlands."

Baker stated (2: 24) in 1928:

"As originally defined the Lebo member consists predominately of yellow coal-bearing rocks. In passing northward from Sheridan [Wyoming], however, the lithologic change from somber-colored to yellow beds takes place at progressively lower horizons, so that the Tongue River member as mapped near Ashland, Montana, includes from 800 to 1,000 feet of beds corresponding to beds that lie below the Carney coal and hence are included in the Lebo of the Sheridan field."

Paleontology, age and correlation. -- In the paper in which they named the Lebo shale member in 1910, Stone and Calvert (293: 756) assigned the Lebo shale to "basal Tertiary" time. In 1923 Rogers and Lee (236: 39) made a somewhat more definite age determination:

"The age of the Lebo in the Crazy Mountains was determined as Fort Union by the presence of Torrejon mammal remains near its top, but in that locality the member is some 2,000 feet thick and no diagnostic fossils were found in the lower portion; and in other localities only leaves or

shells that are of little value in distinguishing between the Fort Union and Lance have been collected."

In 1924 Thom and Dobbin (296) correlated the Lebo shale of eastern Montana and the Dakotas with the lower part of the Fort Union of the Big Horn Basin. They also stated (p. 494) that "the upper marine beds of the Cannonball are of the same geologic age as type Lebo which on Fish Creek, Montana, contains a considerable Torrejon mammalian fauna". Thom and Dobbin considered the Lebo shale to be also in part equivalent to the Ludlow member of the Lance formation.

Simpson, in his paper of 1929 on the Fort Union of Montana, listed the positively identified genera of the fauna of the Fish Creek horizon in Sweetgrass County, Montana. His tabulation (271: 4-5) and analysis of the fauna was as follows:

Ptilodus	Genus elsewhere confined to the Torrejon, so far as surely known. Comparable and in some cases apparently identical species.
Picrodus Coriphagus	Affinities very doubtful. No value in correlation.
Megopterna Myrmecoboides	Leptictidae, Cretaceous to Oligocene. An isolated genus of no precise bearing on correlation.
Pronothodectes	More primitive than its ally Plesiadapis in the Upper Paleocene.
Paromomys Palaechthon	No closely comparable forms elsewhere known in the Paleocene. More primitive than their Wasatch allies.
Elphidotarsius	Probably allied to, but if so more primitive than, Carpodaptes of the Tiffany and Carpolestes from Bear Creek.
Neoclaenodon	Genus elsewhere confined to the Torrejon, so far as known. Species closely comparable.
?Psittacotherium	Identification not wholly certain, but species apparently close to one from Torrejon.
Mioclaenus	Confined elsewhere to Puerco and Torrejon. Ft. Union includes one indistinguishable from M. acolytus, a Torrejon species.
Anisonchus	Elsewhere confined to Puerco and Torrejon. Species doubtful.
Tetraclaenodon	Elsewhere confined to Torrejon. Species comparable.
Pantolambda	Elsewhere confined to Torrejon. Species comparable.

LEBO SHALE MEMBER - Paleontology, Age and Correlation

Simpson's analysis of the Fish Creek fauna convinced him (p. 6) that

"The main Fish Creek fauna is from the Lebo, about 30 to 65 feet below the top of this member at Bear Butte. The top of the Lebo is, therefore, of Torrejon age. About 50 feet above the base of the Lebo were found Claenodon sp. nov. and ?Mioclaenus sp. These are not certainly diagnostic, but also suggest the Torrejon, so that the entire Lebo may provisionally be considered as of that age."

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PALEOCENE TONGUE RIVER MEMBER

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; member of the Fort Union formation or group. The type locality is along the valley of the Tongue River between Carneyville, Wyoming, and Brandenberg, Montana.

TYPE DESIGNATION. -- In 1909 Taff described the geology of the Sheridan coal field of Wyoming. He divided the *De Smet "formation" of Darton[1] into upper and lower members. The "upper" member, in turn, was divided into the Tongue River "coal group", *Intermediate coal group, and Ulm "coal group". Taff's description of the Tongue River "coal group" (295: 128-129) was as follows:

"The rocks from the lower member /of Darton's *De Smet/ upward to the top of the section exposed in the Sheridan district consist of shale, sandstone, and coal, in many beds interstratified. It is estimated that the aggregate thickness of the shale is approximately twice that of the sandstone. The shales range from clay of bluish tints to brown carbonaceous clay and bony coal, on the one hand, and from clay through grades of sandy clay to shaly sandstone, on the other. In weathered surfaces the shale and sandstone ... present various hues of light yellow, brown, and white, except where the burning of the coal has transformed them to hues of red and pink. The sandstones range in color from drab or brown to white ... As a whole the surface coloring is yellow.

"The thickness of the upper member exposed in the Sheridan district is estimated to be not less than 2,200 feet. The rocks are very slightly tilted or lie in a horizontal position, and the edges of the beds are spread over a wide area ...

"With respect to the occurrence of coal, this member may be separated into three divisions. From the base upward, through nearly 800 feet of rock there are at least seven workable beds of coal. These coal beds are exposed principally in the valley of Tongue River, and for convenience of reference and economic discussion they will be termed the Tongue River coal group."

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[1]The *De Smet terrane was discussed on page 26 of the present paper.

TONGUE RIVER MEMBER - Specific Information

RESTRICTIONS. -- In 1924 Thom and Dobbin published a paper (296) on the so-called "Cretaceous-Eocene transition beds" of eastern Montana and the Dakotas. In this paper they re-classified the beds described by Taff and Darton, and stated that the lower part of Taff's lower member belongs to the Lance formation, and the upper part of the lower member belongs to the Lebo shale member of the Fort Union. They also proposed the title, "Tongue River member of the Fort Union", in lieu of the "coal group" terminology of Taff and described the member in greater detail. Thom and Dobbin said (296: 494-495):

"The Tongue River member of the Fort Union consists of yellow or light-colored strata containing massive sandstones and numerous thick coal beds. It is well exposed along Tongue River between Carneyville, Wyoming, and Brandenberg, Montana, and along the Yellowstone between Burns, Montana, and Buford (Fort Union), North Dakota. It is also exposed in the Missouri Valley above Fort Clark, North Dakota. The top of the member as here defined is placed beneath bed K of the Sidney Field [Dawson County, Montana], bed F of the Sentinel Butte field, and the Roland coal bed of the Sheridan field, The base of the member is placed beneath the light-colored, coal-bearing rocks which characteristically form a marked clinker-capped escarpment rising above the lowlands or badlands developed from the somber Lebo shale. The Lebo-Tongue River contact, though clean cut in the average exposure, does not, however, occur at a single plane when traced over great distances, but rises and falls in the geologic column by the intertonguing of the yellow Tongue River and somber Lebo strata. Massive channel sandstones are numerous both in the Tongue River member and at its base ..."

SYNONYMY. -- Prior to the designation of the Lebo shale, the entire Fort Union was customarily described as a single homogeneous unit, and the early synonymy is therefore involved with that of the Fort Union proper (see pp. 66-67). After Stone and Calvert (293: 746-747) named the Lebo shale member of the Fort Union, in 1910, it was customary to refer to beds above this member simply as "upper Fort Union", "upper member of the Fort Union" or "the Fort Union above the Lebo". These usages persisted until 1909, when Taff described the Tongue River member. Tongue River "coal group" of Taff, however, had apparently not been widely accepted as a term of general application until it was more fully described by Thom and Dobbin.

The Tongue River member may be represented in the lower part of the "Wasatch" of Wegemann (312: 23-24) (313: 57-60).

*De Smet formation of Darton (56: 8-9, 16) (57: 59-67) and of Knowlton (138: 210) included the Tongue River member.

"Fort Union" and *De Smet of Gale and Wegemann (81: 144-145) included the Tongue River member.

DISTRIBUTION. -- Northeastern and east-central Wyoming; southern Montana; the Dakotas.

IMPORTANT REFERENCES. -- Baker (2: 23-28); Dobbin and Barnett (60: 9-10); Renick (232: 19-24); Rogers and Lee (236: 35-41); Simpson (271: 6-7, 12); Taff (295: 128-129); Thom and Dobbin (296: 488-489, 494-495).

TONGUE RIVER MEMBER

GENERAL INFORMATION

Distribution and lithology; stratigraphic relations. -- In 1923 Rogers and Lee described an "upper division" of the Fort Union in the Tullock Creek coal field, Rosebud and Big Horn Counties, Montana. They stated (236: 40, 41) that this "division"

"is composed of well-consolidated material consisting of arkosic sandstone, more or less sandy shale, carbonaceous shale, and coal. Many of the beds are calcareous, though no limestone was observed. The color of this part of the Fort Union is normally yellow, but the thick coal beds have burned along the outcrop and baked the overlying strata to a strong birck-red to reddish-brown color, and in the southern part of the field the lower 300 feet is prevailingly red."

* * *

"The yellow beds of the Fort Union are considerably more resistant than those of the Lebo shale member ..."

In his description of the northward extension of the Sheridan coal field into Montana, Baker said (2: 24-25) in 1928:

"The Tongue River member of the Fort Union formation includes most of the sedimentary rocks that crop out in this area. It corresponds closely to the Tongue River coal group as defined by Taff ... Taff included in this coal group about 800 feet of coal-bearing rocks extending from the base of the Carney coal bed to the top of the Roland coal bed. In the Sheridan coal field the base of the member (so selected) corresponds to the plane of lithologic change from somber-colored beds ... below to the lighter-colored buff sandstone and interbedded gray shale above. North of Ashland, in the Tongue River Valley, Montana, the base of the Tongue River member has been placed at the top of the Lebo shale member of the Fort Union formation. ... The classification accepted by the Geological Survey places the top of the member at the top of the Roland coal bed. There is, however, no great lithologic difference between the Tongue River and Wasatch rocks ... in the area here described.

"Continental deposits, such as those of the Tongue River member, vary so much in lithology that the series of beds shown in one columnar section would scarcely be recognizable as the same beds in a section measured a short distance away. In these deposits correlation on the basis of lithology is uncertain. At some localities there is a preponderance of shale and at others of sandstone ..."

Dobbin and Barnett (60: 9-10) described the member as developed in the Gillette coal field, northeastern Wyoming in 1927:

"The Tongue River member of the Fort Union formation, which is at least in part equivalent to the sandstone of Great Pine Ridge, in the Sussex area, consists in this field of 250 to 400 feet of bluish-white sandstone, gray sandy shale, and coal beds exposed in the Rochelle Hills escarpment, which is capped by clinkers produced by the burning of the Roland coal bed, the top of which is the top of the Tongue River member. Beds of highly ferruginous sandstone are common features of the Tongue River member in this field ..."

TONGUE RIVER MEMBER - General Information

In 1924 Thom and Dobbin tabulated (296: 488-489) the general distribution and known thicknesses of the Tongue River member. The data given by them is in part as follows:

Tullock Creek field, Montana	675', plus or minus
Crow reservation, Montana	800', plus
Sheridan--Buffalo, Wyoming	800', plus or minus
NE of Crazy Mountains, Montana	Not differentiated
Little Powder River-Gillette area, Wyo. .	500' - 800'
Pumpkin Butte area, Wyoming	Unconformable overlap

Baker stated (2: 24) in 1928:

"As originally defined the Lebo member consists predominantly of somber-colored shale and sandstone, and the Tongue River member of yellow coal-bearing rocks. In passing northward from Sheridan, however, the lithologic change from somber-colored to yellow beds takes place at progressively lower horizons, so that the Tongue River member as mapped near Ashland, Montana, includes from 800 to 1,000 feet of beds corresponding to beds that lie below the Carney coal and hence are included in the Lebo of the Sheridan field."

Paleontology, age and correlation. -- Thom and Dobbin considered (296: 494-495) that the Tongue River member is equivalent to the upper part of the Fort Union (undifferentiated) of the Big Horn Basin of Wyoming. They stated also that a few teeth and bones "of mammals resembling those of the Lebo have been obtained from the Tongue River member in Montana and Dakota areas, and it contains the brackish-water fossil *Corbula mactriformis* in North Dakota".

In 1929 Simpson (271: 6-7) summarized his conclusions as to the age and correlation of the Tongue River member in the following paragraphs:

"The Tongue River member has furnished very few fossils. On Fish Creek, about 3000 feet above the 'Fish Creek Fauna' or 'Gidley-Silberling Quarries' level, and presumably in the Tongue River, Gidley records *Claenodon ferox* and Pantolambda ?cavirictus, both Torrejon species.

"Thom and Dobbin state that the vertebrate remains redorded by Lloyd and Hares /151: 538-539/ from the Fort Union in Billings County, North Dakota, also came from the Tongue River. Gidley identified these as *Tetraclaenodon* sp. and *Pantolambda* cavirictus. The remains are poor, but as identified they indicate Torrejon age."

Simpson conceded, however, (p. 7), that evidence of the Torrejon age of the Tongue River is inconclusive. Simpson's correlation chart (see p. 29, this paper) shows the Tongue River equivalent to the uppermost part of the Torrejon.

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PALEOCENE -- EOCENE UNITS:

THE "WASATCH" FORMATIONS OF THE ROCKY MOUNTAIN REGION

UPPER PALEOCENE(?) SENTINEL BUTTE SHALE

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; probably the upper member of the Fort Union group, marking the summit of the Paleocene series. Some writers consider it the basal member of the so-called Wasatch. The type locality is at Sentinel Butte, in the Sentinel Butte lignite field of west-central North Dakota and the adjacent part of Montana.

TYPE DESIGNATION. -- The Sentinel Butte shale was named and described by Leonard and Smith (S.358: 20-21, 30-33) in 1909. The *Intermediate coal group, which is probably at approximately the same stratigraphic horizon, was named and described by Taff in the same year, from exposures in the Tongue River Valley of Sheridan County, Wyoming. Taff's paper is in the same bulletin as that of Leonard and Smith (U.S. Geol. Survey Bull. 341, pt. 2) and precedes Leonard and Smith's paper. Taff's nomenclature, however, did not comply with the accepted custom of naming stratigraphic units after geographic localities. The adoption of Leonard and Smith's name has therefore been favored. The latter two writers referred to the Sentinel Butte shale variously as "upper member of the Fort Union", "Sentinel Butte group", and "Sentinel Butte group of lignite beds". A detailed section was given (pp. 20-21) and the name was formally applied (pp. 30-31) in the following passage:

"The Sentinel Butte group of lignite beds is so named on account of its occurrence in Sentinel Butte. ... hundreds of clinker-capped buttes at the horizon of the two lower members of the group, dotting almost the entire eastern half of the area surveyed, bear evidence of the fact that these members covered at some earlier time a much larger area than at present ...

"The lowest [coal] member of the group ... has its greatest development in the eastern part of the field, where it is from 10 to 16 feet thick. It is found at the contact of the buff sandstone and gray shale with the somber-colored member above. This contact is well marked on account of the abrupt change in the color and character of the material ...

"The second [coal] member of the group ... from 25 to 50 feet above the lowest member, shows to better advantage in the south-central part of the surveyed area, in the base of the higher buttes ... Both the lower members become thin and disappear toward the northwest. These beds have been so generally burned that few exposures showing their whole thickness can be found. Other members ranging from 100 to 250 feet above the base of the group are ... limited in distribution in the region examined ...

"A few exposures of parts of the two lower members of the Sentinel Butte group were noted in the southeast corner of the field, where small patches of somber-colored beds are underlain by them. The coal is about 350 feet above the level of Little Missouri River at the southern boundary of the field."

SENTINEL BUTTE SHALE - Specific and General Information

RESTRICTIONS. -- None. The name, Sentinel Butte, came into general use and application, and the formation was called Sentinel Butte shale, rather than "lignite beds".

SYNONYMY. -- "Wasatch" of Wegemann (312: 23-24), (313: 57-60), and of Wegemann, Howell and Dobbin (314: 4), included the Sentinel Butte shale.
*De Smet formation of Darton (56: 8-9) (57: 59-67), and of Gale and Wegemann (81: 143-146), included the Sentinel Butte shale.
*Intermediate coal group of Taff (295: 130-131) = Sentinel Butte shale.

DISTRIBUTION. -- Southern and eastern Montana; west part of the Dakotas; northeast and east-central Wyoming.

IMPORTANT REFERENCES. -- Baker (2: 23-24); Darton (57: 59-67); Gale and Wegemann (81: 143-146); Leonard and Smith (S.358: 20-33); Simpson (271: 1-12); Taff (295: 127-131); Thom and Dobbin (296: 481-506); Wegemann (312: 23-24), (313: 57-60).

GENERAL INFORMATION

Distribution and lithology; stratigraphic relations. -- In 1909 Taff proposed the name, *Intermediate coal group, for the equivalent of the Sentinel Butte shale in the Tongue River Valley in Sheridan County, Wyoming. He said (295: 130) that

"From the Roland coal, which marks the top of the Tongue River coal group, upward 700 feet the rocks are composed chiefly of shale. Here and there are thin strata of white to brown sandstone. Bands of carbonaceous shale are of common occurrence, and there are several beds of coal that are evidently limited to small areas. Continuing upward there are 450 to 470 feet of shale and sandstone in alternating strata, each kind of rock being nearly equal to the other in aggregate thickness. A number of carbonaceous shale beds 10 to 20 feet thick were noted, with a few beds of coal or workable thickness though of small areal extent."

Wegemann (311: 269), in 1913, recognized Taff's division, *Intermediate coal group, applied the term to strata in the Barber coal field, Johnson County, northeastern Wyoming, and assigned it to the Fort Union.

Thom and Dobbin (296: 495-496) offered the following observations on the Sentinel Butte shale in 1924:

"The Sentinel Butte shale, classed as Fort Union(?) by the U.S. Geol. Survey, though regarded as Wasatch by Hares and the writers, is typically developed at Sentinel Butte, North Dakota, and consists of dark clay shales resembling those of the Hell Creek and Lebo ... to some extent in appearance.

"The Sentinel Butte shale is essentially equivalent to the Intermediate coal group of northern Wyoming, plus the Roland coal bed, and to the lower part of the Kingsbury conglomerate, which overlaps on the granite

core of the Big Horn Mountains. This unconformable overlap Wegemann regards as marking the base of the Wasatch.

"In southern Montana and in the Powder River Basin of Wyoming the Sentinel Butte shale (Intermediate coal group) is conformably overlain by yellow coal-bearing strata belonging to the Ulm coal group, which is correlated with the Wasatch beds of the Pumpkin Buttes, Wyoming.

"It is believed by the writers that strata representative of both Sentinel Butte shale and Ulm coal group may be included in the Fort Union as mapped in the Red Lodge coal field (Montana) ...

" ... the Kingsbury conglomerate, as suggested by Wegemann apparently marks the base of the Wasatch, and represents the coarse phase of the Sentinel Butte shale where it overlaps on the Bighorn fold."

Thom and Dobbin (pp. 488-489) also offered the following tabulation of the distribution and thickness of the Sentinel Butte shale:

Tullock Creek field, Montana ...	Not present or not differentiated
Crow Reservation, Montana	500' plus
Sheridan and Buffalo, Wyo.	1100' to 2500'
Little Powder River-Gillette area, Wyoming	900' plus
Pumpkin Butte area, Wyoming	700'

Baker, who described the northward extension of the Sheridan coal field into Montana, noted (2: 28) in 1928:

"The contact of the Fort Union and Wasatch formations has been traced northward from Wyoming by Thom and Dobbin, who now regard the top of the Roland coal bed as marking the Wasatch-Fort Union contact. Within the area here described there is, however, locally no marked difference between the beds below and above the Roland coal bed, although variegated beds such as are characteristic of the Wasatch are reported to overlie the Roland bed near Pumpkin Buttes, Wyoming."

Paleontology, age and correlation. -- Thom and Dobbin considered (296: 498) that the Intermediate coal group (= Sentinel Butte shale) "and interfingered conglomerate" (Kingsbury) are correlative with the Clark Fork horizon of the Big Horn Basin. In 1930 Jepsen (128: 493-499), for paleontologic reasons, assigned the Clark Fork to the Fort Union, and considered that the Clark Fork horizon marked the summit of the Paleocene. In 1929 Simpson (271: 8) had also tentatively correlated the Sentinel Butte shale with the Clark Fork. He regarded the Clark Fork as transitional between the Torrejon horizon and "true Wasatch". Simpson believed that the fauna of the Bear Creek facies of Montana, which he described in three papers (269) (S.357) (271), came from the Sentinel Butte shale horizon. He said (271: 7) that

"The Sentinel Butte shale has no previously recorded mammal fauna, although the single tooth from the Fish Creek region named Tetonius rex by Gidley may have come from this member. It was found about 4,000 feet above the 'Silberling - Gidley Quarry' level, which is said to be in the Lebo. The specimen is quite insufficient to establish the age of the

horizon, but it is of Upper Paleocene or even Lower Eocene aspect, and, for the very little that this evidence is worth, agrees with Thom and Dobbin's correlation of this higher 'Fort Union' as about equivalent to the Clark Fork or lower Wasatch."

Simpson's reasoning (271: 7-8) concerning the stratigraphic position and time equivalence of the Sentinel Butte shale was as follows:

"To return once more to the bearing of the Bear Creek fauna on the general Fort Union problem, its position in the Tullock-Ulm Coal sequence and its stratigraphic horizon relative to the Silberling and Gidley Quarries (Fish Creek fauna) is not certain.

"Woodruff [333: 94-107] has discussed the Red Lodge Coal Field, in which Bear Creek is located. He states that the Fort Union is here 8500 feet thick--obviously including some beds not admitted as Fort Union by Thom and Dobbin. Coal Bed No. 3, just above which the mammals occur, would be, by his figures, about 6175 feet above the base and about 2325 feet below the top of the formation. Brown (personal communication) states, on the other hand, that it is about 1500 feet above the base. The datum planes of the two observers are obviously entirely different.

"Thom and Dobbin [296], taking the data given by Woodruff supplemented by unpublished work by Hares, questionably assign 700 feet of Woodruff's section to the Colgate sandstone and Hell Creek, 4300 feet to the Tullock and Lebo, no definite thickness to the Tongue River, and 3200 feet to the Sentinel Butte and Ulm Coal. This would place the mammal horizon probably in the Sentinel Butte. If this proves to be its correct position, the fauna furnishes strong and very important confirmation of the approximate contemporaneity of the Sentinel Butte and the Clark Fork.

"If this distinctly Paleocene type of fauna does belong in the Sentinel Butte, it would be much more satisfactory from a faunal point of view to retain this member in the Fort Union Formation or Group, rather than to follow Thom and Dobbin in placing it in the Wasatch. Equivalence with the Clark Fork fauna does not necessitate inclusion in the Wasatch. The known Clark Fork fauna may be slightly later than the Bear Creek fauna, ... but it is still essentially of final Paleocene type."

The following list of fossils, with an interpretation of their significance, was given by Simpson (271: 1-2):

Bear Creek Mammals	Closest Allies
Litotherium complicatum Simpson	?Ptilodontidae -- Cretaceous to lower Eocene
Planetetherium mirabile Simpson	Plagiomene -- lower Eocene (Greybull)
Protentomodon ursirivalis Simpson . . .	Nyctitheriidae -- lower and middle Eocene
?Pentacodon cf. inversus Cope	Pantolestidae -- middle Paleocene to middle Eocene

SENTINEL BUTTE SHALE - Paleontology, Age and Correlation

Leptacodon (Leipsanolestes siegfriedti (Simpson)	Leptacodon -- upper Paleocene (Tiffany)
?Plesiadapis sp.	?Plesiadapis -- upper Paleocene (Tiffany, Clark Fork)
Labidolemur kayi Simpson	Labidolemur -- upper Paleocene (Tiffany)
Carpolestes nigridens Simpson . . . . . C. acquilae Simpson (new species)	Carpodaptes -- upper Paleocene (Tiffany)
?Psittacotherium lobdelli Simpson . . (new species)	Psittacotherium -- middle Paleocene (Torrejon) Calamodon -- lower Eocene
Thryptacodon pseudarctos Simpson . .	Thryptacodon -- upper Paleocene (Tiffany, Clark Fork) and lower Eocene (Sand Coulee, Greybull)
Dissacus cf. navajovius Cope	Dissacus -- middle Paleocene to lower Eocene
Phenacodus cf. primaevus hemiconus. . (Cope)	Phenacodus -- upper Paleocene and lower Eocene

Simpson commented (p. 3):

"The cumulative evidence now seems to indicate beyond reasonable doubt that this /Paleocene/ is the true age of the fauna. It is approximately equivalent to the Tiffany of Colorado, the Clark Fork of Wyoming, the 'Erickson's Landing' Paskapoo of Alberta, and the Cernaysian of France."

In 1935 Henderson listed (119: 41) the following invertebrates, which he said had been described by Russell from the Bear Creek horizon of Carbon and Sweetwater counties, Montana: Goniobasis ursarivulensis Russell, Elliptio silberlingi Russell, Medionidus /Unio?/ senectus declivis Russell. Henderson was apparently in error in his reference to "Sweetwater" County in Montana. Carbon County is adjoined on the northwest by Sweetgrass Co.

The following invertebrate fossils were listed by Wegemann in 1911 (311: 270) from the Fort Union(?) of the Barber coal field, Wyoming:

Unio priscus Meek and Hayden	Viviparus leai M. & H.
Planorbis sp.; Viviparus sp.	Goniobasis sp. related to
Physa sp.; Sphaerium sp.	G. tenera (Hall)

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UPPER PALEOCENE(?) KINGSBURY CONGLOMERATE

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Probably a coarse facies of the Sentinel Butte shale. It may also represent part of the Tongue River member of the Fort Union. The type locality is at Kingsbury Ridge southwest of Buffalo, Johnson Co., Wyoming, on the east flank of the Big Horn Mountains.

TYPE DESIGNATION. -- Darton (57: 60-62) named and described the typical Kingsbury conglomerate in 1906:

"The conglomerate deposits overlying the Piney formation appear on the south side of Beaver Creek, developing either out of the lower portion of the top beds of the Piney formation or of the lower beds of the De Smet formation. They thicken rapidly, and from Johnson Creek to Buffalo have a thickness of several thousand feet. Toward Crazy Woman Creek they rapidly thin and disappear or give place to fine sediments. The conglomerate attains its greatest prominence in the high ridge lying east of North Fork of Rock Creek, where for several miles there are conspicuous ledges over a hundred feet high. The materials are pebbles and bowlders, mostly of Carboniferous limestones and darker colored chert and the very distinctive flat-pebble conglomerate of the Deadwood formation ... Granite pebbles occur in small numbers to the north, but they are more abundant in the exposures along Piney Creek, and none were observed near Clear Creek and southward. Many of the pebbles are in a disintegrating condition and some show evidences of more or less shearing. The conglomerate occurs mostly in layers 6 to 12 feet thick, interbedded with dark-greenish to light-yellow clays. Layers, of coarse, gravelly sandstones also occur, which usually grade into the conglomerate ... One of its most striking exposures is on the north bank of North Piney Creek ...

* * *

"On the north side of Rock Creek Valley the conglomerate trends southeast, away from the limestone front ridge, so that the underlying basal series appears.

* * *

"The name Kingsbury, here used for the first time[1], is from Kingsbury Ridge southwest of Buffalo."

DISTRIBUTION. -- (See also Sentinel Butte shale: General Information, pp. 96-99). In addition to the type exposures the conglomerate has been identified in the Powder River Basin, and Buffalo coal field, Wyoming, in southern Montana, and in the west part of the Dakotas.

IMPORTANT REFERENCES. -- Darton (56: 8), (57: 60-62), (58: 300-303); Gale

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[1]In another U.S. Geological Survey publication of the same year (Geol. Atlas, Bald Mountain - Dayton folio, No. 141) Darton (56: 8) described the Kingsbury conglomerate, stating that in that paper the name "is proposed". As this description is less complete than the one quoted above, the latter has been chosen as the type designation.

and Wegemann (81: 143-145); Knowlton (138: 210); Thom and Dobbin (296: 481-506); Wegemann (312: 23-24), (313: 57-60).

GENERAL INFORMATION

Areal distribution and lithology. -- Darton (57: 61) noted that on the north side of Rock Creek Valley

"The bowlders vary greatly in size and occur in great disorder ... At the west end of this ridge the conglomerate abuts against a low mound of Deadwood shales and limestone overlain by Bighorn limestone mostly in broken ledges, apparently part of the old shore from which the fragmental materials were derived. The thickness is 2,000 feet or more."

* * *

"The conglomerate series in this area [ridge south of Clear Creek] includes numerous layers of sand, yellow clay, and conglomerate. The latter is in part hard and in part apparently a loose deposit of pebbles. In places it merges into coarse sandstone and this in some layers gives place to clay. The thickness in this vicinity is about 2,500 feet. Fifteen miles south of Buffalo the conglomerate series consists of alternating layers of gray sandstone, green, yellow, red, gray, and black clays, with the conglomerate mostly in layers 3 to 4 feet thick, which stand out in small ridges on the slopes. The dip is 20°. In this region the member is not over 400 feet thick."

In another paper of 1906 (58: 303), on the mineral resources of the Big Horn Mountains, Darton treated the Kingsbury conglomerate as a member of the "Laramie" formation:

"The [Laramie] formation is several thousand feet thick, and on the eastern side of the mountains comprises three members ... The basal member, the Piney formation, consists of 2,000 feet of sandstone and carbonaceous shale ... The medial member is a thick mass of conglomerate of considerable extent, which contains materials from the mountains to the west. It has been designated the Kingsbury conglomerate."

Gale and Wegemann (81: 144), in their paper of 1910 on the Buffalo coal field of Wyoming, described in the Kingsbury conglomerate, material derived from the Cambrian, Ordovician and Mississippian rocks of the adjacent mountains. They considered the conglomerate a shore, delta or alluvial fan deposit. Wegemann (313: 59-60) later remarked that in the type locality at Kingsbury Ridge the conglomerate

"appears to represent a great alluvial fan, its outcrop being some 40 miles in length from north to south and 2 to 5 miles in width from east to west. It was apparently deposited by streams which flowed from the highest part of the Big Horn Mountains and which had, prior to the deposition of the conglomerate, cut deep valleys in the underlying beds."

Stratigraphic and structural relations. -- In 1906 Darton (57: 61) made the observations:

KINGSBURY CONGLOMERATE - Stratigraphic and Structural Relations

"In the vicinity of French, Clear, and Johnson creeks, and again from North Fork of Rock Creek to Moncrief Ridge, the comglomerate extends to the slope of the front range and abuts against the limestone. In other portions of the area it is separated from this ridge by the outcrop zone of the Piney formation. This irregularity in relations is due partly to faulting and partly to overlap. At several points the overlap relations are plainly observed, notably in the ridges 8 miles west and 9 miles southwest of Lake De Smet, where the conglomerate lies across edges of Deadwood, Bighorn, Madison, and Amsden beds and includes pebbles from all these formations. It was observed again at the cross fault 5 miles south of Buffalo, where an old ridge of Madison limestone extends north along an early Laramie fault line and presents knobs surrounded by comglomerate and breccia, mostly of limestone material. South of this locality nearly to Rock Creek the conglomerate lies against the foot of the limestone front range."

Knowlton (138: 210), in 1909, expressed the belief: that

"the unconformity at the base of the Kingsbury is not of wide significance is shown by the fact that it was not detected in a section made at Parkman, only about 25 miles north of the northernmost extension of the Kingsbury, nor has it been found a few miles to the southward of the southern limits of the formation. Along the eastern margin of the Kingsbury it may be observed fingering into the soft shales and sandstones of the De Smet formation, the name given by Darton to the 5,000 feet or more of beds overlying the Piney, and with which sedimentation was apparently continuous; in fact the Kingsbury was regarded by Mr. J.A. Taff, who surveyed this area for coal in 1907, as merely the near-shore phase of the upper member [= Tongue River member, Sentinel Butte shale, and Ulm formation] of the Fort Union."

Gale and Wegemann (81: 144-145), from observations in the Buffalo coal field, reached the conclusion that the Kingsbury conglomerate

"is clearly unconformable with the underlying formations, as its outcrop transgresses obliquely across them and its dip is somewhat discordant with that of the adjacent beds. ... The transition from the Kingsbury conglomerate to the finer sediments overlying it is by no means an abrupt one. ...

"To the north and also to the south the Kingsbury conglomerate member fingers out and disappears and the normal Fort Union ("De Smet") strata succeed the dark shale of the Piney formation [Cretaceous] without sign of break between them."

It has since been found that Darton's *De Smet included more than Fort Union, i.e., Lance formation below, and Ulm formation above (see p. 26).

Wegemann (313: 59, 60) reasoned in 1917:

"We may therefore refer to the rocks of the Great Pine Ridge as the Fort Union of this region, and to the formation overlying it as Wasatch.

KINGSBURY CONGLOMERATE - Stratigraphic and Structural Relations

"That the Wasatch rests unconformably upon the Fort Union would seem to be indicated ... At Kingsbury Ridge ... is a thick conglomerate ... which appears to represent a great alluvial fan ...

* * *

"The conglomerate thus rests unconformably on the rocks below it, transgressing at Kingsbury Ridge strata ranging in age from Tertiary to Carboniferous.

* * *

"Along Dry Fork of Cheyenne River 35 miles south of Pumpkin Buttes and 90 miles southeast of Kingsbury Ridge there is some evidence of an unconformity between the Wasatch and underlying Fort Union beds.

* * *

"A coal bed ... which at the head of the Dry Fork of the Cheyenne rests almost directly on the Fort Union beds has below it in an area 15 miles farther east at least 275 feet of strata that appear to be Wasatch, and it seems probable that an unconformity is here present between the two formations. Inasmuch, however, as the coal beds in the lower part of the Wasatch do not extend for any great distance north and south in the region of the Fort Union outcrop, and as there are, besides the coal beds, no other key rocks that are easily recognizable in the lower part of the Wasatch, it is impossible to prove conclusively the amount of the unconformity."

Thom and Dobbin (296) believed, in 1924, that the Kingsbury conglomerate is in part equivalent to the Sentinel Butte shale of North Dakota and noted that the conglomerate overlaps on the granite core of the Big Horn Mountains. They ventured the observation (p. 496) that "the Kingsbury conglomerate, as suggested by Wegemann, apparently marks the base of the Wasatch, and represents the coarse phase of the Sentinel Butte shale where it overlaps on the Bighorn fold". If this suggested relation to the Sentinel Butte shale is correct, inclusion of the Kingsbury conglomerate in the "Wasatch" may be erroneous, as suggested by Simpson (271: 8) in 1929 (see pp. 97-99, ante), because the Sentinel Butte shale may belong to the Fort Union.

Paleontology, age and correlation. -- Darton (57: 61-62) said that he had collected invertebrates from the "upper beds of the conglomerate, in sec. 14, on the south side of Johnson Creek". These had been identified by Stanton as Unio danae Meek and Hayden, Sphaerium, and Viviparus retusus M. & H., "which have such a wide range that they do not indicate the precise age of the beds".

In 1909 Knowlton, in his paper on the Hell Creek, "Ceratops" and Fort Union beds (138: 210), stated that Fort Union plants had been collected from a number of horizons in the Kingsbury conglomerate, and that H.S. Gale had collected, from an horizon 650 feet above the base of the Kingsbury, a mammal jaw identified by Gidley "as identical with a Fort Union species found at Fish Creek, Montana." The members of the following list of fossil plants were stated by Knowlton to come from the Kingsbury conglomerate, and were "given to show how similar is the

flora of the upper and lower members of the Fort Union", to which he considered that the Kingsbury belongs:

Sequoia sp.?	Berchemia multinervis Al. Br.
Cyperacites sp.	Aristolochia cordifolia Newberry
Populus sp.?	Cornus newberryi Hollick
Platanus haydenii Newberry	Viburnum sp.
Ficus planicostata Lesquereux	Viburnum whymperi Heer
Cinnamomum affine Lesquereux	Carpites sp.
Sapindus grandifoliolus Ward	Dryophyllum subfalcatum Lesquereux
Diospyros ficoidea Lesquereux	Cissites parrotiaefolia Lesquereux

Gale and Wegemann (81), in 1910, considered the Kingsbury to be an upper member of their "Fort Union". Wegemann (313: 60) believed in 1917, however, that southward from the type locality

"the conglomerate as a member thins out within a few miles, although layers a few inches to several feet in thickness can be found at or near its horizon as far south as Powder River. To the east the Kingsbury conglomerate appears to become finer grained and to finger out into the shale and sandstone of the coal-bearing beds that are now believed to be of Wasatch age. In other words, it is the writer's opinion that the Kingsbury conglomerate is equivalent to part of the Wasatch, and that the unconformity at its base separates that formation, in the Kingsbury region at least, from all older rocks."

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LOWER EOCENE ULM FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation. The type locality is southeast of Sheridan near the town of Ulm, in south-central Sheridan County, Wyoming.

TYPE DESIGNATION. -- The formation, then called Ulm "coal group", was named by Taff (295: 130-131) in 1909:

"Two workable beds of coal of considerable areal extent occur in the rock section 1,100 to 1,200 feet above the top of the Tongue River coal group. Over the larger part of the Sheridan field these upper coal beds have been removed by erosion. Their remnants are found in the south-central part of the mapped area, near the top of the watershed between Tongue River and Clear Creek. These two coal beds are termed for convenience the Ulm coal group, because of their best known occurrence in the vicinity of Ulm, on the Burlington Railroad. They are separated by about 100 feet of shale and soft sandstone beds similar to the sandstone and shale lying below. The Ulm coal beds vary both in section and thickness. Exposures of these beds, however, are rare on account of the extensive burning they have suffered near the surface. Both beds are broken by shale partings,

usually into two or more benches, but the total coal in each is ample for mining. Above these two coal beds there is an estimated thickness of 200 feet of soft shale and whitish to light-yellow sandstone, making the topmost part of the section of rocks exposed in this field."

SYNONYMY. -- *De Smet formation of Darton (56: 8-9), (57: 59-67), (58: 303) in 1906 included rocks later described by Taff as the Ulm formation.

*De Smet formation of Gale and Wegemann in 1910 (81: 143-146) included the Ulm formation.

"Fort Union" of Wegemann (310: 446-447) in 1912 included the Ulm formation.

"Fort Union" of Wegemann in 1913 (311: 269-270) included most of the Ulm formation.

"Wasatch" of Wegemann (312: 23-24) (313: 57-60) probably included the Ulm formation.

"Wasatch" of Wegemann, Howell and Dobbin (314: 4-5) probably = Ulm formation plus Sentinel Butte shale.

DISTRIBUTION. -- Northeastern and east-central Wyoming.

IMPORTANT REFERENCES. -- Baker (2: 23-24); Darton (57: 59-67); Gale and Wegemann (81: 143-146); Simpson (271: 6-8); Taff (295: 126-130); Thom and Dobbin (296: 496, 488-489); Wegemann (311: 269-270), (312: 23-24), (313: 57-60).

GENERAL INFORMATION

In 1929 Baker (2: 24) summarized the synonymic relations of the Ulm formation to nomenclatural usage as follows:

"In his work in Wyoming in the Dayton quadrangle, which adjoins the area here described on the southwest, Darton grouped together the whole of the Lance and FortUnion formations and part of the Wasatch in a thick series which is called the "De Smet formation". Taff subsequently divided the "De Smet" into a lower member and an upper member, the latter consisting of the Tongue River, Intermediate, and Ulm coal groups. According to the classification more recently proposed by Thom and Dobbin the lower part of Taff's lower member corresponds to the Lance formation, the upper part to the Lebo shale member of the Fort Union, and the Tongue River coal group to the Tongue River member of the Fort Union, and the Intermediate and Ulm coal groups belong to the Wasatch formation."

Thom and Dobbin (296: 488-489) listed the following thicknesses of the Ulm formation:

Sheridan-Buffalo, Wyoming	800' plus
Little Powder River-Gillette area .	150' plus
Pumpkin Butte area	1800' plus

The question of the correct position of the *Intermediate coal group

(= Sentinel Butte shale), whether in the Fort Union or in the so-called Wasatch, has been discussed by the writer on pages 97-99. Wegemann was the first person to assign the Ulm formation to the "Wasatch", and did so principally because of the finding of Coryphodon and Hyracotherium ("Eohippus") in the Pumpkin Buttes area in strata believed to represent the Ulm formation. Thom and Dobbin (296: 496) correlated the Ulm formation with the Greybull horizon of the Big Horn Basin, but the Wasatch age of the latter is almost entirely conjectural, since the fossil yield of the typical Wasatch in southwestern Wyoming is too scanty for close correlation.

Presence of the genera, Hyracotherium and Coryphodon, in a portion of the Ulm formation, does not appear to the writer to be sufficient reason for discarding the name, Ulm, and applying the much-abused term, Wasatch. Ulm is a valid name, adequately defined by Taff in the type designation. The remains of the two mammals mentioned justify the opinion that the Ulm formation may be synchronous with some part of the type Wasatch. Both, however, have been found in beds older than the mammal-bearing portion of the Wasatch (Knight member), and the Ulm formation may well cover all or part of the time-gap represented in the unconformity at the base of the Knight. The fossils mentioned do not, in the writer's opinion justify substituting the name, Wasatch, for Ulm.

Simpson (271: pl. f.p. 12) assigned the Ulm formation to the lower Eocene and tentatively correlated it with the Greybull and *Sand Coulee horizons of the Big Horn Basin.

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UPPER PALEOCENE(?) CLARK FORK HORIZON

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation(?) or faunal zone. Jepsen (128: 463, 491) considered the Clark Fork a member of the Fort Union. Other writers have referred to it as a formation or as the Clark Fork "beds". The writer prefers to retain formation as a designation for conveniently mappable lithologic units and to rank the Clark Fork horizon as a faunal zone at or near the top of the Paleocene. Various writers have included the Clark Fork horizon in the so-called Big Horn Wasatch. The writer, however, considers the application of the name, "Wasatch", in the Big Horn Basin both unnecessary and undesirable. The type locality of the Clark Fork horizon is in the Clark Fork Basin, a minor depression within the Big Horn Basin, north of Ralston and Powell, Wyoming.

TYPE DESIGNATION. -- The beds now known as Clark Fork were first called "Ralston formation", a name which, unfortunately, was pre-occupied. The "Ralston beds" were designated in 1912 by Sinclair and Granger, who said (277: 59-60):

CLARK FORK HORIZON - Type Designation

"Due east from the lower end of Irma ditch, on the southwest slopes of the [McCulloch] peak, the red-banded Knight beds[1] [= Greybull formation] with Eohippus and other characteristic fossils rest on a series of bluish shales or clays, with one or two pink bands, overlain by a heavy yellow-brown sandstone. These beds dip at a steeper angle (21°-23°) than the banded clays above, although in the same general northwesterly direction, and are slightly discordant with them in strike. Apparently the two series are unconformable. Fisher's map [76: pl. 3] includes the bluish beds below the banded series in his 'Laramie and associated' formations, now known to be in large part Fort Union. At a locality on the southwest slopes of McCulloch Peak ... about a mile due east of the point where the Wasatch-Fort Union contact line crosses the Shoshone River, 245 feet stratigraphically below the contact with the red-banded beds, the following vertebrates, determined by Dr. Matthew, were found in the so-called 'Laramie and associated', probably the top of the Fort Union:

Phenacodus sp., cf. primaevus	Miacid, cf. Vassacyon
Phenacodont, small form	?Coryphodon
Creodont, indet.	Bird, indet.

?Plagiaulacid or Insectivore, one specimen

"What is believed to be the same faunal horizon occurs on the north side of the Shoshone River in the Bluffs opposite Ralston station on the Burlington railroad where the beds seem to dip below the Systemodon horizon on the south side of the river. From these bluffs a partial skeleton of a new species of Limnocyon was obtained and also some teeth and limb bones of a medium-sized Phenacodus. The Limnocyon, although a new species, does not seem to be primitive, as compared with forms already known from the Bridger.

"To the northwest of Ralston on Big and Little Sand Coulee, the following forms determined by Dr. Matthew, were obtained from beds believed to be the same as those exposed below the Knight formation on the southwest slopes of McCulloch Peak:

Phenacodus sp.	?Palaeonictis sp.
Phenacodus sp., cf. hemiconus	Esthonyx sp. indesc.
Phenacodus sp., cf. primaevus	Bathyopsis sp.
Didymictis cf. leptomylus	?Small Esthonychid

Edentate, gen. indesc. (probably Metacheiromyidae).
Primate or Insectivore

"No doubt is entertained regarding the stratigraphic position of the fauna from the southwest slopes of McCulloch Peak. At other localties, the nearest Systemodon-bearing beds are several miles distant on the south side of the Shoshone, where they dip toward the peak. The beds north of Ralston and the exposures on Big and Little Sand Coulee seem to

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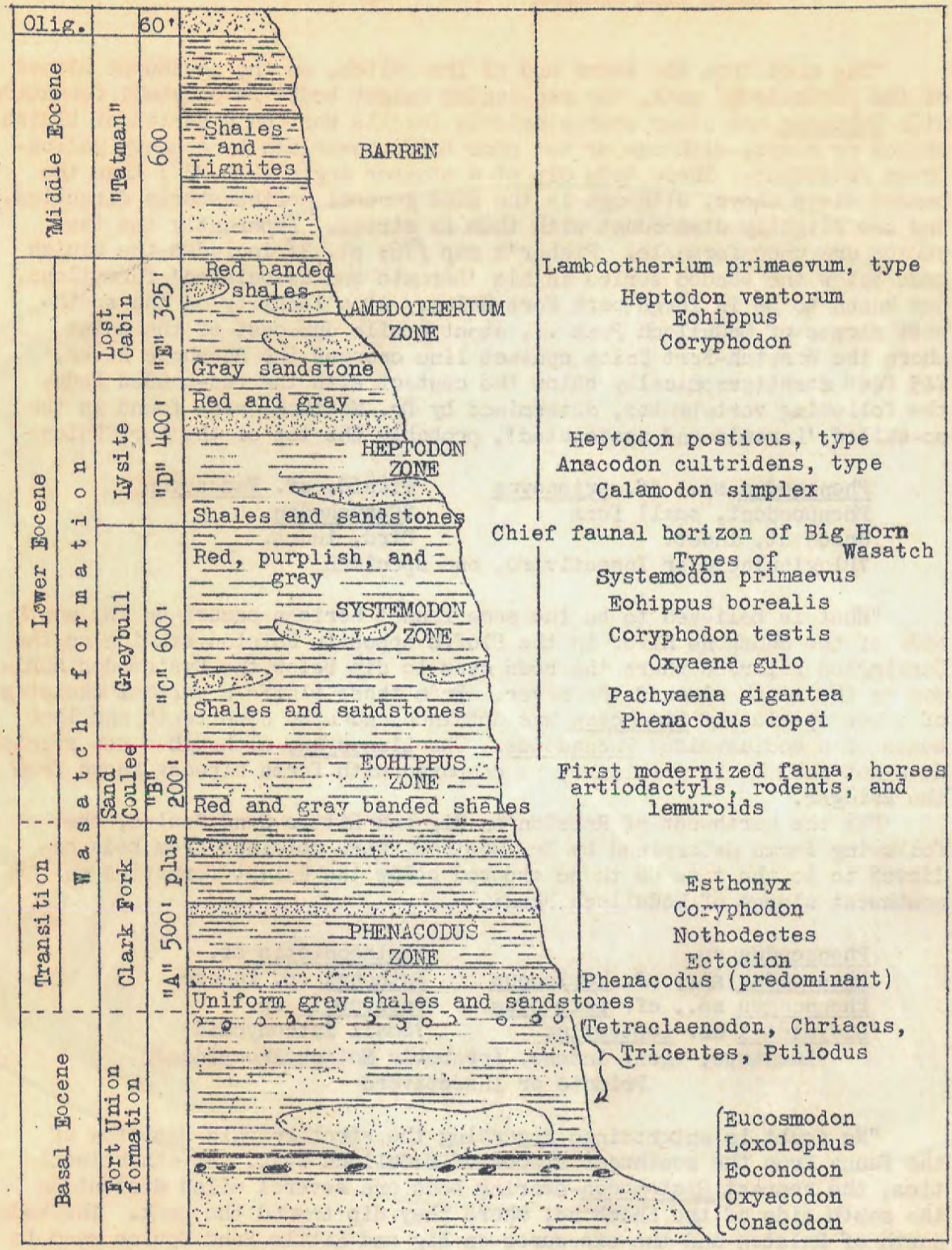
[1]The so-called Knight beds of the Big Horn Basin were later (1914) found to be older than Knight and were given (Granger 88: 203) the distinctive name Greybull.

Composite Section of the Paleocene and Eocene Deposits of the Big Horn and Clark Fork Basins, Wyoming (after Osborn[1])



[1]After Osborn, H.F. (224: 70), Titanotheres of ancient Wyoming, Dakota, and Nebraska: U.S. Geol. Survey Mon. 55, vol. 1, 1929; with modifications in the Fort Union portion of the section from data by Jepsen, G. L. (128: 479), Stratigraphy and paleontology of the Paleocene of northeastern Park County, Wyoming: Am. Philos. Soc. Proc., vol. 66, 1930

CLARK FORK HORIZON - Specific Information

bear the same relation to the Systemodon beds on the north side of the McCulloch Peak syncline as do the 'Laramie and associated' beds on the south side, namely to underly the Knight, but owing to the discovery in them of Limnocyon and Bathyopsis, neither of which has heretofore been found in beds as old as the Knight, we feel that further examination of the stratigraphy is desirable. Should the beds in question prove to be older than the Knight, and it be deemed advisable to give them a formation name, they may be referred to as the Ralston beds or Ralston formation."

In 1914 Granger found it necessary to change the name of this horizon. He stated (88: 203-204):

"It was suggested by Sinclair and Granger that ... these lower beds ... might be called the Ralston beds or Ralston formation. In 1912 the writer with the assistance of Mr. Wm. Stein made a careful search of these beds ... and still further collecting was done in this region last season /1913/ by Messers Stein and P.L. Turner. The fossils obtained, representing nearly 200 individuals, demonstrated clearly that this horizon is a very distinct one, older than the Gray Bull[1] and perhaps representing the top of the Paleocene series. Unfortunately the name 'Ralston' is preoccupied[2] and the name CLARK FORK beds is substituted. The Clark Fork beds are exposed principally in the Clark Fork basin and in the adjoining part of the Bighorn basin along the bluff lying north of Ralston and Powell, also at the southwestern base of McCulloch Peak. The maximum thickness of the beds is at least 500 feet and they rest upon beds whose age is not positively determined, perhaps Cretaceous, perhaps Fort Union."

SYNONYMY. -- The term "Ralston formation" did not find an extensive place in the literature before Granger corrected his and Sinclair's oversight of 1912. Wherever the name "Ralston beds" has been applied to Tertiary strata in Wyoming, it appears to be an exact synonym of Clark Fork.

"Laramie and associated formations" of Fisher (76: pl. 3) included the Clark Fork.

DISTRIBUTION. -- Northern portion of the Big Horn Basin, Wyoming

IMPORTANT REFERENCES. -- Granger (88: 203-205, 207), (89: 829-830); Jepsen (128: 463, 469-473, 491-499); Osborn (224: 64-65); Simpson (271: 1-12); Sinclair and Granger (277: 58-60); Thom and Dobbin (296: 498).

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[1]The Greybull beds = the strata called "Knight formation" in the paper previously quoted.

[2]Granger stated (p. 204, footnote) that Ralston Group is the name of a division of the "Pennsylvania series", Gould, Ohern and Hutchison: State Univ. of Oklahoma, Research Bull. No. 3, p. 13, 1910.

CLARK FORK HORIZON

GENERAL INFORMATION

Areal distribution and lithology; stratigraphic relations. -- Granger (88: 203) referred to the Clark Fork as "low-lying gray shales at the southwestern base of McCulloch Peak and also from the vicinity of the low divide between the Clark Fork and Bighorn basins north of Ralston ..." Jepsen (128: 491) described the Clark Fork in northeastern Park Co., as "several hundred feet of somber clays, sandstone, thin limestones, and occasional leafy layers associated with gypsum" which overlie the 'Princeton Quarry' beds. Jepsen added (p. 493), however, that "some of the beds yielding the 'Clark Fork' fauna are red-banded, and hence the color criterion, formerly used for differentiating the Paleocene from the Eocene in the Bighorn Basin, must be cashiered".

Granger (74: 203) did not determine definitely the stratigraphic relations of the Clark Fork with the Greybull ("Systemodon") beds which overlie it. He noted an apparent angular unconformity between the two in the McCulloch Peak region. In an earlier paper Sinclair and Granger had stated (277: 59) that the "Ralston" (Clark Fork) and "Knight" (Greybull) are apparently unconformable. Apparently Jepsen found no unconformity at the lower part of the Clark Fork. He stated (p. 494), moreover, that an "angular unconformity at the margins of the basin, where the 'Gray Bull' beds truncate the underlying 'Clark Fork beds', does not extend to the central reaches of the basin".

Paleontology, age and correlation. -- Granger's analysis (88: 204) of the paleontologic characters of the formation was as follows:

"The Clark Fork fauna is characterized by the absence of Perrissodactyls, Artiodactyls,[1] Rodents, and Primates, and by the predominance of Phenacodonts ... The Amblypoda are represented by Coryphodon and a primitive form of Bathyopsis. Creodonts of several Lower Eocene genera are present and the species in most cases are more primitive than the Gray Bull species. The genus Esthonyx is fairly common but the two species are distinct from the Gray Bull species. So far as known the mammalian fauna does not include and Torrejon or Fort Union[2] genera not found in the overlying Gray Bull beds but it does include many Gray Bull genera which do not extend down to the Torrejon or Fort Union. However, the reptilian genus Champsosaurus is not uncommon and this is distinctly a Cretaceous

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[1]From the Paleocene "Princeton Quarry level", below and older than the Clark Fork zone, of northeastern Park Co., Wyoming, Jepsen later described the new genus and species, Phenacodaptes sabulosus Jepsen, and assigned it (128: 491) tentatively to the Artiodactyla (see p. 85 ante).

[2]Granger appended the footnote: "By Fort Union is meant the fauna from Sweetgrass County, Montana, as described by Douglass and Gidley." The complete "Fish Creek" fauna, from Sweetgrass County, was listed by Simpson (271: 4-5), who said it is from the Lebo member of the Fort Union, and is of Torrejon age.

and Paleocene form. This with the absence of the four orders of mammals mentioned above, which is the most important feature of the fauna, favor the placing of these beds as Paleocene rather than Lower Eocene."

Osborn, however, believed that the Clark Fork is in the base of the "Big Horn Wasatch", and is lower Eocene in age. He said (224: 64-65):

"(1) The first Wasatch life zone is represented in the 'Tiffany beds' of southwestern Colorado, in the basal part of the Wasatch formation (horizon Big Horn A = 'Clark Fork') of the Big Horn Basin, Wyo., and probably in the summit of the Fort Union formation of Montana.

* * *

"(2) The Nothodectes zone ('Tiffany' and 'Clark Fork') is basal Eocene, as indicated by the absence of the four orders Primates, Perissodactyla, Artiodactyla, Rodentia; it is Lower Eocene, as indicated by the presence of Phenacodus and Coryphodon.

* * *

"(3) Lower Eocene (Wasatch) time began, it may be said, with the first appearance of Coryphodon and Phenacodus in the 'Clark Fork' and 'Tiffany beds' ... The modernization occurred later, in the 'Sand Coulee beds' (Eohippus zone), which overlies the 'Clark Fork'. "

The classic distinction between the Paleocene ("basal Eocene") and lower Eocene, by the presence or absence of Phenacodus, is no longer acceptable, since Jepsen (128: 491) recorded the genus from the "Princeton Quarry level" of the Big Horn Basin, stratigraphically below the Clark Fork in beds admitted by Osborn and others as Paleocene. Contrary to the opinion of Osborn on the age and correlation of the Clark Fork horizon, Jepsen (128: 498), believed that the Clark Fork is not lower Eocene, but upper Paleocene in age, and that, moreover, it is younger than the Tiffany. Brief notes on the critical characters of the Tiffany horizon are therefore germane to the present discussion.

The Tiffany beds were named by Granger in 1917, in a paper on the mammal horizons of northern New Mexico and southern Colorado. In this paper Granger stated (89: pp. indicated) that in southern Colorado

"The area near Ignacio has been studied and measured ... by Gardner and his section taken there has been published by W.T. Lee.[1] The beds are referred by Gardner to the Wasatch and his section shows a total thickness of 2275 feet ... The beds, in the Ignacio region, lie nearly horizontal; they overlap the Torrejon and Puerco and rest on the Animas formation, according to Gardner, with unconformity not perceptible." (p. 826)

* * *

"J.W. Gidley ... succeeded in obtaining from the lower part of the

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[1]Granger cited the article referred to as Lee, W.T., Stratigraphy of the coal fields of northern central New Mexico: Geol. Soc. Am. Bull., vol. 23, p. 584, 1912.

beds a small but interesting mammalian fauna. ... the lower beds containing the fauna discovered by Gidley cannot properly be correlated on a faunal basis with any part of the Gallina Wasatch.

"A brief report by Mr. Gidley on this collection has recently been published. In this he states that the fauna appears to be intermediate between the Fort Union and the Wasatch and lists the following forms: Coryphodon sp. indet., a phenacodont intermediate between Phenacodus and Euprotogonia, Hemiacodon (?sp. nov.), Nothodectes sp., miscellaneous teeth apparently belonging to species of the Clark Fork beds.

" ... Last summer ... a small collection was secured which fully substantiates Gidley's contention that the fauna is intermediate between the Torrejon (Fort Union) and the Wasatch. The fossils were in every case from the lower beds, a vertical range of not over 300 feet ... The material obtained may be divided into two classes: first, such specimens as were found isolated ... and second, an aggregation of remains ... imbedded in a stratum of mottled purplish and brownish clay[1]." (p. 827)

* * *

"The material of the first group comprises the following forms:

Periptychus, sp. nov.	Nothodectes sp.	?Chriacus
?Dissacus	Phenacodonts, 3 species	

(p. 828)

* * *

"To those familiar with our Eocene mammalian faunas the position of this one as intermediate between the Torrejon and Wasatch[2] is manifest.

* * *

"The closest correlation of these beds seems to be with the Clark Fork beds of Wyoming. The predominance of phenacodonts, the presence of Nothodectes, and the general intermingling of Paleocene and Lower Eocene genera are points of resemblance. The Clark Fork beds immediately underlie the lowest Eohippus-bearing levels of the Wasatch in the Bighorn Basin, and these Colorado beds seem to occupy about the same stratigraphic position. Although no fossils have yet been found in the overlying beds of the Ignacio region, yet the lower beds fauna is certainly older than the lower fossiliferous levels of the Gallina region which contain a typical Wasatch fauna.

"This Colorado horizon should be specially designated and the writer suggests the name Tiffany Beds, after the station of Tiffany on the Denver and Rio Grande Railway, four miles south of the Mason Schoolhouse."

(p. 829)

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[1]The locality from which the second fauna was obtained is known as the "Mason Quarry" and is located in Colorado in Sec. 20, T.33 N., R.6 W.

[2]Granger appended the footnote: "The term 'Wasatch' is here used in the generally accepted paleontological sense, comprising such beds as contain Eohippus and its associated forms, which include lemuroids, rodents and artiodactyls." It is worthy of note, however, that "Wasatch", so defined, includes only the upper (Knight) member of the type Wasatch of southwestern Wyoming.

CLARK FORK HORIZON - Paleontology, Age and Correlation

"Dr. Matthew is inclined on the basis of fauna only, to consider them as the top of the Paleocene while the writer at present feels that they may more consistently be placed as the base of the Lower Eocene. The Tiffany beds have been treated in Gardner's section as a part of a stratigraphic unit referred to the Wasatch and hence are to be considered as Lower Eocene. ... the fauna is distinctly more primitive than that which is commonly known as Wasatch and, considering both those forms which are present and those which are conspicuous by absence, it actually resembles the Torrejon more than the Wasatch." (pp. 829-830)

Matthew stated in 1921 (S.352: 218-219) that the Tiffany

"is still faunally Paleocene, the mammals archaic placentals. The phyla that can be traced through show in some instances a considerable advance beyond the Torrejon, indicating considerable lapse of time, and are very close to the succeeding Wasatch horizons of the true Eocene. But in the Tiffany as in the Torrejon, the modernized placentals, abundant in the overlying horizons of the Wasatch, are almost wholly absent. There is between Tifffany and true Eocene very little lapse of time but a great change of fauna. ... I hold that the change is not explainable as due in any degree to difference in facies, but must be due to migration. The same relations hold partly true in the sub-Wasatch beds of the Bighorn basin in Wyoming, Clark Fork Beds, and in the Cernaysian-Sparnacian succession of France. A new fauna, practically identical in Europe and North America, suddenly displaces in the record an old one which had endured for a long time, gradually evolving in loco. This new fauna then undergoes the same process separately in the two continents, of gradual evolution in loco, throughout the Eocene ..."

Osborn commented in 1929 (224: 65) that the Tiffany Nothodectes "is particularly interesting because of its structural affinity to Plesiadapis of the Cernaysian of France". In contrast to Granger's and Osborn's correlations of the Tiffany with the Clark Fork horizon of Wyoming, Jepsen maintained (128: 498) that the Tiffany is correlative with the Bear Creek level of the Montana Fort Union which, in turn bears a fauna nearly equivalent to that of the "Princeton Quarry level" of the Big Horn Basin, and that since "the Clark Fork Horizon is superposed above the quarry level, a continued apposition of Bear Creek (or Tiffany) and Clark Fork may be questionable practice".

In 1929 Simpson stated (271: 8) that the Clark Fork fauna is "essentially of final Paleocene type", and that

"The marked faunal break is between this horizon and the Sand Coulee. The presence of an unconformity in this part of the geologic column usually has little bearing on age unless it is very marked, but there is evidence of at least a local unconformity between the Clark Fork and Sand Coulee. The time break, however, either at the top or bottom of the Clark Fork is probably negligible, and in this general region there is said to be almost complete continuity between undoubted Cretaceous beds and the true Eocene Wasatch or Upper Wasatch."

CLARK FORK HORIZON - Paleontology, Age and Correlation

Simpson also believed (pp.7-8) that the Bear Creek faunal horizon of the Fort Union of southern Montana probably falls within the Sentinel Butte shale, and that the Clark Fork is slightly younger than the Bear Creek, though still Paleocene in age. If this interpretation is correct, the Clark Fork is in part correlative with the Sentinel Butte shale, which is classified by the U.S. Geological Survey as Fort Union(?).

Thom and Dobbin (196: 498) considered the Clark Fork of the Big Horn Basin as equivalent to the *Intermediate coal group (= Sentinel Butte shale) and "interfingered conglomerate" (Kingsbury conglomerate). They assigned the *Intermediate coal group to the Wasatch.

Cockerell and Henderson (29) listed the fresh-water gastropods Planorbis militaris White, and the land molluscs Oreohelix grangeri Cocerell and Henderson, and Gastrodonta(?) evanstonensis var. sinclairi Cockerell, from the Clark Fork ("Ralston beds") of the Big Horn Basin. Jepsen listed the invertebrates Unio danae Meek and Hayden?, and Oreohelix sp.

Jepsen stated (128: 491-493) that the "Princeton Quarry level" in the Big Horn Basin is overlain by "several hundred feet of somber clays, sandstones, thin limestones, and occasional leafy layers", yielding specimens of Phenacodus, Ectocion and Dissacus, but that "it is not until the top of the Paleocene is approached that a sizable fauna again appears, and this 'Clark Fork' proper has the following forms":

Parectypodus sp.
Apheliscus insidiosus (Cope)
Paleanodon parvulus Matthew
Plesiadapis dubius Matthew
P. cookei Jepsen (first described here, p. 525)
Thryptacodon sp.
Dissacus praenuntius Matthew
Oxyaena sp.
O. aequidens Matthew
Dipsalidictis platypus Matthew
Dipsalodon matthewi Jepsen (gen. et. sp. nov.; described p. 524)
Ambloctonus priscus Matthew
Didymictis protenus leptomylus Cope
Haplomylus speirianus (Cope)
Phenacodus primaevus Cope
Phenacodus intermedius Granger
Ectocion osbornianum Cope
Ectocion ralstonensis Granger
Ectocion parvus Granger
Meniscotherium(?) priscum Granger
Probathyopsis praecursor Simpson
Probathyopsis sp.
Coryphodon (sp. undet.)
Esthonyx sp.
Corpolestes[1] dubius Jepsen (first described here, p. 520)

Jepsen commented (p. 494) that only two Clark Fork genera, Carpolestes and Dipsalodon, had not been found in the Greybull also.

The most recent correlation note on the Clark Fork horizon found by the writer is that of Patterson (1935), who described (S.365: 85) a

[1]In the type description (p. 520) the generic name was spelled Carpolestes, which, presumably, is therefore the correct spelling.

skeleton of Titanoides faberi, and said that

"The fauna of the Titanoides level in Mesa Co., Colorado includes Phenacodus grangeri Simpson, Phenacodus sp., Ectocion osbornianum (Cope), Ectocion sp., a rather large and advanced uintathere, Esthonyx sp.; (a primitive type), and ?Psittacotherium sp. The assemblage is certainly of upper Paleocene age and is probably either a Clark Fork or a Tiffany equivalent. Ectocion osbornianum is perhaps suggestive of Clark Fork age, but this species has a rather extensive vertical range and its value as a horizon marker is therefore not great. Phenacodus grangeri, a somewhat better index fossil, is a Tiffany species. Probathyopsis sp. was found some 200 feet higher in the formation. The name Plateau Valley beds is given to the upper Paleocene formation in the area."

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LOWER EOCENE GREYBULL HORIZON

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Faunal zone. The Greybull is paleontologically, though not lithologically, distinct from underlying and overlying rocks, and only by detailed and painstaking collecting could it be separately mapped. It is most commonly treated as a member of the so-called Big Horn Wasatch,-- a treatment to which the writer objects on the ground that the "Big Horn Wasatch" is not Wasatch. Only a small portion of the "Big Horn Wasatch" (Lysite stage of the Wind River formation) has been definitely correlated with any part of the type Wasatch. In the absence of a suitable collective name for the lower Eocene rocks in the Big Horn Basin, the Greybull is perhaps best defined as a faunal zone in the lower Eocene series. The type locality is along Greybull River in the Big Horn Basin of Wyoming.

TYPE DESIGNATION. -- The Greybull beds were named by Granger (88: 203) in 1914:

" ... the name Wasatch has been commonly used for the whole series of mammal-bearing beds of this basin. The name was originally used by Hayden for a group of formations in the vicinity of Evanston in southwestern Wyoming, the uppermost of which, and the only one containing mammals, has been designated by Veatch the Knight formation. The known fauna of the typical Knight beds is a very small one and the material is very fragmentary. The types of Cope have been either too fragmentary or too uncharacteristic to be of much value for accurate correlation. A small collection obtained by the writer from the type locality in 1906 does, however, contain some characteristic forms and a more recent examination of this material shows that the fauna is more nearly that of the Lysite than of any other Bighorn horizon. The genus Heptodon is present and the species of Hyopsodus and Cynodontomys are Lysite species. The beds lying below the Lysite in the Bighorn basin were referred by Sinclair and Granger to the Knight, but it now seems that a new name is needed to

distinguish this most important Lower Eocene faunal horizon and the name GRAY BULL beds is proposed."

EXTENSURES. -- Granger (88: 205) applied the name, *Sand Coulee beds, to a zone underlying his typical Greybull beds. His type designation of these beds was as follows:

"Near the head of Big Sand Coulee in the Clark Fork Basin there is a series of about 200 feet of red-banded shales lying between the gray shales of the Clark Fork and the Systemodon-bearing gray shales above which are referred to the Gray Bull beds. The outcrop of these red-banded beds extends, from the high bluff on the south side of the Coulee, in a northwesterly direction across the basin for several miles. The dip is to the southwest and the beds appear to be conformable with the overlying strata. There may be an angular unconformity between this series and the underlying Clark Fork beds ... This horizon does not contain Systemodon but it does contain the Perissodactyl genus Eohippus in abundance as well as Artiodactyls, Rodents, and Primates, and marks the first appearance of these four orders. It also marks the last appearance of the primitive order Multituberculata which is represented in this horizon by a genus of Plagiaulacids, and in the generally more primitive character of such genera as are common to both horizons. ... the name SAND COULEE beds is proposed for the horizon. Besides the outcrop mentioned above this horizon is exposed for a small area on the point of the bluff, about four miles northeast of Ralston, and again on the south bank of Clark Fork River, just above the mouth of Pat O'Hara Creek."

In 1930 Jepsen (129: 119) re-defined the Greybull horizon to include the *Sand Coulee of Granger:

"As typical Homogalax was found by the Princeton Scott Fund Expedition of 1928 in 'Sand Coulee' beds, the distinction between them and the Gray Bull proper is no longer valid. ... Homogalax is exceedingly rare in the lowest Gray Bull. To date, only one good specimen has been found. ... the great abundance of the genus just above the lowest Gray Bull beds is the result of a sudden expansion and not a migratory invasion."

DISTRIBUTION. -- The Greybull beds are confined to the Big Horn Basin of north-central Wyoming. They crop out for some miles along the south side of the Greybull River in the type locality in the central part of the basin, and southeastward near the town of Worland. There are also some exposures in the Clark Fork Basin, a secondary depression in the northern part of the Big Horn Basin proper. North of the Greybull River they are well exposed about the east and north base of McCulloch Peak.

SYNONYMY. -- "Big Horn Wasatch" of all writers includes the Greybull zone in regions where it is exposed.
"Knight formation", wherever applied as a formation name to Big Horn Basin strata = Greybull.
"Knight formation" of Sinclair and Granger in the Big Horn Basin (277: 57-63) = Greybull.
*Sand Coulee beds = basal Greybull.

GREYBULL HORIZON - References; General Information

IMPORTANT REFERENCES. -- Granger (88: 203-205); Henderson (119: 40); Jepsen (128: 494-496), (129: 117-131); Osborn (224: 12, 58, 67-70); Sinclair and Granger (277: 57-63).

GENERAL INFORMATION

Distribution and lithology; stratigraphic relations. -- In 1912 Sinclair and Granger referred to the Knight formation, beds now known as Greybull. They said (277: pp. indicated):

"Banded clays are found to the very summit [of McCulloch Peak]. The lowest beds rising above the broad bench on the south side of the Shoshone opposite Ralston and Powell contain Systemodon and are, therefore, referable to the Knight [Greybull] formation. At higher levels the Wind River may occur, but fossils are scarce ... ... on the southwest slopes of the peak, the red-banded Knight beds with Eohippus and other characteristic fossils rest on a series of bluish shales or clays, with one or two pink bands overlain by a heavy yellow-brown sandstone. These beds dip at a steeper angle than the banded clays above, although in the same general northwesterly direction, and are slightly discordant with them in strike." (p. 59)

* * *

"The Knight formation is exposed in the valley of the Gray Bull from a point about five miles west of Fenton to the contact with the Fort Union near Basin and on the west side of the Bighorn as far south as the mouth of Fifteen-mile and beyond. On going up Fifteen-mile successively younger formations are found to overlap the Knight, first the Lysite ..., then the Lost Cabin ... and finally, on the highest buttes in the basin, the lignitic beds of the Tatman formation. Where the contact between the Knight and the Lysite in Buffalo basin should be drawn ... is somewhat doubtful as it depends on the presence or absence of certain none-too-abundant fossils in a conformable series of beds and not on stratigraphic or lithologic differences. It certainly lies well to the eastward of the intersection of the main branch of Fifteen-mile with the large dry-wash coming in from the eastern end of Tatman Mountain. ...

"Although the Eocene beds have been uptilted about the southwest margin of the basin, dipping in general, with the exception of minor flexures, toward Tatman Mountain, we have not been able to find any exposures of the Knight formation in this area, the Wind River horizons ... apparently overlapping unconformably on the Fort Union and entirely concealing the Knight ... It follows from this that Doctor Loomis's section from near Meeteetse to the top of Tatman Mountain does not show 'the character of the Wasatch deposits' but combines four elements, the Fort Union, Lysite, Lost Cabin and Tatman formations." (pp. 61-62)

* * *

"The discovery of thick gravel lenses in the Knight, Lysite, and Lost Cabin formations is one of the most important additions to our knowledge of the lithology of the Tertiary sediments of the Bighorn basin, for it demonstrates conclusively that their source is the older rocks of the surrounding mountains.

"Gravel lenses interstratified with coarse yellow-brown sandstone

occur in the Knight formation on the south side of Dry Creek, northwest of Fenton, where they overly clays affording Systemodon." (p. 63)

Paleontology, age and correlation. -- Osborn observed in 1929 (224: 68-69) that the *Sand Coulee beds (basal Greybull)

"mark the first appearance in the Rocky Mountain basin region of four modernized orders of mammals -- the lemuroids, rodents, artiodactyls,[1] and perissodactyls ... There are two or possibly three species of Eohippus in these 'Sand Coulee' beds, which are not yet separable from the species found in the 'Gray Bull' horizon above. Here also occurs Palaeanodon, an ancestral armadillo, which left descendants in Lower and Middle Eocene time."

* * *

"No other exposures containing this very primitive Wasatch fauna have thus far been discovered."

In 1924 Thom and Dobbin (296: 498) ventured the opinion that the Ulm formation, exposed on the east of the Big Horn Mountains, is equivalent to the Greybull horizon.

Simpson was of the opinion in 1929 (271: 8) that the faunal change from the Clark Fork below, to the *Sand Coulee is very marked. In the following year Jepsen (129: 117-131) described some new lower Eocene vertebrates from the Big Horn Basin and remarked (pp. 118-119) that the names of new species of Dipsalidictis and Probathyopsis must be added to the fauna of the "lowest Gray Bull Horizon of the Lower Eocene (or so-called Sand Coulee)". Jepsen commented that the "presence of these Paleocene genera in the lower Eocene Gray Bull beds may be noted as corroborating the testimony of the stratigraphy that in places the Paleocene-Eocene division is transitional both faunally and physically". Jepsen's complete list of new genera and species, named and described in the paper quoted, was as follows:

Parectypodus simpsoni Jepsen (gen. et sp. nov.)
P. tardus Jepsen (new sp.)
Diacodon tauri-cinerei Jepsen (new sp.)
Probathyopsis successor Jepsen (new sp.)
Tetonius tenuiculus Jepsen (new sp.)
Teilhardella chardini Jepsen (gen. et sp. nov.)
Dipsalidictis amplus Jepsen (new sp.)

Later in 1929 Jepsen repeated his belief in the unity of the *Sand Coulee and Greybull horizons, and remarked (128: 493-495):

"In lieu of any lithologic separation between the Eocene and the Paleocene sediments, the presence of Eohippus in the former, a classic

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[1]Jepsen (128: 494) has presented evidence indicating that the appearance of the Artiodactyla may have antedated the Eocene epoch.

distinction, proved still to be the most workable faunal criterion.

* * *

"A faunal basis for dividing the Paleocene and the Eocene sediments was necessarily employed after the failure of color-banding to serve as a distinction, and because the angular unconformity at the margins of the basin where the 'Gray Bull beds' truncate the underlying 'Clark Fork beds' does not extend to the central reaches of the basin.

* * *

"The evidence now at hand indicates that two orders, Perissodactyla and Rodentia, and one Primate family; the Adapidae, are the only large groups of mammals which appear suddenly in the Eocene assemblages, unheralded by ancestors in the Paleocene collections.

* * *

"Only one mammalian genus, embracing two species ... has so far been found exclusively confined to the lowest Gray Bull ('Sand Coulee beds'). Every other species of the 'Sand Coulee' presents itself in the Gray Bull or higher zones. Possibly the varieties within the species are more primitive in the lower than in the upper levels of the Gray Bull, as others have suggested; but such a situation is not unique and cannot be a basis for division."

Jepsen (128: 495) introduced the following comparative tabulation of invertebrate lists from the Greybull and so-called *Sand Coulee "as testimony to the essential unity of the 'Sand Coulee'-Gray Bull sequence":

	*Sand Coulee	Greybull
Unio clinopisthus White		X
Unio sp.	X	
Helicina evanstonensis (White)	X	X
Vivipara leidyi (Meek and Hayden)?	X	
Vivipara wyomingensis Meek	X	
Vivipara, new species		X
Goniobasis carteri Conrad	X	X
Planorbis, new species		X
Physa bridgerensis Meek		X
Physa pleromatis White		X
Physa sp.	X	
Polygyra veternior (Cockerell)	X	X
Gastrodonta coryphodontis Cockerell	X	
Oreohelix megarche Cockerell and Henderson	X	X
Oreohelix grangeri Cockerell and Henderson	X	X
Oreohelix sp.	X	
Goniodiscus ralstonensis (Cockerell)	X	X
Grangerella sinclairi (Cockerell)	X	X
Grangerella megastoma Cockerell	X	
Protoboysia complicata Cockerell	X	

Jepsen (p. 495) quoted the following remarks by Russell on the invertebrates:

"'The species of this Lower Eocene fauna are, with few

exceptions, either confined to these particular beds or are known elsewhere only from Eocene strata. As to habitat, almost three-quarters of the genera represented are terrestrial; and if species and individual specimens are considered, the aquatic element becomes almost insignificant.'"

In addition to the above, Henderson (119: 40) has listed the following invertebrates from the "upper Gray Bull Eocene, 15 miles west of Basin, Park County, Wyoming: Unio sinopae Cockerell?, Viviparus jepseni Russell, Planorbis storchi Russell.

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PALEOCENE and LOWER EOCENE WASATCH GROUP

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Though often called a formation, the Wasatch is here ranked as a group, since its members, themselves ranked as formations, are separately mappable units in the type locality. The type locality extends from Carter, Wyoming to the "Narrows on Weber River", seven miles below Echo City, Utah, and some 10 to 15 miles east of the crest of the Wasatch Mountains. The name is not derived from the Wasatch Mountains, as is commonly supposed, but from Wasatch Station on the Union Pacific Railroad, Summit,Co., Utah, in the neighborhood of which it is said to reach its most extensive and typical development.

TYPE DESIGNATION. -- The Wasatch group was named and described by Hayden in 1869, in the 3rd Annual Report of the United States Geological Survey of the Territories. This report was reprinted in 1873 in a combination edition of the 1st, 2d and 3d Annual Reports, from which the following quotation (Hayden 104: 191) is made:

"Immediately west of Fort Bridger commences one of the most remarkable and extensive groups of tertiary beds seen in the West. They are wonderfully variegated, some shade of red predominating. This group, to which I have given the name of Wasatch group, is composed of variegated sands and clays. Very little calcareous matter is found in these beds ...

"In Echo and Weber Canons are wonderful displays of conglomerates, fifteen hundred to two thousand feet in thickness. ... this group occupies a vast area, and attains a thickness of three to five thousand feet ..."

Hayden later (1871) published a more complete and detailed description of the formation (103) from which he was quoted by Veatch (300: 87-88) to the effect that the "variegated beds of the Wasatch group"

"'present almost every variety of shade of color from white and yellow to a deep, brick-red, the red and purple tints so predominating that they impart a singularly curious aspect to the scenery. ... The tunnel at the head of Echo Canyon is

cut through the reddish and purplish indurated sands and clays of what I have called the Wasatch group. ... I have included in this group all the variegated beds which we have observed west of Carters station, and we have noticed especially that some shade of red has prevailed in the clays and sands as well as in the conglomerates of this group. Some of the sandstones in the upper portion of Echo Canyon are noticeable for their deep yellow hue.'"

RESTRICTIONS. -- Extreme latitude in the application of the term, Wasatch, has led to a degree of confusion equalled only by the ramifications of the classic "Laramie problem". In its type locality the Wasatch group includes strata of both lower Eocene and Paleocene age. The upper member (Knight formation), separated from underlying strata by a pronounced unconformity, has yielded characteristic lower Eocene fossil mammals. The Paleocene age of the underlying portion has been inferred chiefly from the characters of plant, invertebrate, fish and reptile remains. Many paleontologists have applied the term, "Wasatch", in other localities only to those beds which yield remains of Hyracotherium ("Eohippus"), Phenacodus, and Coryphodon, which, in the type locality of the Wasatch group, are confined to the Knight member. Other paleontologists and many stratigraphers, have used the term in a less exact sense, to apply to the whole body of early Tertiary and Tertiary(?) sediments, including in the "Wasatch group" such units as the "Black Rock coal group" of Hanna (Fort Union?) age, the Paleocene and lower Eocene of the Big Horn Basin, and equivalent strata of many other areas. The name has also been applied to strata as far from the type locality of the group as the San Juan Basin of New Mexico and Colorado.

There is, in the writer's opinion, no need for continued use of "Wasatch" as a name for beds containing Hyracotherium, Phenacodus and Coryphodon. The usage is incorrect because, in the type locality, only the Knight member fulfills this definition. Beds below the Knight, known as the Almy and Fowkes formations (members of the Wasatch group), have not yielded Hyracotherium and associated forms. Strata in the Big Horn Basin, formerly known as "Wasatch", are now adequately differentiated under the names Clark Fork, Greybull, Wind River and Tatman horizons. If a name is needed to designate collectively the Big Horn horizons, a new name, without the unfortunate and inexact connotations of "Wasatch" should be proposed. The names, Hanna and Wind River formations, used by the Geological Survey of Wyoming in south-central Wyoming, have proved to be stratigraphically adequate and suitable for mapping purposes. The "Wasatch" of New Mexico and southern Colorado, has been differentiated into the Tiffany, Almagre and Largo horizons and, because of its remoteness from southwestern Wyoming, should be given a new name, if a group term is necessary.

The nomenclature of the entire Paleocene and lower Eocene of Wyoming is in need of careful revision and recapitulation. Pending such a restudy, it is suggested that the name, Wasatch, be avoided, both because it is unnecessary, and because it is meaningless.

WASATCH GROUP - Synonymy

SYNONYMY. -- (See tables, pp. 16, 18, 22-23, 108.)

In general the name, Wasatch, was used by most geologists of the Hayden, King, Powell and Wheeler surveys, to include the whole body of early Tertiary sediments. The synonymic list given below is by no means complete. It is sufficiently so, however, to indicate the great variety of usages of the name, Wasatch.

"Third series" of Engelman (72: 45-75) in the Tertiary of the Green River Basin of Wyoming in 1859 = Wasatch.

"Wasatch" of Hayden in 1869 (104: 191), in 1870 (103) and in 1871 (105) = Wasatch and "Wasatch".

*Vermilion Creek group of the 40th Parallel Survey reports (134)(135)(136)(137), published from 1870 to 1878 = Wasatch, plus Hanna in some places.

"Wahsatch beds" and "Wahsatch group" of Cope in 1872 (in Hayden 106) = Wasatch.

Cope, in 1874 (in Hayden 108: 440-441), used the terms, "Wasatch" and "Green River", interchangeably, as names of the same stratigraphic significance.

"Green River epoch", "Green River beds", "Green River formation", "Green River strata", of Cope in 1873 (39: 279-280)(in Hayden 107: 545-649), in 1874 (in Hayden 108: 440-441), and in 1884 (44: 6-11) = Wasatch plus Green River.

"Coryphodon beds" of Marsh and Cope in various writings = Knight formation.

"Green River beds" of Comstock in 1879 (in Jones 131: 123-125) = Wasatch plus Green River.

*Bitter Creek group of Powell (229: 45-47, 64-66, 162-166), in his Uinta Mountain report of 1876, included the "Wasatch" and Wasatch.

"Wahsatch limestone" of Vol. 2 of the final reports of the 40th Parallel Survey (136), by Hague and Emmons, belongs to the Paleozoic rock system and underlies the Weber quartzite.

"Post-Cretaceous" of White, after 1877, included the lower third of the Wasatch, according to Ward (303: 423).

"Wasatch" of White in 1886 (323: 9-12) included what is now known as the Evanston formation in southwest Wyoming.

"Wasatch" of Stanton in 1892 (284: 113) included the Evanston formation.

"Wasatch" of Eldridge in 1894 (69: 25-27) in the Big Horn Basin, included the Tatman, Wind River and Greybull horizons, and possibly a portion of the Fort Union.

"Wasatch" of Eldridge in 1894 (69: 27) in the Wind River Basin = Wind River formation.

"Wahsatch" of Osborn in 1895 (214: 73), in his paper on the Uinta Basin = upper Wasatch (Knight member).

"Wasatch" of Loomis in 1907 (153: 356-364), and of Fisher in 1906 (76: 33), in the Big Horn Basin = Fort Union, Wind River, and Tatman formations.

"Wasatch" of Darton in 1908 (59: 463) in the Wind River Basin and Sweetwater Plateau = Wind River plus all or part of the "Bridger" and "Uinta".

Ulm "coal group" of Taff in 1909 (295: 130-131), which he divided out of his "upper member" of Darton's *De Smet (56: 8-9, 16)(57: 59-67) in the Sheridan region of Wyoming, has been said to be equivalent to the "Wasatch". Retention of the name, Ulm formation, however, is suggested as a preferred practice.

"Wasatch" of Gale in 1910 (79: 69-80), and Sears in 1924 (260: 292-293), in southwest Wyoming and adjacent parts of Colorado and Utah, probably included the Hanna formation.

WASATCH GROUP - Specific Information

SYNONYMY (cont'd)

"Wasatch" of Wegemann (312: 23-24) (313: 57-60), in the Powder River Basin, in 1917 and 1918, had been included by him in 1911 (309: 50-54) in the "Fort Union". His "Wasatch" should, in the writer's opinion, be called Sentinel Butte shale and Ulm formation (see pp. 130-132).

"Wasatch" of Hewett and Lupton (132: 29-30), in the Big Horn Basin in 1917 = Greybull, Wind River and Tatman formations.

"Big Horn Wasatch" of the Big Horn Basin of Wyoming = Clark Fork, *Sand Coulee (lower Greybull), Greybull, Lysite and Lost Cabin horizons, and in some cases, the whole of the underlying Fort Union.

"Wasatch" of Schultz (248: 222), in Sweetwater County, Wyoming in 1910, included the Tipton tongue of the Green River group, and the equivalent of the Hanna formation.

"Green River formation" of Schultz (251: 28-30) included the Cathedral Bluffs tongue of the Wasatch.

"Wasatch" of Love in 1934, at the west end of the Owl Creek Mountains (132: 12-17), is probably of Wind River age, though it may represent a greater time interval than the typical Wind River.

DISTRIBUTION. -- The name, Wasatch, has been applied generally to strata throughout southwest Wyoming, the southwest slopes of the Wind River Mountains, the southeast slopes of the Big Horn Mountains, and the Big Horn Basin. In Colorado the name has been applied in the northwest part of the state in the White River district, in the Grand River Basin, and in the Vermilion Creek Basin. Elsewhere "Wasatch" strata have been described in northeast Utah, southeast Idaho, southeast Montana, and in the San Juan Basin of New Mexico and Colorado. It is impossible to summarize the distribution of the true Wasatch, since there has never been any agreement as to what consitutes "true Wasatch".

NOMENCLATURAL DIVISIONS. -- The typical Wasatch group was divided by Veatch (300: 87-96) into the member formations, Almy, Fowkes and Knight. Nightingale (213: 1023)named the lower portion of the group, in the Vermilion Creek Basin of southwestern Wyoming and adjacent parts of Colorado, the Hiawatha member. The Cathedral Bluffs tongue, designated by Schultz in 1920 (251: 28) as a member of the Green River group, is now considered to be a tongue of the Wasatch. The name, "Big Horn Wasatch", varies in significance with individual writers, but the name is most commonly used to embrace the Clark Fork, Greybull, Lysite, Lost Cabin, and Tatman horizons. In the Gallina region of northwest New Mexico, Granger (88: 205-206) divided the so-called Wasatch into the Almagre and Largo members. The Tiffany horizon of the "Wasatch" in the Ignacio region of southern Colorado was distinguished and named by Granger (89: 826-829) in 1917. In the Wasatch Plateau of Utah, the group has been divided by Spieker (283: 45-48) into three members. The middle member he named Flagstaff; the two other members he left unnamed.

IMPORTANT REFERENCES. -- Cope (44: 6-11); Emmons (in King 136: 203, 209, 210, 225-226); Granger (88: 205-206), (89: 826-830); Hayden (104: 191), (105: 156), (111: 189-290), (113: 35, 79), (114: 635-636); Hewett (122: 40-62); Hewett and Lupton (123: 29-30); King (137: 354-356, 360-377); Loomis (153: 356-364); Marsh (175: 321-326); Matthew (in Osborn 219: 92-95);

WASATCH GROUP - References; General Information

Matthew and Granger (195: 1-103), (196: 429-483), (S.359: 565-657); Osborn (219: 36-41), (224: 43, 48, 57, 64-73); Schultz (251: 28); Sears (260: 291-296); Sears and Bradley (263: 94-107); Spieker (283: 45-48); Thom and Dobbin (296: 481-506); Veatch (300: 87-96).

GENERAL INFORMATION

Areal Distribution and Lithology

Southwest Wyoming; adjacent parts of Idaho, Utah and Colorado. -- Mansfield (166: 109), in 1927, described the "Wasatch" in southeast Idaho. In that region, he said, the "Wasatch" consists mainly of "coarse red conglomerate, with pebbles or boulders that range from less than an inch to 3 feet or more in diameter". The group as a whole, there reaches an exposed thickness of about 1500 feet.

In 1871 Hayden, in his 4th Annual Report, described (105: 156) the development of the Wasatch group in the type area in terminology almost identical with that of his earlier descriptions. This description was apparently mistaken by White, in 1878, for the type designation, for he said (in Hayden 113: 35) that, "in his annual report for 1870 /published in 1871/ Dr. Hayden proposed the name 'Wasatch Group' for a series of strata that are extensively developed in Southern Wyoming and adjacent parts of Utah and Colorado".

On page 148 of his 4th Annual Report, Hayden had mentioned outcrops of Wasatch sediments within a distance of 10 miles west of Bridger Butte on the east rim of the Great Salt Lake Basin, Utah, where, he said, the upper beds are composed of indurated whitish marly clays and concretionary layers.

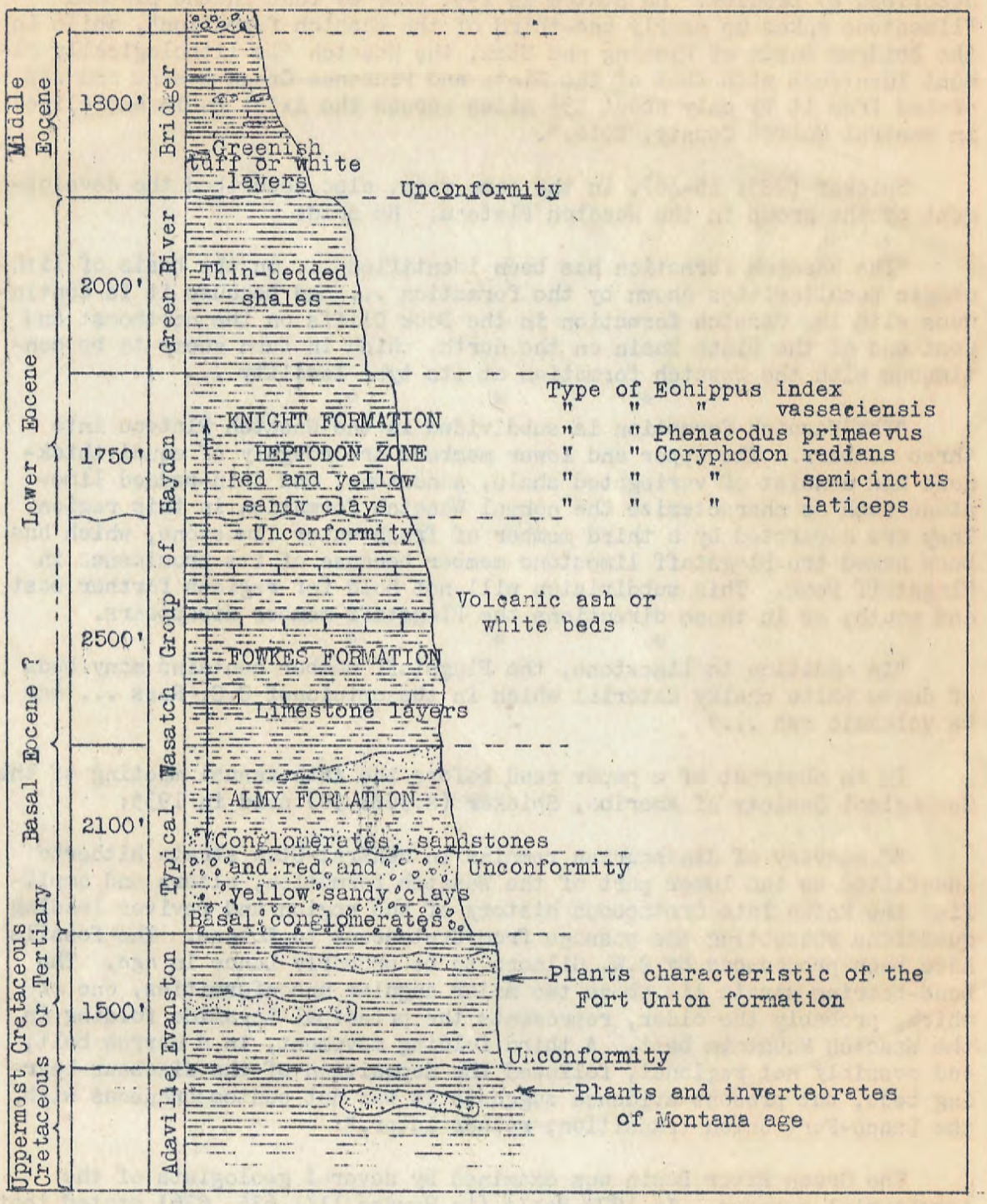
White examined the Wasatch and "Laramie" beds of Utah in an effort to determine the stratigraphic and structural relations of the two formations. In 1886 he said (323: 10) that in the San Pete Valley and adjacent portions of the Wasatch Mountains in Utah, the Wasatch group reaches an estimated thickness of about 2,500 feet, and that

"These strata consist of sandstone, shales, marlites, and a few layers of impure limestone, resting upon a very coarse conglomerate which forms the base of the hills ...

" ... Some two or three hundred feet above the conglomerate there is a bed of coal ... The fossils which were collected from these strata were found at different horizons, ranging from about 100 feet beneath the coal to the top of the hills, the vertical range of the fossil-bearing strata being more than 1,500 feet. I have recognized 26 species of invertebrate fossils which were obtained here, all plainly belonging to one and the same fauna, and in a layer immediately above the coal some undetermined vertebrate remains were found."

In 1914 Woodruff and Day (337: 11) reported 1,000 to 4,000 feet of Wasatch present in northwest Colorado and northeast Utah, where, they said, the group consists of variegated shale and sandstone.

Columnar Section of Late Cretaceous and Early Tertiary Sediments Exposed Along Bear River, Near Evanston, Southwestern Wyoming, Showing the Typical Wasatch Group of Hayden[1]



[1]After Osborn, H.F., Titanotheres of ancient Wyoming, Dakota and Nebraska: U.S. Geol. Survey Mon, 55, vol. 1, p. 66, 1929.

WASATCH GROUP - Areal Distribution and Lithology

The Wasatch group of the Wasatch Plateau of Utah was examined and described by Bradley. He stated in 1931 (22: 8) that in the plateau "limestone makes up nearly one-third of the Wasatch formation", while in the Bridger Basin of Wyoming and Utah, the Wasatch "is lithologically almost identical with that of the Uinta and Piceance Creek Basins and separated from it by only about 13½ miles across the Axial Basin anticline in central Moffat County, Colo.".

Spieker (283: 45-46), in the same year, also described the development of the group in the Wasatch Plateau. He said:

"The Wasatch formation has been identified ... on the basis of lithologic peculiarities shown by the formation ... and because it is continuous with the Wasatch formation in the Book Cliffs on the northeast and west end of the Uinta Basin on the north, which in turn seems to be continuous with the Wasatch formation at its type locality ...

* * *

"The Wasatch formation is subdivided in the Wasatch Plateau into three members. The upper and lower members are roughly of equal thickness and consist of variegated shale, sandstone, and thin-bedded limestone such as characterize the normal Wasatch formation in this region. They are separated by a third member of fresh-water limestone, which has been named the Flagstaff limestone member because of its prominence in Flagstaff Peak. This subdivision will not hold for regions farther east and south, as in those directions the Flagstaff member disappears.

* * *

"In addition to limestone, the Flagstaff member contains many beds of dense white chalky material which in the opinionof C.S. Ross ... may be volcanic ash ..."

In an abstract of a paper read before the 48th annual meeting of the Geological Society of America, Spieker (S.368: 30) said in 1935:

"Discovery of dinosaurian remains in central Utah strata hitherto identified as the lower part of the Wasatch formation, alters and amplifies the known late Cretaceous history of the region and revives leading questions respecting the passage from Cretaceous to Eocene. The fossils have been pronounced by C.W. Gilmore to be probably Lance in age. The bone-bearing strata lie above two major angular unconformities, one of which, probably the older, represents the principal Laramide folding in the Wasatch Mountain belt. A third folding movement, in a narrow belt, and possibly not regional, followed the deposition of the dinosaur-bearing beds, but present evidence suggests it was not contemporaneous with the Lance-Fort Union transition, rather later."

The Green River Basin was examined by several geologists of the territorial surveys. In 1879 Peale (in Hayden 114: 635, 636) stated that

"The largest areas of the Wahsatch are in the northern portion of the Green River Basin, where a large part of the surrounding surface is covered by its deposits.

* * *

WASATCH GROUP - Areal Distribution and Lithology

"The line that I have drawn in separating the Wahsatch Group from the Green River is lithological. All the variegated beds that lie below the laminated light-colored sandstones have been referred to the Wahsatch Group and all above to the Green River."

In 1878 King said (137: 354) that he had recognized Hayden's Wasatch formation in the immediate vicinity of the Wasatch Mountains, but that in the Vermilion Creek Basin in northwest Colorado he had "been led to reject this name, and to apply ... the name 'Vermilion Creek group,' because upon Vermilion Creek was exposed the whole thickness of the series, while at the Wahsatch the full volume of the group was never seen". His description of the *Vermilion Creek group coincided, in general features, with descriptions of the Wasatch.

The name, *Vermilion Creek group, was adopted by other geologists of the King Survey. In 1877 Emmons, in his report on the Green River Basin (in King 136: 209, 211) stated that

"On the western borders of the Little Muddy Creek, the characteristic upper beds of the Vermilion Creek series are exposed ... They consist of an intimate admixture of sands, clays, and marls, in varying proportions, which are more or less colored by oxide of iron. The lines of stratification in these beds are indicated rather by difference of color than by change in the material of which they are composed. The colors vary from a greenish-white to a deep, almost brick, red ... The best exposures of these beds are seen at Washakie Mountain and at Cathedral Bluffs.

* * *

"From a point a few miles west of Washakie Station, just south of the railroad, a line of low bluffs extends westward toward Red Desert Station, and southward toward Washakie Mountain, marking some of the middle beds of the Vermilion Creek series. They are composed of whitish clays, capped by thin flaggy sandstones, in exposures of about 250 feet in thickness. ...

"To the south of Red Desert Station the country rises in a series of steps or terraces, the first of which is formed of the whitish clays and sandrocks already mentioned as extending parallel to the line of the railroad toward Washakie Station. About 4 miles south of these, a second line of bluffs of greater elevation [Cathedral Bluffs] is composed of the striped red beds of the Upper Vermilion Creek series. ... A thickness of about 600 feet of these peculiarly-variegated beds is here exposed, composed of fine clays of red, greenish, and purple colors, with a varying admixture of fine white sand."

"The "Wasatch" of the borders of the Washakie Basin, as described by the territorial geologists, included the intertonguing phase of the Wasatch and Green River groups, i.e., Cathedral Bluffs tongue of the Wasatch, and Tipton shale tongue of the Green River.

King's name, *Vermilion Creek group, has not been generally accepted, though there are numerous references to it in the literature. In 1894 Eldridge (69: 25), for example, applied the name to the distant Tertiary

exposures of the Big Horn Basin. Smith, who reported on the geology of the Great Divide Basin, in 1909, found (279: 234-235) that

"The basal member of the Wasatch near the Union Pacific Railroad is very thin and contains numerous small granite pebbles. It thickens to the north and contains more and more conglomerate until in the Green Mountains many of the granite boulders are 6 feet in diameter.[1] The coal-bearing portion of the Wasatch immediately overlies this basal member and is present in the southern and western parts of the field only. Lithologically it resembles the upper member of the undifferentiated Tertiary [= Ferris?] except that the shales have a slightly more pronounced color."

Smith added (p. 234, footnote) that

"These beds represent the lower part of the Wasatch group of Hayden. They also represent the lower part of the Vermilion Creek group of King and have been traced into the type section on Vermilion Creek in northwestern Colorado."

In 1925, however, Sears (260: 292-293) applied the name, Wasatch, to rocks in the type locality of King's *Vermilion Creek. He assigned a thickness of from 3,000 to 5,600 feet to the "Wasatch" in Moffat Co., Colorado, and southern Sweetwater Co., Wyoming. He also applied (pp. 276, 291-293) the names "Laramie" and "post-'Laramie'" to beds underlying the "Wasatch" in the flanks of the Axial Basin anticline. The region had been previously described by Gale (79: 69-80), who used similar nomenclature. The descriptions of Gale and Sears indicate a strong probability that the "Laramie" = Medicine Bow, the "post-Laramie" = Ferris, and the "Wasatch" included, at least in some localities, the equivalent of the Hanna formation.

The "Wasatch" in northwest Colorado had been described by White (in Hayden 113: 35) in 1878. He found that the group consists "very largely of soft, variegated badland sandstones that reach a thickness of about 1,500 feet, together with from 100 to 300 feet of ordinary indurated sandstones, alternating with bad-land material at the base, and a similar amount of similar material at the top, the estimated aggregate thickness being about 2,000 feet". Endlich examined the White River district of Colorado and reported (in Hayden 113: 79) that southeast of Rifle Creek Canyon "the general appearance strikingly resembles that of the Puerco marls in southern Colorado". Endlich's supposed "Puerco marls in southern Colorado" were said by Gardner (83: 711) to belong to the Animas formation.

Sears and Bradley, who worked together in northwest Colorado and southern Wyoming, stated (263: 94) in 1924 that in "the Vermilion Creek

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[1] S.H. Knight, of the University of Wyoming, has made actual measurements of some of the granite boulders in the so-called Wasatch conglomerates in the north face of Green Mountain, and states (personal communication) that some of the boulders have a maximum diameter of from 30 to 40 feet. It seems probable that at least a part of these beds represent the Hanna formation, of Carbon County, Wyoming.

Basin the middle part of the Wasatch contains a few beds of coal, fissile carbonaceous shale, shell marl, and many more beds of sandstone than elsewhere in the field", and that in Godiva Ridge the maximum thickness is 5,600 feet. In a more detailed passage (p. 96), they said that

"Conglomerates in both the Wasatch and the Green River are thickest and carry the largest boulders near the mountains and thin rapidly toward the basin. ... Most of the boulders are well rounded by stream action, but some are angular and subangular; the largest boulders are 6 feet in diameter. This notable aggregation of coarse detritus, in which there is only the crudest kind of stratification, grades laterally within less than a mile to the north and east into carbonaceous shale, shell marl, and coarse but regularly bedded sandstone -- the typical Wasatch assemblage of this vicinity."

Central and east-central Wyoming. -- In his "Report on the Geology of the Sweetwater District" in 1879, F.M. Endlich (in Hayden 114: 88-89) said that on the east of the Wind River Range, a "series of variegated, arenaceous marls" rests on the yellow sandstones of the upper portion of the "Laramie Group", and are overlain by "a succession of yellow sandstones and shales", which are terminated above by the beds of the *Sweetwater group. He assigned the variegated beds to the Wasatch, stating that he regarded them "as parallel to the Puerco marls of New Mexico". In 1908 Darton also applied the name, Wasatch, to strata in the Wind River Basin and Sweetwater Plateau. As late as 1934 Bauer (11) also applied the name to the Wind River formation.

The work of Granger (87: 235-251) and of Sinclair and Granger (276: 88-105), from 1910 to 1912, shows that the section previously called "Wasatch" in the Wind River Basin, included the Wind River, "Bridger" and "Uinta" formations, and that the *Sweetwater group is White River in age. There appears to be no further need for using the name, Wasatch, in the Wind River Basin.

In 1934 Love described "Wasatch" sediments in the west end of the Owl Creek Mountains, stating (162: 12, 15) that the Wasatch, as a whole, is "extremely variable in color, texture and composition", and that these features "depend, to a large extent, on the local relationships of the Wasatch sediments to the surrounding older rocks". In this region Love discovered volcanic extrusive rocks interbedded with sediments of "known Wasatch age". He said that these "Wasatch flows" are "of uniform lithological character throughout the area and with but one exception they consist of pink, green and white porphyritic rhyolites and rhyolitic agglomerates". It seems probable that Love's "Wasatch" is chiefly, if not all, of Wind River age, though the fossils he collected (Coryphodon and Calamodon) are not sufficiently diagnostic to establish an exact age relationship.

Wegemann described "Wasatch" sediments in 1918 in a paper on the Salt Creek oil field of northeast Natrona Co., Wyoming. He said (312: 24) that in this region,

"Above the Fort Union lies the principal coal-bearing formation of

this region, which is believed to represent the Wasatch formation. It consists of alternating beds of yellow sandstone and gray shale, with here and there beds of coal. The upper part of the formation is exposed in the Pumpkin Buttes, the formation as a whole being about 2,400 feet thick. Near its base is a coal bed 17 feet thick, which is mined in a small way near the Puggsley ranch and which is the most valuable coal bed within reach of the Salt Creek field."

In an earlier (1911) paper on this same region Wegemann (309: 50-54) had assigned the sequence described above, to the Fort Union formation. In 1917, however (313: 59-60), he evaluated paleontologic evidence which had come to light, and decided that the beds should be called Wasatch. Wegemann stated (313: 58) that, between the north and middle Pumpkin Buttes, "950 feet below the top of the formation as there exposed", he had found fossil teeth assigned by Gidley to the species Coryphodon molestus, "a genus known only from the Wasatch". Wegemann reasoned (pp. 58-59):

"It would seem, therefore, that these remains afford definite evidence for correlating the rocks that form the Pumpkin Buttes, or the upper 1,000 feet of the formation heretofore called Fort Union, with the Wasatch, The 1,400 feet of beds from the base of the Pumpkin Buttes down to the top of the Great Pine Ridge are lithologically similar to the rocks of the Buttes themselves, and there is every reason, on lithologic grounds, to suppose that they belong to the same formation as the rocks from which Coryphodon has been obtained."

Wegemann added that in 1910 Stanton, Schultz and himself had made a small collection of mammals at a place 20 miles west of Pumpkin Buttes at an horizon "700 feet above the top of the beds forming the Great Pine Ridge". Wegemann quoted a report on the collection by Gidley, who stated that he had first been led to assign the deposits to the Fort Union because of the presence of "a little insectivorous mammal", which is represented by the same, or a closely related, species in the Fort Union beds of Sweetgrass County, Montana. Gidley concluded with the statement:

"Coryphodon and Eohippus are not known to occur lower than the beds designated by Granger Sand Coulee beds.[1] Therefore, as Coryphodon has been found in the Pumpkin Buttes locality and as Loomis has reported Coryphodon and Eohippus from the Davis ranch locality it seems reasonable that these beds should be classed with the Wasatch formation and that those at the Davis ranch should be regarded as probably equivalent to one of the lower members of this group, either the Sand Coulee or the Clark Fork of Granger."

Wegemann stated (313: 59-60), moreover, that the Kingsbury conglomerate, typically developed 50 miles northwest of Pumpkin Buttes,

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[1]Since Wegemann's paper was written, the known range of Coryphodon has been extended by Jepsen (128: 493) and others downward into the Clark Fork horizon, below the *Sand Coulee.

"appears to become finer grained and to finger out into the shale and sandstone of the coal-bearing beds that are now believed to be of Wasatch age. In other words, it is writer's opinion that the Kingsbury conglomerate is equivalent to part of the Wasatch ..."

Subsequent work has born out Wegemann's conclusions concerning the relations of the Kingsbury conglomerate to his "Wasatch". Thom and Dobbin (296: 496) observed that "the Kingsbury conglomerate, as suggested by Wegemann apparently marks the base of the Wasatch, and represents the coarse phase of the Sentinel Butte shale where it overlaps on the Bighorn fold". Simpson (271: 7), however, disagreed with the assignment of the Sentinel Butte shale to the "Wasatch", but included it in the Fort Union and correlated it with the Clark Fork of the Big Horn Basin, and the Tiffany of Colorado. Both these horizons are included in the "Wasatch" by some writers.

In the present writer's opinion, the paleontologic evidence proffered by Wegemann does not justify use of the name, Wasatch, in the Pumpkin Buttes area. The nearest equivalents of the Pumpkin Buttes "Wasatch" appear to be the Clark Fork and lower Greybull horizons, both of which are defintely older than the only known mammal-bearing horizon (Knight member) of the typical Wasatch in southwest Wyoming. The Clark Fork and Greybull have been included in the so-called Big Horn Wasatch by some writers, but the legitimacy of this usage is questioned, since the Clark Fork horizon has no known equivalent in any part of the typical Wasatch. The "Wasatch" strata of Wegemann in the Pumpkin Buttes region appear to be continuous with the Sentinel Butte shale and Ulm formation of the Sheridan district. It is the writer's belief that these names should follow the outcrops, and that it is a backward step to apply the name, Wasatch, to strata which have no certain equivalent in any part of that group in the region of its typical development.

Big Horn Basin, Wyoming. -- Perhaps the most carefully studied Eocene outcrops in Wyoming are those in the Big Horn Basin. Eldridge, in his "Geological Reconnoissance in Northeast Wyoming" (69), described extensive outcrops of the "Wasatch" in broad areas of the central portions of the Big Horn Basin and the Wind River Valley. Fisher's description of 1906 (79: 33) conformed to a similar usage. The following passage from Fisher's description is indicative of accepted usage prior to the work of Sinclair and Granger in the period 1910-1912. Fisher said (p. 33) that the "Big Horn Wasatch" has

"a more extensive outcrop than any other formation in the district, occupying a broad area in the central part of the basin, which narrows rapidly to the northwest. It constitutes the prominent McCulloch Peak, extends entirely around the base of the Heart Mountain, occupies the low divide between Bighorn and Clark Fork basins, and gives rise to a number of prominent peaks along the base of the Beartooth Mountains, from Clark Fork to the Montana line. It continues from Gray Bull south to beyond Bighorn River in the region of the Honeycombs. Along Dry Creek, Shoshone River, and Clark Fork the formation is covered by broad areas of Quaternary deposits."

WASATCH GROUP - Areal Distribution and Lithology

Fisher estimated the total thickness of the supposed Wasatch in the Big Horn Basin at from 1,500 to 2,500 feet, and said that it "lies unconformably on preceding Cretaceous deposits".

Woodruff, in 1910 (335: 176), described as "Wasatch" a sequence of sandy tan-colored shales, with some varicolored beds, exposed along the west and north margins of the coal field in the southeast part of the Big Horn Basin, and in the badland area in the central part of the basin where the strata are not coal-bearing.

Sinclair and Granger (276: 106) observed in 1911:

"The Bighorn Wasatch occupies a structural depression, the floor of which was modified by erosion subsequent to the main uplift of the Bighorn Mountains, occuring after the deposition of the Fort Union. At several points where the pre-Wasatch floor can be seen, the basal conglomerate or sandstone of the Wasatch rests on a level surface carved across the uptilted edges of Fort Union beds. A splendid section, showing the contact, may be examined on Antelope Creek, about two miles southwest of the town of Basin. ... A yellow-brown quartzose sandstone forms the basal member of the Wasatch, succeeded by yellow-weathering blue clays, frequently lignitic, interstratified with narrow, pale pink clay bands and occasional sandstone lenses."

Sinclair and Granger pointed out that Fisher, in his earlier work, had incorrectly identified the underlying sediments when he stated that the Wasatch rests unconformably on the Cretaceous. His Cretaceous ("Laramie"), at the head of Dry Cottonwood Creek on the western margin of the basin, is probably the Fort Union (Paleocene) mentioned by Sinclair and Granger. The latter two writers estimated a total thickness of 1,000 feet for the "Big Horn Wasatch", and, in the paper quoted from above, gave (pp. 106-107) a detailed description of the sediments assigned to the "Big Horn Wasatch":

" ... this formation is composed largely of clays varying in texture from fine and unctuous to slightly gritty from intermixture with quartz sand, and in colors from pale blue-green through mottled pink and blue to pale pink, bright red and faded purple. Interstratified with the clays are lenses of yellow-brown, blue and gray quartzose sandstone, usually with a calcareous cement but often quite unconsolidated, crumbling at the slightest touch. The lower levels are of a predominatly bluish to yellowish tone, ... but pink, red and purple banding is by no means absent. At higher levels the red banding predominates ...

* * *

"Calcareous concretions are exceedingly abundant, especially in the red clays ...

"Without exception, the Wasatch sandstones are predominatly quartzose .... In addition to quartz, much feldspathic material is present, usually in an advanced state of kaolinization."

In the following year (1912) Sinclair and Granger published another

paper on the Big Horn Basin. Here they stated (277: 62) that Lommis' section "from near Meeteetse to the top of Tatman Mountain", measured in 1907 (153), did not, as purported, show the "character of the Wasatch deposits", but included the Fort Union, "Bighorn Wasatch", Wind River and Tatman formations. Sinclair and Granger added (p. 63):

"The only change in our previously published diagrammatic section across the Bighorn basin /276: fig. 2B/ necessitated by the work of the past summer is the separation from the Wasatch of 400 to 600 feet of beds immediately beneath the Lambdotherium zone, which, it is now believed, belong to the Lysite."

It is apparent from the remarks quoted, that the name, Wasatch, as applied by Sinclair and Granger in the Big Horn Basin, was not intended to include the Wind River horizons (Lysite and Lost Cabin). The reasons for this usage are not clear. It would seem that if the name, Wasatch, is to be used in the Big Horn Basin at all, it is most logically applicable to the lower Wind River horizon (Lysite), because this horizon is the only portion of the Big Horn Basin section that has been definitely correlated with any portion of the typical Wasatch of southwest Wyoming.

In 1917 Hewett and Lupton applied the name, Wasatch, to strata in the south part of the Big Horn Basin, including in it the Greybull, Wind River and Tatman beds of Sinclair and Granger. They stated (123: 29-30) that the beds attain a probable maximum thickness of 2,500 feet and that

"In areas of pronounced unconformity the basal beds contain lenses of conglomerate and gravel composed of the rock types represented in the Fort Union formation and of limestone and pale-red granite. In the matrix of the gravel angular feldspar is an important constituent. The higher beds contain gritty calcareous sandstones and numerous alternations of drab, olive, and red sandy clay. ... A very striking feature of the formation is the lenticular character of each of the beds, the succession in one badland area rarely being the same as that in an adjacent area."

Hewett described the "Big Horn Wasatch" in some detail in 1926. The area covered in his report comprised the Oregon Basin, Meeteetse and Grass Creek Basin quadrangles. In this area he found (128: pp. indicated) that

"Beds of conglomerate and coarse sandstone are uncommonly abundant in the formation ... ... there are more beds of conglomerate and the beds are thickest in the region east of Greybull River from Meeteetse to Sleeper's ranch." (p. 40)

* * *

"The varieties of rock in the Wasatch conglomerates correspond so closely with those of the underlying Fort Union beds that ... there can be no doubt that the one is largely derived from the other. The additional varieties in the Wasatch, granite and limestone, indicate that the streams were also bringing down new material. The /derived/ fossils that have been recognized in the Wasatch limestone pebbles indicate that part of the sediments were derived from older and more deeply buried beds than

those which supplied the Fort Union chert pebbles ..." (p. 41)

* * *

"The Wasatch formation underlies a larger area in the Oregon Basin Quadrangle than any other formation ...

"Beds of the formation underlie nearly the entire eastern third of the quadrangle. ...

* * *

"It is estimated that the maximum thickness of beds of this formation in this quadrangle is about 1,200 feet. None of the higher groups of beds recognized farther south are present here.

* * *

"In contrast with the sediments of the Lance and Fort Union formations, those of the Wasatch have a greater range in size and mineralogy, and the beds are thinner, are less persistent, and show a wider range in induration. ...

"A review of the exposures within a 3-mile radius of the Sleeper ranch indicates that the zones of conglomerate that are so conspicuous in the lower 200 feet of the formation southeast of that place do not persist more than one mile northeastward, but that their place in the section is taken first by coarse sand, then fine sand, and finally, farther northeast, by clay." (p. 44)

* * *

"Wasatch beds are found in two parts of the Meeteetse Quadrangle. The largest area lies in the northeast corner and is continuous with the large area in the Oregon Basin Quadrangle. ... Still farther southwest, in T. 46 N., R. 101 W., the beds underlie a large area adjacent to the mountains." (p. 45)

* * *

"Beds of the Wasatch formation are found in two parts of the Grass Creek Basin Quadrangle. A small area lies in the northeast corner, and numerous small isolated areas lie along the western border. ...

"The bed of conglomerate that is mapped as the base of the formation in the northeastern area is a conspicuous feature of the region all the way from the valley of Fifteen-mile Creek to Blue Ridge, which is 12 miles farther southeast. Although the observations of strike and dip on this bed of conglomerate correspond closely with those made on the underlying Fort Union beds, the significance of the conglomerate is shown by the two facts that it contains reworked Fort Union pebbles and that it may be traced into an area where it is unconformable on the Fort Union beds. The maximum thickness of Wasatch beds in this locality is about 500 feet.

* * *

"Although the individual beds appear to be highly lenticular the thickness of the aggregate is rather uniform over the entire area. The minimum thickness of 107 feet is found in Sec. 3, T. 44 N., R. 99 W., and from this point the thickness increases southwestward to 164 feet ... and northward to 300 feet. ... In other words, the formation is thinnest where the altitude of the base is lowest and thickest where it is highest." (pp. 46-47)

Northeast Wyoming, south-central Montana and the Dakotas. -- The Sentinel Butte shale of northeast Wyoming and adjacent parts of Montana and the

Dakotas (see pp. 95-99), has been assigned by some writers to the Wasatch formation, and by others to the Fort Union. The Ulm formation of north-central Wyoming has also been called "Wasatch" by some writers, but has been separately discussed (pp. 104-106) in the present paper.

San Juan Basin, New Mexico and southwest Colorado. -- Outcrops of "Wasatch" deposits in the San Juan Basin of New Mexico have been described by numerous writers. Though not discussed in detail here, brief notes are included to illustrate the wide areal application of the name "Wasatch".

The earliest systematic description of the San Juan "Wasatch" that has come to the writer's notice is that of Cope, published in 1877. Cope stated (41: 14):

"West of the Hogback of Cretaceous No. 3, with an interval of perhaps two miles, at a point just north of the Gallinas Mountain, a sandstone bluff presents a bold escarpment to the northeast. This is the angle of a mass of rock whose eastern face extends southward parallel to the mountain-axis, and whose strata dip first 15°, then 10° south, and soon disappear beneath a similar mass. This series also presents an escarpment to the northeast, and its beds also dip 10° south, nearly opposite the cañon of the Gallinas. This façade rises to from 600 to 900 feet elevation, and is cleft to the base by a deep gorge, the Cañoncito de las Yeguas."

Cope continued with a description of the discovery of these variegated marls, "with their close physical resemblance to the Wahsatch beds of Bear River, Wyoming, together with the evidence furnished by a lower molar of Coryphodon ..." He gave an estimated thickness of 1,200 feet for the "Wahsatch" in the Cañoncito de las Yeguas.

The "Wasatch" of the San Juan region of southwest Colorado was described also by Endlich in 1877 (in Hayden 111: 189-190). He believed that the "Puerco marls" of Cope were present in this region and that they constituted the base of the "Wasatch". It is now known, however, that the "Puerco" (sensu lato) is not present in Colorado (see pp. 60-62). It was Gardner's opinion (83: 711) that Endlich's "Puerco marls" in this region belong to the Animas formation and, perhaps in part, to the "Wasatch". Bauer (10: 277) was of the opinion that Endlich's "Puerco" may be what is now called the Kirtland shale.

In 1914 Granger (88: 205-207) described and zoned the "Wasatch" deposits of New Mexico. He said (pp. 205, 206) that

"The thickness of the Wasatch beds of northwestern New Mexico has been estimated at about 1000 feet and mammalian fossils occur throughout the greater part of the vertical range. The beds have much the same general appearance of those of the Wasatch group in the Bighorn Basin, red, gray, and ochraceous bands of shales and sandstones, and there is no evident unconformity throughout the series. Cope who first explored the region for fossils obtained a collection comprising some twenty genera of mammals but the levels of these specimens, many of which are generic types, has not been known ...

* * *

WASATCH GROUP - Areal Distribution and Lithology

"The upper beds are similar in appearance to the lower except that the red strata are more dominant, a condition which is noted in the Bighorn basin also."

In 1916 Bauer reviewed data on the San Juan "Wasatch". He estimated the thickness to be in excess of 2,000 feet, and said (10: 278):

"It consists of an alternation of conglomerate, conglomeratic sandstone and shale. The basal member of the formation on the San Juan River has a thickness of 80 to 100 feet and consists of a well-indurated conglomeratic sandstone which contains pebbles of crystalline, volcanic, and sedimentary rocks ... This lower member of the Wasatch is separated from a similar member above it by 50 to 75 feet of greenish-gray and yellowish sandy shale and a few thin beds of carbonaceous shale. This alternation of shale and conglomeatic sandstone is repeated many times in the section exposed along San Juan River."

The lithologic characters of the San Juan Wasatch were reviewed and summarized by Reeside (S.354: 44-46) in 1924.

Stratigraphic and Structural Relations

Southwest Wyoming; adjacent parts of Colorado, Utah and Idaho. -- The geologists of the territorial surveys were divided in their opinions of the stratigraphic relations of the "Wasatch" with underlying and overlying sediments. White, in his report of 1878 (in Hayden 113: 34-35) on the geology of northwest Colorado, said that he had been "unable to discover any unconformity between the strata of the Laramie Group, which I have designated as Post-Cretaceous, and those of the Wasatch Group, the earliest of the Tertiary groups proper".

In the same year, Endlich, in the same volume of Hayden's annual reports, said (p. 79) that in the White River district of northwest Colorado, southeast of Rifle Creek Canyon, the "Wasatch" beds are found leaning against the steeply-dipping strata of the "Laramie Group".

Eight years later (1886) White published the results of a study of the relations of the "Wasatch" and other strata in Wyoming, Colorado and Utah. He stated (323: 17) in unequivocal language that

"the strata in the western portion of our national domain form one uninterrupted series from the lowest of the marine Cretaceous formations to the top of the Bridger Group, the uppermost of the fresh-water Eocene series, inclusive.

* * *

"That is, although there are numerous instances of unconformity within the vertical range of the great series in question, especially above the distinctively marine Cretaceous strata, that unconformity in no case involves the whole of any formation of the series. In other words, where unconformity between any two formations, or any two portions of the same formation, is apparent at any one locality, perfect conformity is to be

found at some other localities. The greatest and most complete unconformity in the great series has hitherto been understood to exist between the Laramie and the Wasatch groups; but it is now known that at even this horizon there is perfect conformity within a great area which included a large part of the Territory of Utah."

Meanwhile, Emmons had examined the area of the Green River Basin. In 1887 he said (in King 136: 203) that at the close of *Vermilion Creek time

"there was a slight movement in these beds, in general not sufficient to produce sharp flexures, but causing gentle undulations, and a local nonconformity of deposition with the beds of the succeeding group. This movement was greatest along the flanks of the Uinta Range, notably at Henry's Fork Valley ..."

The following year King (137: 354-355) offered a valuable bit of evidence on the stratigraphy of southwest Wyoming. He observed:

"At the classic locality [of his "Laramie"] which has served to fix a very grave error, namely, at Black Butte Station, the uppermost Laramie beds are found ... There is no angular nonconformity at this locality, and this single fact is always appealed to as proof of the uninterrupted passage of the Laramie beds, with their brackish forms, upward into a conformable series, carrying distinctly fresh-water mollusks, and no longer bearing any trace of brackish-water organisms. Were this locality the sole exposure of the contact-relations of the uppermost Laramie Cretaceous and Vermilion Creek Tertiaries the assumption of their conformability would rest upon solid ground; but on the other hand, in numerous localities along the flanks of the Uinta, upon Oyster Ridge in the Green River Basin, and all along the flanks of the Wahsatch, it is evident from abundant exposures that the relation of conformity at Black Butte is a solitary exceptional instance, and that everywhere else the two series are in absolute angular nonconformity, amounting in some instances to a full right-angle."

In 1879 Peale (in Hayden 114: 635-636) stated:

"Along the southwestern slopes of the Wind River Mountains the Wahsatch beds rest on the granitic rocks, and were evidently derived from the disintegration of the granitic rocks that farther to the eastward make up the main range. ... When these beds were deposited it is evident that a large part of the land had been eroded, for the Mesozoic beds must have been largely removed from the mountains. The red character of the sediments, however, is due to the wearing down of the red Mesozoic rocks, as the conglomerates of the Wahsatch are cemented by siliceous material, the predominating color of which is red. The red color, however, is more marked farther from the mountains, where the sediments are finer."

Schultz published a paper in 1914 on the geology and geography of an area which comprised most of Lincoln County, in western Wyoming. His summary (250: 77) of the diastrophic history of the region was as follows:

"The main disturbance giving rise to the structural features in this

region occurred near the close of the Cretaceous period, before the deposition of the Evanston, Almy and Knight formations. In the beds of the Almy and Knight [members of the Wasatch] were found fossils of the older beds that had been reworked by the waters and redeposited in the Eocene sea. ... A minor movement also occurred after the deposition of the Evanston and Almy formations. Movement during this disturbance was for the most part along the old lines of weakness, the younger beds being faulted, folded, and tilted in places to dips of 25° to 50° in opposite directions to those of the older underlying beds. Most of the beds, however, were very little disturbed and the two disturbances mentioned had very little effect on the structural features or units of the region."

Veatch, in his paper of 1907 on southwest Wyoming (300), was unable to detect any unconformity between the Wasatch and underlying Evanston formations. Gale, in his paper of 1910 (79) on northwest Colorado and northeast Utah, stated that in some localities the Wasatch is unconformably overlain by beds of the Browns Park formation. In 1914 Woodruff and Day reported (337: 11) "no unconformity indicated" between the Wasatch and Green River formations of northwest Colorado and northeast Utah. In 1910 Ball and Stebinger (4: 196-197) wrote that the "Wasatch" formation, in the east part of the Little Snake River coal field, rests in pronounced unconformity on older beds.

The period of systematic work in the "Wasatch" of Sweetwater Co., Wyoming and Moffat Co., Colorado began in 1920, with the publication of a paper by Schultz on Sweetwater County. Schultz (251: 28-31) named the Tipton shale and Cathedral Bluffs "redbeds" and ranked them as members of the Green River group. In an earlier (1910) paper, (248: 222), he had assigned these two "members" to the "Wasatch", without applying distinctive names to them. Sears and Bradley, working together in northwest Colorado, extended and modified the observations of Schultz. They reached the conclusion in 1924 that the Cathedral Bluffs "redbeds" and Tipton shale are tongues of the "Wasatch" and Green River respectively. They said (263: 97):

"The present southern edge of the Eocene outcrops is determined partly by the original limits of deposition and partly by structure. At the southwest it is marked in part by the great Uinta fault ...; some if not all of the movement along this fault was post-Wasatch. It is possible that the fault between the Cretaceous and the Wasatch rocks, extending from Diamond Peak southeastward to a point beyond East Fork of Vermilion Creek, is a continuation of the Uinta fault, but their relation is concealed by recent debris.

* * *

"In the vicinity of East Fork of Vermilion Creek, northeastward from sec. 4, T.10 N., R.100 W., a zone of clay shales and sandstone near the top of the lower Wasatch grades laterally into gray fissile shale of Green River appearance. Farther north this zone includes beds of low-grade oil shale; it thickens from about 200 feet in sec. 3, T.10 N., R.100 W., to nearly 400 feet in secs. 27 and 28, T.12 N., R.99 W. The method of thickening is illustrated at the base of the fissile shale in secs. 34 and 35, T.11 N., R.100 W., where a long wedge of paper, low-grade oil shale replaces toward the north a band of gray and buff clay shale, and the whole Green River

zone thickens 100 feet in about a mile." (p. 97)

Sears and Bradley also noted (p. 98) that on the east rim of the Bridger Basin there is no interfingering of the Wasatch and Green River formations. The inference is that in regions where interfingering occurs, there was a temporary regression of the lake in which the lacustrine Green River group was being deposited. The interruption resulted in the deposition of sediments of Wasatch type. Aggression of the lake followed, resulting in the deposition of Green River sediments above the Wasatch material.

Sears, who studied the Vermilion Creek region in Moffat Co., Colorado, observed in 1925 (260: 293) that the Tipton tongue of the Green River

"wedges out southward; and the main part of the Wasatch and the upper part, here called the Cathedral Bluffs tongue, merge into a continuous formation comparable to that east of Godiva Ridge. According to Schultz [251: 28-30] the Cathedral Bluffs tongue ... passes northwestward by lateral variation into typical Green River shales."

Sears and Bradley's observations are doubly interesting in view of the fact that Hayden and Cope, who worked with early territorial surveys, had considered the Wasatch and Green River formation as synchronous deposits la laid down in separate basins.

Bradley, in his paper of 1926 on the Green River formation of northern Sweetwater County, Wyoming, (18: 125) concluded that the Wasatch and Green River formations

"interfinger in such a way that the lacustrine sediments of the Green River formation either thin or disappear entirely toward the north, wereas on the other hand the fluviatile sediments of the Cathedral Bluffs tongue of the Wasatch formation thin or even disappear to the south."

Central Wyoming. -- In 1879 Peale noted (in Hayden 97: 89) an erosional unconformity between the "Wasatch" and overlying *Sweetwater group (White River) on the east side of the Wind River mountains. Peale's "Wasatch", however, included Wind River, "Bridger" and "Uinta", and his *Sweetwater group is White River. A similar usage was employed by Darton in 1908 (59).

As late as 1934, Love, who described the geology of the west end of the Owl Creek Mountains, applied the name "Wasatch" to sediments on the border of the Wind River Basin. He stated (162: 12) that

"A great unconformity separates the Wasatch sediments from all the older rocks, which were folded, faulted and so deeply eroded that all the Paleozoic and Mesozoic sediments and the pre-Cambrian crystallines were exposed. The contact between the Wasatch and older rocks shows a relief of at least 2000 feet."

It is probable that most, if not all, of Love's "Wasatch" corresponds to the Wind River formation, the type locality of which is only about 70

miles east of the area he described, while the type locality of the Wasatch is over 150 miles distant, toward the south and west.

Big Horn Basin. -- In 1894 Eldridge, in the report of his reconnaissance of northwest Wyoming, ventured the observations (69: 29):

"Regarding the statement of Dr. Wortman that the 'Puerco and Laramie do not underlie the Wasatch in the Big Horn Basin, but the strata rest upon the older sedimentary rocks,' it is to be remarked that the itinerary of Osborn and Wortman shows a comparatively limited area of exploration, rendered necessary by the special object to be attained by them. A broader examination would have proved the general existence beneath the Wasatch of the Laramie, except in the localities cited in the preceding pages of this report. The Puerco is absent and the Wasatch does locally rest on older formations than the Laramie."

In 1906 Fisher (76: 33) noted an unconformable contact between the "Wasatch" and his "Laramie" (Fort Union, in part) at the west edge of the basin. Washburne found in 1909 (304: 169) that in the south part of the Big Horn Basin the "Wasatch" rests unconformably on the upturned edges of underlying formations, while in other localities "the unconformity is not conspicuous". Sinclair and Granger observed in 1911 (276: 10) that on Antelope Creek, 2 miles southwest of the town of Basin, the Fort Union shales and sandstones dip to the west at an angle of 35°, and that "the Wasatch contact plane also dips westerly, but at an angle of 1°, increasing to 8° toward the easterly margin of the basin". They observed also (p. 106) that the bedding planes of the Wasatch "parallel the slope of the contact plane, increasing with it in dip toward the east. This has probably been produced by an uplift of the Bighorn Range subsequent to the deposition of the Wasatch."

In 1912 Sinclair and Granger stated (277: 61) that

"Although the Eocene beds have been uplifted about the southwest margin of the basin, dipping in general, with the exception of minor flexures, toward Tatman Mountain, we have not been able to find any exposures of the Knight[1] formation in this area. The Wind River horizon (Lysite and Lost Cabin) apparently overlapping unconformably on the Fort Union and entirely concealing the Knight ..."

Hewett, in his paper of 1926 on the Oregon Basin, Meeteetse and Grass Creek quadrangles of the Big Horn Basin, said (122: pp. indicated):

"Where, as on Blue Ridge, there is no unconformity between the Fort Union and Wasatch and they closely resemble one another, the base of the Wasatch is drawn at the lowest conglomerate bed that contains reworked pebbles." (p. 40).

* * *

"The stratigraphic evidence confirms the interpretation by Sinclair

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[1]So-called "Knight" in the Big Horn Basin is now known as the Greybull formation.

and Granger of the major relations of the faunal zones of the Wasatch formation, based on paleontologic studies

* * *

"If this interpretation is correct the 'border Wasatch' was not deposited at the same time as the basal beds of the Wasatch (Knight [= Greybull]) in the center of the Big Horn Basin but much later, possibly as late as the 'Tatman formation' of Sinclair and Granger, which they regard as possibly equivalents to the Bridger formation. The 'border Wasatch' closely resembles the 'Tatman formation' in lithologic features and in yielding no fossils." (p. 41)

* * *

"The base of the formation is traced northward from two localites in the southeast corner of the [Oregon Basin] quadrangle, where the basal beds rest unconformably upon the Fort Union formation. ... The base of the Wasatch formation is the base of a dark zone that is the lowest bed of conglomerate." (p. 44)

* * *

"The unconformity between beds of the Fort Union and Wasatch formations resembles that between the Lance and Fort Union in that although pronounced in part of the area studied it can not be detected structurally in other parts, especially in several areas nearest the center of the Big Horn Basin." (p. 61)

In 1934 Johnson stated (130: 836) that in the west part of the Big Horn Basin

"Subsidence of the Bighorn Basin continued through the Eocene and large amounts of material were transferred from the elevated regions of Paleozoic and pre-Cambrian exposures to the Basin ... ...

"Upon the Wasatch surface, made even by erosion and aggradation, the great mass of Paleozoic limestones of the Heart Mountain overthrust plate moved forward. New lines of drainage established themselves upon the surface of the overthrust plate. During the Oligocene and early Miocene these rivers removed a large part of the fractured limestone of the upper block and had begun to incise the underlying surface, developed in the early Eocene."

San Juan Region. -- In 1916 Bauer (10: 278) gave the following observations:

"The Wasatch formation, which probably exceeds 2,000 feet in thickness in the San Juan Basin, overlies the Torrejon unconformably and overlaps the Ojo Alamo and Kirtland formation.

Paleontology, Age and Correlation

The information compiled under this heading is scanty. The name "Wasatch" has been so widely and loosely applied that, by itself, it has little value as an exact indication of age. In areas where faunal successions have been accurately worked out, the "Wasatch" has invariably been found to comprise two or more distinct faunal zones. Since the Wyoming zones are discussed separately in this paper, it would be redundant to consider in detail their collective paleontologic characters. Since, moreover, the

WASATCH GROUP - Paleontology, Age and Correlation

type Wasatch of southwest Wyoming is, with the exception of the upper Knight member, singularly barren of diagnostic vertebrate remains, it is possible to make only the broadest generalizations concerning the age of the group as a whole. The following passages from Hayden's and King's reports are indicative of stratigraphic methods and the state of knowledge during the latter part of the 19th Century.

Hayden remarked (105: 148) in 1869 that

"Both the Bridger and the Green River Groups have yielded many organic remains, but the Wasatch Group, although it occupies a very large area ... has never, to my knowledge, afforded any distinct paleontologic evidence of its age."

Hayden, in the type description of the Wasatch in 1869, had referred it to the Miocene, but King stated (137: 355-356) in 1878 that the *Vermilion Creek series ("Wasatch") contained a remarkable abundance of fresh-water mollusks, and that

"in beds very near its base, certainly down 4,400 feet in the series, have been found, as will appear under my description of the Eocene, an extended vertebrate fauna readily to be correlated with a horizon recognized in England and on the Continent as characteristic of the lowest Eocene. We have then, over the Miocene of Hayden a nonconformable body of 5,000 feet, all of whose vertebrate remains refer it to the lowest Eocene; and I may add ... that this 5,000 feet of lowest Eocene is overlaid by 4,000 feet more of middle or upper Eocene [Green River] whose abundant vertebrate remains are of unmistakable Eocene type."

King also recorded the finding of "several bird bones from a coarse, gritty, buff sandstone" from the "higher Vermilion Creek beds" north of Diamond Mountain. He had also found (p. 373) remains of the invertebrates, Melania and Goniobasis, as well as the mammal, Coryphodon, in the localities of Bear River City and Evanston.

Bradley, in his paper of 1931 on the Green River formation stated (22: 8), concerning "the Wasatch formation of lower Eocene age":

"In the vicinity of Evanston, Wyo., it is characterized by fossils from the Heptadon[1]-Coryphodon-Eohippus zone.[2] As indicated by the fossils of these life zones the Wasatch formation of the Uinta and Piceance Creek Basins is equivalent to that in the Bridger Basin. It is also correlative with the 'Sand Coulee' and 'Grey Bull' horizons of the Wasatch formation in the Big Horn Basin."

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[1]"Heptadon" = Heptodon.

[2]This zone is the 8th of Osborn's 17 life zones (224: 9). The zone, however, includes only the Knight member, not the whole of the type Wasatch (see tables, pp. 51, 64).

WASATCH GROUP - Paleontology, Age and Correlation

Bradley's statements of chronologic equivalence are confusing. According to Osborn (224: 12) the Heptodon-Coryphodon-Eohippus zone is represented in the Lysite member of the Wind River in the Big Horn Basin. The *Sand Coulee (now included in the Greybull) is called the Eohippus-Coryphodon zone, and the Greybull proper is the Systemodon-Coryphodon-Eohippus zone. Systemodon made its first appearance in *Sand Coulee (lower Greybull) time.[1] Osborn (224: 67) called the Knight formation the Heptodon-Eohippus zone, a name which he applied also to the Lysite stage of the Wind River. Bradley's reasons for correlating the Knight with the *Sand Coulee and Greybull are decidedly obscure. In the Big Horn Basin, though the faunas are relatively well known, the *Sand Coulee and Greybull have not yielded remains of Heptodon, which made its first appearance in Wind River time. Coryphodon and "Eohippus" both range throughout the known lower Eocene, and hence are of only general value as index genera. The most reliable time-indicator in the Knight is Heptodon, which as above stated, is unknown in the Greybull. Still more significant is the fact that the typical Greybull beds, though originally assigned to the Knight formation and described under that name by Sinclair and Granger (277: 59-63) in 1912, were later set off and given the distinctive name, Greybull (Granger 88: 203), because the fauna was found to be distinctly older than that of the Knight. All subsequent work has substantiated this conclusion (see pp. 115-120, ante). It would seem then, that Bradley's correlations are amenable to revision.

Fossils, particularly mammals, have been found in abundance in the "Big Horn Wasatch". Fisher stated (76: 33, 34):

"The Wasatch beds contain an abundant mammalian fauna. The fossils are generally found in the clays, although their occurrence in the sandstones is not uncommon. The best collecting grounds observed were on the badlands slopes northeast of McCulloch Peak, but fossils were found all along the divide between Shoshone River and Dry Creek.

* * *

"Capping some of the highest areas in the central part of the Bighorn basin, especially that part lying south of Gray Bull River, are brown, leaf-bearing, sandy shales and gray sandstones, which have a total thickness of about 600 feet. ... A number of fossils were collected from the sandstones of the formation in the vicinity of Squaw Buttes."

An examination of the fossils by T.W. Stanton, Fisher said, led to the conclusion that the horizon was Eocene, but whether Wasatch or Bridger could not be determined. The description indicates that these later beds "of the highest areas" are the Tatman formation.

In 1915 and 1918 Matthew and Granger, listed, described and illustrated (195: 1-103)(196: 429-483)(S.359: 565-657) portions of the mammal faunas of the "Wasatch" and Wind River formations. These papers include references to, or descriptions of, the majority of the fossil mammals of the North

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[1]"Systemodon" = Homogalax. Homogalax has been found in the *Sand Coulee horizon (Jepsen 129: 119), though at the time Osborn's momograph was written it was believed to be confined to the Greybull, as then defined.

WASATCH GROUP - Paleontology, Age and Correlation

American Eocene known at the time of publication, within the orders and families described. The known fauna of the Wasatch and "Wasatch", complete to 1909, had been previously listed by Matthew (in Osborn 219: 92-95).

Cockerell and Henderson (29: 230) listed the land mollusc Oreohelix megarche Cockerell and Henderson, from the "Bighorn Wasatch" three miles southeast of Otto.

Concerning the age and general correlation of the Wasatch in the Oregon Basin, Meeteetse and Grass Creek quadrangles, Hewett said (122: pp. indicated):

"In the areas of the Wasatch formation nearest the center of the Big Horn Basin many varieties of vertebrate fossils have been found. ... beds near the base of the formation in sec. 14, T.51 N., R.100 W., have yielded a large number of fossil plants which F.H. Knowlton considers characteristic Fort Union species." (p. 41)

* * *

"In other parts of Wyoming Fort Union plants are found associated with Wasatch vertebrates and the Wasatch formation is not known to have a distinctive flora.

* * *

" ... the beds have been identified over a large area of western Wyoming, eastern Utah, and eastern Idaho. It is interesting that until 1915, when vertebrate fossils characteristic of the Wasatch formation were found in the Powder River basin, east of the Big Horn Mountains, the presence of an equivalent of the Wasatch formation in the Great Plains province was suspected only by a few. The Eocene deposits of eastern Wyoming, eastern Montana, and the Dakotas have long been included in the Fort Union formation on the basis of the fossil plants which they contain." (p. 61)

* * *

" ... the 'border Wasatch' in these three quadrangles is not the equivalent of the beds at the base of the Wasatch formation in the northern part of the Big Horn Basin but the equivalent of beds high in the section in the central part of the basin, possibly those near the top of McCulloch Peak [Tatman formation] correlated with the Bridger formation.

"Even though the bedded tuffs in the southwest corner of the Grass Creek Basin quadrangle rest conformably upon the underlying 'border Wasatch' beds, their age would be obscure if studies in the region west of Cody had not shown critical evidence of their relations. The work of Dake [1918] supplemented by that of the writer, indicates that these tuffs are the equivalent of the early acid breccia of the Yellowstone Park region [Hague S.340: 3-6] of Eocene age, and yet neither the oldest nor the youngest Eocene in the area.

"Except for the brief periods when the thin layers of gravel have been deposited on terraces, erosion has been steadily at work in this region since the tuffs were laid down." (p. 62)

Berry said (12: 57) in 1930:

"Although Osborn [219: 43-44] ... correlated the Wind River with the upper Wasatch of the Big Horn Basin and the lower Huerfano of Colorado, I

believe all three are somewhat younger than the position usually assigned to them by vertebrate paleontologists, and this point comes within the province of paleobotanic correlation when the Green River section is compared with that of the Atlantic Coastal Plain and with the Standard European section."

Almagre and Largo members. -- In the neighborhood of Gallina, Ojo San Jose and La Hara, New Mexico, Granger studied the New Mexico "Wasatch" and found it to be divisible into two faunal zones, which he named the Almagre and Largo beds. His description (88: 205-206) was in part as follows:

"The fauna as a whole presents a rather different facies from that of the Bighorn Wasatch. Particularly to be noted ... is the absence in the New Mexico beds of all Perissodactyls, with the exception of Eohippus, which is very abundant. This difference in fauna ... makes it advisable, it seems, to use distinct horizon names for the New Mexico beds. The fauna falls into two divisions, the upper one, characterized by the Condylarth genus Meniscotherium, resembling the Lost Cabin fauna in general,[1] and the lower one with characters of both the Lysite and Gray Bull. The lower horizon, comprising roughly the lower two-thirds of the New Mexico Wasatch, may be referred to as the Almagre beds and the upper horizon, comprising the remaining third, the Largo beds. The division between the two horizons as indicated by the first appearance of Meniscotherium is found about fifty feet above the low divide which separates the headwaters of Largo Canyon and the southwest branch of Almagre Arroyo, about five miles northwest of Ojo San Jose. The Almagre beds are exposed over the greater part of the Almagre watershed and also at the head of Arroyo Blanco ... The Largo beds are exposed principally in the area drained by the head of Largo Arroyo, in the high bluff just west of Ojo San Jose, and ... southwest of Ojo San Jose ... The upper beds are similar in appearance to the lower except that the red strata are more dominant, a condition which is noted in the Bighorn basin also."

In 1924 Reeside reported his conclusions (S.354: 47-48) that

"The Wasatch formation of the San Juan Basin contains in the higher beds the fauna that in the stricter sense of the name is considered characteristic--that with 'Eohippus and its associated forms, which include lemuroids, rodents, and artiodactyls'. It contains also in the basal 'Tiffany' zone a fauna intermediate between that of the Torrejon and that of the younger Wasatch beds--intermediate in the sense that it associates genera known in the typical Torrejon but not in the typical Wasatch faunas and genera known in the typical Wasatch but not in the typical Torrejon.

* * *

"The assignment of the typical Wasatch to the Eocene has never been questioned. Granger likewise placed his "Tiffany beds" in the Eocene, but

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[1]Granger appended the footnote (p. 206): "The only recorded occurrence of Meniscotherium outside of the New Mexico Wasatch is that of a single specimen of M. terraerubrae, the common species, from the Lost Cabin beds of the Wind River Basin."

Matthew, because of their relations to the Torrejon faunally, proposes to place them with the Torrejon, in the Cretaceous system."

Concerning Reeside's statement that the "assignment of the typical Wasatch to the Eocene has never been questioned", it may be said that he, obviously, did not mean the whole of the typical Wasatch. The lower portion (Almy formation) of the typical Wasatch in southwest Wyoming was studied by Veatch (300: 90) who quoted Knowlton's opinion that "the age should be Fort Union or near it". Moreover, in 1909 Osborn (219: 36) assigned only the upper member (Knight formation) of the Wasatch to the lower Eocene. Some years later (1929) Osborn (224: 66) assigned the Almy and Fowkes members questionably to the "basal Eocene" (Paleocene) though he was in doubt as to the exact position of the boundary between the Paleocene and Eocene.

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PALEOCENE ALMY FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; member of the Wasatch group. The type locality is north of Evanston, Wyoming, on the east side of Bear River.

TYPE DESIGNATION. -- In 1907 Veatch (300: 88, 89), named and described the Almy as the basal member of the typical Wasatch of Hayden. He found that in southwestern Wyoming the Wasatch contains

"(1) a basal member composed of reddish-yellow sandy clays, in many places containing pronounced conglomerate beds, which has been named the Almy formation ...

* * *

"This formation is named from the town of Almy, situated a few miles north of Evanston. It is exposed at this point in the bluffs along the east side of Bear River immediately above the Evanston formation and extends eastward beneath the white beds of the Fowkes formation, from which it is readily distinguished lithologically.

"It consists of yellow and reddish-yellow sandy clays with irregularly bedded sandstones and near the base pronounced conglomerate beds. In the Almy section it has a thickness of 2,100 feet ... The conglomerates are composed of light-colored, well-rounded quartzite and chert pebbles, but contain some sandstones of local origin. These pebbles, both quartzite and sandstone, are very often crushed and recemented ... The matrix of the conglomerate is light-colored, greatly resembling loose mortar."

SYNONYMY. -- (See also synonymy of Wasatch group, pp. 122-123)
The formation was included with undifferentiated Wasatch in descriptions of the type locality written prior to Veatch's work in 1907.
*Bitter Creek group of Powell in 1876 (229: 45-47, 64-66, 162-166), included strata now called Almy formation.
"Laramie" of Emmons in 1877 (in King 136: 330), and of King (137: 373) in 1878 included the Almy.

ALMY FORMATION - Specific and General Information

SYNONYMY (cont'd)
"Laramie" of White (319: 721), and his *post-Cretaceous rocks (after 1877), throughout his writings, included the Almy.

DISTRIBUTION. -- Southwest and west-central Wyoming; adjacent parts of Utah and southeast Idaho.

IMPORTANT REFERENCES. -- Veatch (300: 88-89); Schultz (246: 366), (250: 71-72); Mansfield (166: 109).

GENERAL INFORMATION

Areal distribution and lithology. -- Schultz, in 1908, reported on the geology of an area, then in Uinta County, which, since 1912, has been in Lincoln County. He showed (246: 366) a generalized section of the rocks in the Labarge oil field of east-central Lincoln County in which are represented 500 feet of the Almy formation, resting conformably on the Evanston, unconformably overlain by the Knight member of the Wasatch, and consisting of "red and yellowish-white conglomerates, sandstones, and sandy clays".

In his Lincoln County paper of 1914, Schultz said (250: 71):

"The Almy formation in this area consists for the most part of pronounced conglomerate beds. Some of the pebbles are angular and irregular; others are well-rounded and uniform. In some localities, as east of Thompson Plateau and on South Piney Creek, they are deep red and are associated with irregularly bedded sandstone and reddish clays, whereas at other localities, as on Snake River and east of Lookout Peak, they are light-colored and are associated with light-colored sandstone. The color seems to be very irregular and often the reddish conglomerate is found within a few miles of the light-colored beds. The thickness, as well as the relation to the overlying and underlying formations, is difficult to determine. The thickness approximates 2,500 feet ..."

Schultz added (pp. 71-72) that

"At the north end of the field this conglomerate lies along the south flank of Gros Ventre Mountain, extends west over Hoback Range, and occurs in the Snake River bottoms. Conglomerate beds were also observed near the southwest corner of the area. The contact between the conglomerate and the overlying nearly horizontal Knight formation is not very distinct ..."

In the paper quoted Schultz described Almy beds in the following parts of Lincoln County: east of the Thompson Plateau; along South Piney Creek and Snake River; Lookout Peak; east flanks of Wyoming and Hoback ranges; south flank of the Gros Ventre Mountains; near Bear River Valley; east and south of Bear Lake, west of Randolph and Woodruff.

Mansfield (166: 109), in 1927, found it impracticable to distinguish the Almy and other members in southeast Idaho. The Eocene rocks were therefore "mapped and described under the name of Wasatch formation".

ALMY FORMATION - General Information

Stratigraphic and structural relations. -- Veatch (300: 89) observed that along the east side of the Rock Creek-Needles anticline the Almy beds

"have been brought up here and in places highly inclined, by movement along the thrust fault associated with this anticline. These lower conglomerates are along this line unconformably overlain by the almost horizontal Knight beds. An unconformity of over 4,000 feet is thus indicated. Everywhere these Almy beds show pronounced disturbance, and at many places show very distinct angular unconformity with the Knight beds."

In the same paper Veatch (p. 88) recorded his opinion that the Almy and overlying Fowkes formations belong, with the Evanston, "in the conformable series separated on the one hand by a pronounced period of folding and erosion from the Laramie beds [= Mesaverde or Adaville], and on the other from the Coryphodon Wasatch beds [Knight formation] by a period of folding and erosion of great magnitude though of much less importance than the one between the Adaville [Cretaceous] and the Evanston".

Schultz found (250: 71) that in Lincoln County the "strata appear to be conformable on the Evanston formation, the same as in southern Uinta County, although the overlying Knight formation in many places rests unconformably on the Evanston formation and conceals the true relations".

In 1912 Osborn represented (220: 235) an unconformable relation between the Almy and overlying Fowkes in southwestern Wyoming though Veatch stated positively (253: 90) that the two are conformable. Osborn's 1929 section (224: 66) of the "typical Wasatch group of Hayden", represented the Almy and Fowkes formations as conformable (see table, p. 125).

Mansfield, in his paper on southeastern Idaho, in 1927 stated (166: 109):

"G.B. Richardson and later P.V. Roundy and the writer have examined parts of the field described by Veatch. ... the Fowkes formation may in reality be a lens and ... the postulate of unconformity between the Knight and Almy formations, which closely resemble each other lithologically, may not be compulsory. More extended study of the Tertiary formations of the general region of southwestern Wyoming and northern Utah will be necessary before a definite opinion on the matter can be rendered."

Paleontology, age and correlation. -- Veatch remarked (300: 88) that

"The fossils from the Almy and Fowkes have, without exception, been considered Eocene, but the formations are treated with the Evanston because of their very intimate stratigraphic relation to it and the stratigraphic isolation of the Evanston, Almy, and Fowkes from the beds above and below."

He reported specimens of Physa, Planorbis, Aplexa, Valvata and leaves of Platanus, and added(p. 89), "'If correctly determined, the age should be Fort Union or near it.'" At the time Veatch wrote, the Paleocene ("basal Eocene") epoch was not generally recognized in North America, and the Fort Union was called Eocene, rather than Paleocene.

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PALEOCENE(?) FOWKES FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; member of the Wasatch group. The type locality is east and northeast of Almy, Uinta Co., Wyoming.

TYPE DESIGNATION. -- The Fowkes formation was named and described by Veatch (300: 90). His field work in 1905 had shown that the typical Wasatch of southwestern Wyoming, as defined by Hayden, consisted of three members. The lower member, Veatch named Almy formation, in 1907, and said:

"Overlying the Almy formation is a thick series of light-colored beds composed largely of rhyolitic ash containing thin layers of white limestones. These beds are well exposed in the valley east of the Almy hills and thence northward to the Narrows. This formation is named from Fowkes ranch, about 9 miles from Evanston, around which these beds are well exposed. West of Bear River they occur along the base of the hills and show in the numerous cuts on the Chapman canal. South of Evanston along Yellow Creek there are limited exposures, here showing a conglomeratic or agglomeratic phase and underlain by white limestones. Farther north, along Dry Hollow, there are extensive exposures of almost pure ash. This formation conformably overlies the Almy, though the minor movements which occurred before the deposition of the Knight formation may have been initiated in this period and may slightly affect the upper beds."

SYNONYMY. -- The member was included with the undivided Wasatch in papers written prior to 1907.

DISTRIBUTION. -- Southeastern Wyoming.

IMPORTANT REFERENCES. -- Veatch (300: 90-92).

GENERAL INFORMATION

Areal distribution and lithology. -- A passage in Volume I of King's 40th Parallel Survey reports, published in 1878 (137: 608), contains observations on rocks whose characteristics seem to correspond with those of the Fowkes formation:

"About 10 miles north of Evanston, in the neighborhood of some limited Cretaceous exposures, but otherwise altogether surrounded by the nearly horizontal beds of the Vermilion Creek Eocene group [Wasatch], is a small outcrop of rhyolite, far removed from all other volcanic rocks. It is a fine-grained, pumiceous, lavender-colored rock, the groundmass being the ordinary intimate mixture of sanidin and quartz, in which are interspersed laminae of very dark and of brownish mica. The outcrop is only of importance from its wide separation from other volcanic fields, the nearest eruptions being some miles down Bear River in the neighborhood of its great bend."

Emmons (in King 136: 237-238) described deposits near the Fowkes ranch as follows:

"About midway between Evanston and the Narrows of Bear River occurs an outburst of rhyolitic tufa, rising above the foothills of Aspen Plateau,

which is of interest, since it is far separated from any other known occurrence of this rock. In its physical habit it is a uniform fine-grained rock, of an arenaceous, pumice-like texture, crumbling readily, and having a prevailing lavender tint. The ground-mass is an intimate admixture of fragments of feldspar and quartz grains, with thin laminae of dark biotite plates and some bronze-colored mica."

Veatch stated (300: 91) in 1907:

"South of Sage there are three limited exposures of a light-colored pisolitic limestone, which is regarded as lower Wasatch and has been indicated on the geologic map as belonging to the Fowkes. These exposures are located in the northeast and southeast corners of sec. 24 and the southwest corner of sec. 36, T.21 N., R.121 W."

Veatch reported (p. 91) that 5 miles southwest of Evanston a conglomerate is present in the Fowkes:

"The exposure of the conglomerate or agglomerate material is very limited, covering only a few square feet ... It suggests greater proximity to a volcanic vent than the material found at any other point. ... no similar deposits of volcanic origin are reported in the section on Echo Creek, a few miles to the west, and Chalk Creek, a few miles to the south. This appears to indicate that the source does not lie in that direction. There is no evident source for this material, and it is supposed to have been derived from local cones, perhaps comparable to, though older than, those penetrating the Cretaceous and Tertiary beds in the Leucite Hills in Sweetwater County, situated in the region now buried in by Knight deposits south of the Crawford Mountains and immediately west of this region.

" ... They are represented as igneous rocks on the geologic map of the Fortieth Prarllel Survey, which shows such rocks near the present site of Fowkes ranch, and on the geological map of Wyoming by Knight, which shows them in Dry Hollow."

Stratigraphic and structural relations. -- Veatch (300: 88) reached the general conclusion that

"The Almy and Fowkes formations belong, with the Evanston, in the conformable series separated on the one hand by a pronounced period of folding and erosion from the Laramie beds, and on the other from the Coryphodon Wasatch beds [Knight] by a period of folding and erosion of great magnitude though of much less importance than the one between the Adaville and Evanston."

Veatch also noted (p. 90) that opposite Almy on the west side of Bear River, the contact between the Fowkes and overlying Knight "appears distinctly unconformable", and that the Fowkes formation is "entirely absent between the Knight and the Almy east of the Rock Creek-Needles anticlinal".

Osborn (220: 235), in 1912, represented an unconformable relationship between the Fowkes and Almy. Later (1929) Osborn (224: 66) represented the

FOWKES FORMATION - General Information

Fowkes as conformable with the underlying Almy, and assigned the Fowkes a thickness of 2500 feet. Mansfield, who had made observations on the Wasatch in southeastern Idaho, stated that he believed the Fowkes may be a lentil, and that

"In the region considered in this paper the Fowkes formation has not been definitely recognized, although at one locality rhyolitic debris has been found in beds here assigned to the Pliocene(?). It is also impracticable to distinguish the Almy and Knight formations. The Eocene rocks are therefore mapped and described under the name of Wasatch formation."

Paleontology, age and correlation. -- Veatch (300: 88) stated his opinion that the Evanston-Almy-Fowkes succession is stratigraphically isolated by unconformity above and below, that the paleontologic data were not sufficient to decide the question of which system -- Cretaceous or Tertiary -- the sequence belongs to, that the intimate relations of the three formations suggested their treatment together, and that he preferred to draw the Cretaceous-Tertiary boundary at the base of the Evanston.

Veatch said (p. 92) that a small collection of invertebrates had been made from the Fowkes formation on the west side of Bear River, immediately below the Knight beds. The collection included, according to identifications by W.H. Dall, the fossils Planorbis, Planorbula, Physa, Succinea?, Limnaea, Goniobasis, Ancylus and Pisidium. The only vertebrate remains listed were Ganoid fish scales and fish bones.

Cope recorded the vertebrates Trionyx scutumantiquum, Rhineastes calvus and Clastes glaber from an horizon 500 feet below the "Coryphodon zone" in the Knight formation. Veatch was of the opinion (300: 95) that the specimens came from that portion of the Wasatch which he named Fowkes member.

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LOWER EOCENE KNIGHT FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; member of the typical Wasatch group. The type locality is near Knight station on the Union Pacific Railroad, in southwest Uinta Co., Wyoming.

TYPE DESIGNATION. -- Veatch named the member in 1907. He found that in Uinta County the typical Wasatch of Hayden is divisible into three members. The lower two members he named Almy and Fowkes. Concerning the third and upper member he said (300: 92, 93):

"This formation, named from Knight station on the Union Pacific Railroad ..., consists of yellow and reddish-yellow sandy clays, with irregularly bedded yellow sandstones and occasional thin layers of fresh-water limestones in its upper portion. ... Some difficulty was experienced in this

reconnaissance in differentiating the Knight and Green River beds. In a broad way the Knight beds are sandy clays of a predominantly reddish cast, and the Green River beds are light-colored and calcareous. There is certainly a great difference between the characteristic fish-bearing shales of the Green River and the characteristic Knight beds, but the exact line between the two can not always be fixed with certainty. Light-colored calcareous beds occur at several points overlain by the characteristic reddish clays of the Knight, and sufficiently near the top of the formation to raise the question whether they should be considered Green River or Knight.

"Around the type locality these beds are extensively and characteristically exposed."

* * *

"Its estimated thickness in the type locality is over 1,500 feet."

SYNONYMY. -- "Coryphodon Wasatch" and "Bathmodon[1] bone beds" of Marsh and Cope, in various writings = Knight member of the Wasatch.
"Wasatch" of Osborn (214: 73) = Knight formation.
Veatch (298: 549, footnote) conjectured:

> "Certain considerations suggest that the Knight formation may be an exact synonym of King's Vermilion Creek formation, but ... the writer ... has proposed the provisional name 'Knight' pending a study of the Vermilion Creek section."
>
> It appears to the writer that this can be true only in special cases, since King applied the name *Vermilion Creek to the type exposure of the Wasatch and stated that his *Vermilion Creek was a more complete section than the Wasatch. No one, however, has either contradicted or proved Veatch's surmise.

"Knight formation" of the Big Horn Basin, Wyoming, wherever described = Greybull plus *Sand Coulee, as the latter two horizons are now defined.

AREAL DISTRIBUTION. -- In addition to the exposures in the type locality the Knight formation has been identified in Lincoln Co., west-central Wyoming. The exposures identified to date are apparently confined to Lincoln and Uinta counties.

IMPORTANT REFERENCES. -- Veatch (298: 549), (300: 92-95); Schultz (250: 72-73), (246: 366); Osborn (224: 64-67).

GENERAL INFORMATION

Areal distribution and lithology. -- Veatch (300: 93) noted in his description of the typical Knight formation:

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[1] "Bathmodon" is an old synonym of Coryphodon. This is a good example of the disadvantage of naming formations after fossils -- relegation of the fossil name to synonymy. There is the added disadvantage that the fossil may be found above and/or below the stratigraphic limits of the formation named after it.

KNIGHT FORMATION - General Information

"The total thickness of this formation is not known and is difficult to determine exactly, because of its unconformable relations to the underlying beds. ...

"Just east of Cumberland the basal beds of this formation are composed almost entirely of fragments of Aspen shale, indicating the presence of a local beach line and the irregularity of the surface on which these beds were deposited."

Schultz identified the formation in 1908 in the east-central part of Lincoln County (then a part of Uinta County). His generalized section of rocks in the Labarge oil field (246: 366) represents 500 feet of strata in the Knight formation.

In 1914 Schultz rendered another report on an area which included most of Lincoln County. He said (250: 72-73) that the Knight formation

"consists of yellow and reddish clays, yellow and reddish sandstones, and some thin layers of fresh-water limestone. ...

"The Knight formation occurs along the eastern part of the field, east of Meridian Ridge and the Wyoming and Hoback ranges. It apparently grades up, without erosional unconformity, into the Green River formation, the overlap that seems to exist in certain parts of the field probably being due to conditions of sedimentation and to the accompanying minor earth movements. In part of the field the Knight formation was not separated from the overlying Green River formation, and the two have been mapped together as undifferentiated Eocene. About the only differentiating lithologic characteristic between them is that the Knight formation generally consists of reddish sandy clay and shaly sandstone, whereas the Green River formation is light colored and more calcareous."

Stratigraphic and structural relations. -- Veatch stated (300: 95) that

"The dip along Bear River from Evanston to the locality of the 'upper or red-banded Tertiary beds' is for the most part easterly ..."

Veatch reported an easterly dip also in the fossiliferous limestones "in the strata at the head of Bridger Creek, in the hill just south of Sage, and a few miles east of Cumberland."

Schultz (250: 74-75) observed that in the Lincoln County area, "near the south end of the field the Green River formation can readily be differentiated from the underl ying Knight formation, for here the light-colored sandstones of the Green River ... rest conformably on the soft variegated beds of the Knight formation". He noted, however (p. 75), that north of the south end of his field some difficulty was experienced in locating the contact between the Knight and overlying Green River, for "the white calcareous limestone of the Green River, which is so characteristic near the southern part of the field ... loses its identity toward the north and more and more of the white limestone appears in the Knight formation". Concerning the relations of the Knight with underlying formations, Schultz said (p. 72) that "the formation rests unconformably upon the Evanston

formation and apparently unconformably upon the Almy formation, although in places the dips are so nearly alike that the beds appear to grade into one another".

Schultz (246: 366) represented the Knight formation, in the Labarge oil field, resting unconformably on the Almy member of the Wasatch, and conformably underlying the Green River formation.

Paleontology, age and correlation. -- Marsh, in 1877, mentioned (171: 354) "freshwater Eocene deposits of our Western Territories", and said:

"The lowest of these, resting unconformably on the Cretaceous, has been termed the Vermilion Creek, or Wahsatch, Group. It contains a well-marked mammalian fauna, the largest and most characteristic genus of which is the ungulate Coryphodon, and hence I have called these deposits the Coryphodon Beds."

Veatch (300: 95-96), in his paper of 1907, listed the following common fossils of the Knight formation:

Mammals

Coryphodon radians	Eohippus vasacciensis
C. semicinctus	E. index
C. latipes	Coryphodon hematus

Phenacodus primaevus

Other Vertebrates

Crocodilus heterodon	Clastes(?) glaber
Trionyx scutumantiquum(?)	Emys gravis
Emys testudineus	Rhineastes calvus

Molluscs

Goniobasis tenera nodulifera	Viviparus paludinaeformis

The above list was compiled from various sources by Veatch, and he believed (300: 95) that Trionyx scutumantiquum, Rhineastes calvus and Clastes glaber are certainly from what he defined as the Fowkes formation, since Cope recorded them in an impure limestone 500 feet below the Coryphodon zone, which would place them in the Fowkes.

In 1929 Osborn (224: 12) divided what he considered the lower Eocene sequence into five "life zones", as indicated in the following passage and tabulation:

"The long duration of Eocene time is further indicated by the subdivision of the Wasatch (Coryphodon) epoch (the 'Coryphodon beds' of Marsh and Cope) into five lesser time divisions. Thus the term Coryphodon alone no longer serves as the designation of a life zone because Coryphodon is now known to

have survived through at least five life zones":

"CORYPHODON BEDS OF MARSH AND COPE"

9. Lambdotherium-Eotitanops-Coryphodon zone ...	First appearance of the titanotheres in America. "Wind River" fauna of Cope.
8. Heptodon-Coryphodon-Eohippus zone	First appearance of lophiodonts in America. "Lysite" fauna of Granger.
7. Systemodon-Coryphodon-Eohippus zone	First appearance of tapirs in America. "Gray Bull" fauna of Granger.
6. Eohippus-Coryphodon zone	First appearance of horses in America. "Sand Coulee" fauna of Granger.
5. Phenacodus-Nothodectes-Coryphodon zone	Phenacodus extremely abundant. "Clark Fork" and "Tiffany" fauna of Granger. The closing phase of the reign of the archaic mammals of North America, Pantolambda, Coryphodon, Phenacodus.

Zones 5 to 8 inclusive of this tabulation correspond to Osborn's "Big Horn Wasatch" zones A to D, respectively. The Knight formation, according to Osborn's correlation chart (p. 3), is equivalent to some portion of the "Big Horn Wasatch". Zones A to D comprise the Clark Fork, *Sand Coulee, Greybull and Lysite (lower Wind River; Wind River "A") formations. In none of Osborn's correlations did he draw homotaxial lines from the base of the Knight to any portion of any other formation. This fact illustrates the uncertain state of knowledge of the exact equivalence of the typical Knight. Osborn summarized the present knowledge of the chronological equivalence of the Knight in the following passage (p. 65):

" ... the Wasatch stage of mammalian life derives its name from the typical Wasatch group of Hayden in western Wyoming, a single mammal-bearing member of which is the Knight formation ..., 1,750 feet in thickness, containing Cope's types of Eohippus index, E. vasacciensis, Phenacodus primaevus, Coryphodon radians, C. semicinctus, C. latipes. These species of mammals do not represent the oldest Wasatch fauna; they are of the same age as the species found at the 'Lysite' horizon (life zone No. 8) of the Big Horn Basin."

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LOWER EOCENE(?) HIAWATHA MEMBER

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation; member of the "Wasatch" group. The type locality is in the Vermilion Creek Basin in southern Sweetwater County, Wyoming, and northern Moffat County, Colorado.

TYPE DESIGNATION. -- Nightingale (213: 1023) named and described the member in 1930:

"Wasatch formation. -- The Wasatch formation of the Vermilion Creek gas area is divided into two distinct stratigraphic units, the Hiawatha member, of lower Wasatch age, and the Cathedral Bluffs red-bed tongue, of upper Wasatch age. Separating these two divisions of the Wasatch is the Tipton tongue formation, of Green River age. ...

"Hiawatha member (lower Wasatch). -- In this paper the term 'Hiawatha member' is assigned to the Wasatch sediments lying below the Tipton tongue formation of Green River age in the Vermilion Creek gas area. Several hundred feet of sedimentary beds assigned to the Hiawatha member have been examined along Shell Creek, immediately south of the Hiawatha dome, and on Vermilion Creek and its tributaries immediately west of the same structure. In addition some 3,500 feet of sediments have been penetrated by holes drilled for gas. In the absence of micro-paleontological information on the lower drill cuttings, this entire drilled thickness of sedimentary rocks is believed to be lower Wasatch and is assigned to the Hiawatha member. Thus a minimum thickness in excess of 4,000 feet of beds is believed to comprise the Hiawatha member, and it is possible that the maximum thickness may be considerably greater, as the base has not yet been reached."

SYNONYMY. -- In geologic work prior to that of Nightingale the member was included with undifferentiated "Wasatch" or *Vermilion Creek.

DISTRIBUTION. -- The member probably extends into regions neighboring the type locality, but the name has not, to the writer's knowledge, been applied elsewhere than in the type locality.

IMPORTANT REFERENCES. -- Nightingale (213: 1013, 1018-1031).

STRATIGRAPHIC AND STRUCTURAL RELATIONS. -- Nightingale stated (p. 1031):

"In the Vermilion Creek area the Sparks fault offsets Mancos shale of Upper Cretaceous age against Hiawatha beds of Eocene age. The normal stratigraphic interval between these two sedimentary horizons is approximately 10,000 feet. However, this is believed to be much greater than the actual displacement."

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SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Tongue of the Wasatch formation. The type locality is along Laney Rim and Cathedral Bluffs, southwest of Wamsutter, Sweetwater Co., Wyoming.

TYPE DESIGATION. -- Schultz designated the unit in 1920 (251: 28-29), ranked it as a member, and assigned it to the Green River formation:

"The third member [from the top] of the Green River formation consists of red or varicolored conglomeratic sandstone, shale, and clay, to which the name Cathedral Bluffs red beds member is here given, as they are well exposed in the Laney Rim and Cathedral Bluffs, southwest of Wamsutter, Wyoming. These beds overly and are conformable with the Tipton shale ...

* * *

"A thickness of about 500 feet of these peculiarly variegated beds is here [at Cathedral Bluffs] exposed, consisting of fine red, greenish, and purple clays, with a varying admixture of fine white sand. These beds may be traced eastward and southward more or less parallel to the outcrop of the Tipton shale to Little Snake River in northern Colorado.

* * *

"The same beds may be traced southwestward along the Laney Rim to Pine Bluffs, where there are 700 to 800 feet of bright-red and gray clays that resemble more nearly the Wasatch than the Green River formation. The same thickness of red beds prevails along part of the Kinney Rim, to the south, but toward the west, in the vicinity of Pine and Bishop mountains, the beds are much thinner and can be separated from the overlying and underlying shales only with difficulty. Southward along the Kinney Rim the thickness of the red-bed portion of the Green River increases rapidly and attains 1,200 feet at Lookout Mountain (Vermilion Bluff). In this section the Tipton shales are not well exposed, though sufficiently to establish their presence. It seems very probable that farther south the underlying Tipton shale may be absent entirely and the Cathedral Bluffs red beds and the underlying Wasatch may merge into one another much like the Tipton shale and the overlying beds along the west side of the Rock Springs dome."

RESTRICTIONS. -- Schultz (247: 259) (248: 222, 225-226), in 1909 and 1910, had included the Cathedral Bluffs tongue, which was not then named, in the "Wasatch" (see table, p. 18). In the paper in which he named the tongue, Schultz, as above noted, included it in the Green River formation. In 1924, however, Sears and Bradley, in their paper on the relations of the Wasatch and Green River formations in south Wyoming and northwest Colorado, concluded (263: 98-99) that the Cathedral Bluffs "redbeds" were a tongue, and belonged to the Wasatch formation.

SYNONYMY. -- Schultz, in 1909 (247: 259) and 1910 (248: 222, 225-226), correctly included the Cathedral Bluffs tongue in the Wasatch. In a later (1920) report, however, he described it (251: 28-29) as a member of the Green River (see tables, pp. 18, 22).

Sears and Bradley stated (263: 98) in 1924 that the territorial geologists included the intertonguing phase of the Wasatch and Green River formations (Cathedral Bluffs and Tipton shale tongues) in the "Wasatch".

CATHEDRAL BLUFFS TONGUE - Specific and General Information

DISTRIBUTION. -- Southern, western and northern Sweetwater County, and southern Fremont County, Wyoming; Moffat County, Colorado.

IMPORTANT REFERENCES. -- Bradley (18: 122); Nightingale (213: 1023-1025); Schultz (247: 259), (248: 222, 225-226), (251: 28-29); Sears (260: 293, 294), (262: 16); Sears and Bradley (263: 94, 96-100, pl. 24).

GENERAL INFORMATION

In 1920 Schultz included (251: 28) with his type designation of the unit the statement:

"These beds overlie and are conformable with the Tipton shales ... and have approximately the same distribution on the east side of the Rock Springs dome. They have been traced northward from Steamboat Mountain to Oregon Buttes, and Centennial Peak, on the east side of the Continental Divide, and thence nearly as far east as the Tipton shale. They have also been traced along the west side of the Continental Divide as far north as Oregon Buttes and Pacific, in the vicinity of the Wind River Mountains. ... Near the axis of the anticline the red beds lose their characteristics and merge laterally into typical Green River shales so that their identity can no longer be recognized.

"About 4 miles south of the low shale ridge in the vicinity of Red Desert station on the Union Pacific Railroad there is a second line of bluffs, of greater elevation, composed of these striped red beds. To these bluffs Emmons gave the name Cathedral Bluffs, on account of the remarkable buttress-like forms into which their peculiarly variegated beds is here exposed, consisting of fine red, greenish, and purple clays, with a varying admixture of fine white sand."

Sears noted (260: 293) that northwest of Lookout Mountain, in Moffat County, Colorado, "the Cathedral Bluffs tongue of the Wasatch loses its identity and the Tipton tongue merges with the overlying Green River shales".

Bradley, who studied the Green River formation in northern Sweetwater County, stated (18: 125) in 1926:

"Near the head of Alkali Brook the Cathedral Bluffs tongue is about 200 feet thick, but at Steamboat Mountain it is only a little more than 100 feet thick. A more striking example, however, is to be seen in the western part of the area, where the same tongue of fluviatile clay thins from 200 feet in the north until it pinches out completely between the Laney shale member and Tipton tongue of the Green River formation about 16 miles to the southwest."

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SECTION OF TERTIARY DEPOSITS IN THE BEAVER DIVIDE, AT "GREEN COVE"[1]

Age	Formation	Lithology	Thickness (feet)
		Top of divide	
Oligocene	White River group	9. Buff and gray calcareous marls with some coarse sandstone and a little sandy shale. Marls more highly calcareous than No. 8, and toward the top weather out into hard ledges	210
		8. Buff-colored calcareous marls, very uniform in nature except the lower 50 feet where the marls are interbedded with coarse, sandy layers from one inch to two feet in thickness	330
		Erosional unconformity	
Upper Eocene	Uinta formation	7. Coarse greenish sandstone	10
		6. Yellowish green and olive coarse, loosely compacted sandy stones	55
		5. Gray and yellowish clay	27
Middle (?) Eocene	Bridger (?) formation	4. Blue-gray clay and sandstone, forming a prominent ledge along the face of the bluff; weathers nearly vertical	20
		3. Beginning at the base of the main bluff where there is a red stratum corresponding with the one at the top of the butte in No. 2, the rock is pale yellowish brown and alternates between sandy and clayey shales, with coarse sandy beds at intervals. Some layers weather out harder, forming rounded ledges	165
Lower Eocene	"Wasatch" (Wind River formation)	2. A small outlying butte is composed of alternating layers of gray and purplish clays, gray-green sandy shales and strata of coarse sand. Some of the sandy layers weather out salmon-colored	125
		1. One mile out from the foot of the bluff, and resting nearly horizontally on upturned Cretaceous, are sandy clays, becoming more sandy toward the top, and with a two-foot stratum of calcareous sandstone midway. The clays are yellowish, greenish, and purplish (Corresponding level at Barrel Spring contains ?Wasatch fauna.)	140
		Total thickness of Tertiary rocks	1,082
		Angular unconformity	
		Cretaceous (Montana)	

[1]Adapted from Granger, Walter (87), Tertiary faunal horizons in the Wind River Basin, Wyoming, with descriptions of new Eocene mammals: Am. Mus. Nat. History, Bull., vol. 28, art. 21, 1910. Compiled from generalized section fig. 1, p. 238, and notes, pp. 237-239.

The section was reproduced in 1911 by Sinclair and Granger (276: 89-90) for comparison with a more complete section measured at Wagon-bed Spring, several miles north and a little east of Green Cove.

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation. The type locality is in the Wind River Basin, Wyoming.

TYPE DESIGNATION. -- Wind River was first used as a formation name by Meek and Hayden in 1861, in their tabular "general section of the Tertiary rocks of Nebraska [Territory]", which is reproduced on page 65 of this paper. Meek and Hayden (205: 434) added the explanatory note that

"As the Wind River deposits have not yet been seen in contact with any well marked beds of the other Tertiary formations of this region, and few fossils have been found in them, their position in the series remains doubtful. It is therefore only provisionally that we have placed this formation between the Fort Union and White River Groups in the foregoing section. It may possibly belong to the horizon of one of these rocks, or even represent them both in part, or, what is more probable, it may occupy an intermediate chronological position."

In a later publication (1879), Hayden (116: 975) gave a more exact indication of his intended application of the name:

"Throughout the Wind River Valley is a series of beds, of great thickness ... We first observed them near Willow Springs on the North Platte, and thence westward toward the Sweet Water Mountains and near the 'divide'. ... between the North Platte and Wind River they reach a thickness of 400 feet. From this 'divide' throughout the Wind River Valley they occupy the greater portion of the country ... They differ from the other deposits in the great predominance of arenaceous sediments and in the absence of vegetable remains, but they contain fragments of turtles and numerous fresh-water and land shells of the genera Helix, Planorbis, Vivipara, &c. The entire thickness of these deposits may be estimated at from 1,500 to 2,000 feet."

SYNONYMY. -- "Wind River" of Scott (S.362: 409) in 1898 = a partial synonym of Green River.

According to Granger (88: 202), the Wind River collections of Cope and of the early expeditions from the American Museum "were all from the upper horizon, and the name 'Wind River' as previously used, with reference to the fauna, is equivalent to Lost Cabin". Sinclair and Granger stated (277: 62) that the "Lost Cabin formation ... includes all the Wind River of earlier writers". Osborn (224: 69) also has said that the Wind River of Hayden and Cope, = Lost Cabin, and that "the typical Wind River life of all the literature of Cope" belongs to this horizon.

"Wasatch" of Endlich (in Hayden 114: 110) in 1879, on the Sweetwater Divide = Wind River, "Bridger", and "Uinta".

"Wasatch" of Eldridge (69: 26-27), and his "Bridger" (69: frontispiece) in the Wind River Basin in 1894 = Wind River formation.

"Wind River" of Loomis (153: 356-364) in 1907 = Lost Cabin member of the Wind River only. His "Wasatch" includes the Wind River.

"Bridger" of Darton (57: 70) at the south end of the Big Horn Mountains in 1906 may = Wind River.

WIND RIVER FORMATION - Specific and General Information

SYNONYMY (cont'd).

"Wasatch" of Darton (59: 463) in 1908 in the Wind River Basin = Wind River and possibly all or part of the "Bridger" and "Uinta".

"Bridger" of Smith in 1908 (280: 450-451) includes Wind River and Green River.

"Wasatch formation" shown, in northwest Albany County and adjacent areas of southern Wyoming, on the U.S. Geological Survey Map of Wyoming, published in 1925, = Wind River formation.

"White River" formation shown, in the adjacent corners of Carbon, Albany, Natrona and Converse counties, in Wyoming, on the U.S. Geological Survey 1925 Map of Wyoming, includes extensive areas of Wind River formation outcrops.

"Quaternary alluvium, gravel and glacial deposits" shown on the U.S. Geological Survey Map of Wyoming in the Bates Hole region in northeast Carbon County = Wind River.

"Hanna formation" of Dobbin and his associates (62: 142-143) included a small thickness of Wind River strata in the south part of the Rock Creek oil field.

"Wasatch" of Love (162: 12-17), in the west end of the Owl Creek Mountains, probably = Wind River.

DISTRIBUTION. -- Wind River, Big Horn, Laramie and Shirley basins of Wyoming. There are probably other important areas of outcrop which have not yet been studied.

NOMENCLATURAL DIVISIONS. -- In the Wind River and Big Horn basins the Wind River formation has been subdivided into the Lysite and Lost Cabin "stages", or zones.

IMPORTANT REFERENCES. -- Berry (15: 55; includes list of principal explorations and publications on the Wind River Basin); Collier (30: 78-79); Cope (43: 183-202), (44: 9-10), (S.363: 745-748); Granger (87: 235-251), (88: 201-207); Hares (93: 233-279); Hayden (102: 97), (117: 960); Loomis (152: 416-424), (153: 356-364), (157: 217-219); Love (162: 12-21); Matthew (in Osborn 219: 92-95); Matthew and Granger (195: 1-103), (196: 429-483), (S.359: 565-657); Meek (199: LXI); Meek and Hayden (205: 433-434); Osborn (219: 41-48), (224: 48, 57-59, 65-72); Osborn and Wortman (S. 364: 135-144); Peale (in Hayden 109: 148); Sinclair and Granger (276: 83-97, 103-110, 111, 117), (277: 61-67); St. John (in Hayden 115: 175); Woodruff (336: 3-36).

GENERAL INFORMATION

Areal Distribution and Lithology

Wind River Basin. -- In 1869 Hayden noted (102: 79) that near the "divide between the Wind River Valley and the banks of the Platte", outliers of Wind River strata occupy denuded buttes from 200 to 300 feet high, and that "near the head of Wind River they develop a thickness of 1,500 to 2,000 feet".

WIND RIVER FORMATION - Areal Distribution and Lithology

Comstock (in Jones 131: 128) said in 1875 that he had found Wind River sediments in the area between the Owl Creek and Wind River mountains, and north of the Owl Creek Mountains.

As late as 1876 Hayden (109: 24) was not sure of the stratigraphic position of the Wind River and placed it only provisionally in a position between the Fort Union and White River groups, to either of which, he said, it might belong. He had not yet seen the Wind River "in contact with any well-marked beds of the other Tertiary formations". Three years later Hayden again described the Wind River formation, which, he said (117: 960), rested directly on Cretaceous rocks, "near the source of Wind River", in angular unconformity. In a footnote Hayden added the opinion that the Wind River here described = his "Wahsatch group" of 1878.

St. John believed in 1883 (in Hayden 115: 259) that he had identified the Wind River formation in the Gros Ventre Basin, north of the Gros Ventre Mountains and east of the Wind River Range. He suggested that the beds called Wind River formation are either "Wasatch strata or a much later" formation.

Darton (55: 25) remarked in 1906 that

"The Tertiary rocks of the Wind River Basin consist of sandstones, clays, and sandy clays, which in the greater part of the area lie nearly horizontal. To some extent they are cut into bad lands ... They extend to the foot of the Owl Creek Mountains and apparently at one time reached far up the slopes, for several outlying remnants still remain at an altitude of about 8,000 feet in the vicinity of longitude 109°. They are supposed to be underlain by the 'Wasatch' formation in at least part of the Wind River Basin, and this formation may appear in some of the local uplifts which have steeply upturned the Tertiary beds in the vicinity of Muddy Creek. In these upturns a series of conglomeratic beds is exposed in conformable succession with the supposed Laramie formation, all having a nearly vertical dip."

In 1911, Woodruff (336: 23) who examined the Lander oil field of Fremont Co., Wyoming, observed that in that area

"The Wind River formation is composed of sandstone and sandy shale in about equal parts. The sandstone members are lenticular, reaching in places a thickness of 20 feet and a lateral extent of 1 mile, and are composed of subangular grains of quartz, feldspar, and various kinds of igneous rocks. The shale consists of intercalated gray, pink, and red members. Locally a conglomerate containing coarse, moderately well rounded pebbles is the basal member of the formation ... Areally, the Wind River formation is distributed along the northeastern border of the field and in an isolated outlier several square miles in extent lying between Little Wind River and Big Popo Agie River."

In 1910 Granger (87: 235-251) studied in some detail the Wind River exposures in the Beaver Divide, and along Alkali and Cottonwood creeks,

near Lost Cabin in the Wind River Basin. The general results of his examination of the lithology of the Sweetwater Divide section are illustrated in the table on page 159, which is adapted from his own generalized section and notes (87: 237-241). The "Lambdotherium zone" Granger found well exposed along Cottonwood Creek, where he estimated the thickness to be over 350 feet. Granger commented (p. 246) that

"The extent of these exposures is small. They may be traced along Bad Water Creek, above Lost Cabin, for some distance, and probably extend considerably to the westward of Bridger Creek ... It seems not unlikely that these beds may be of the same age as those at the base of the Beaver Divide section."

Finally, summarizing the results of his investigations of the Wind River Basin, Granger said (p. 247)

"1. The Wind River Basin is covered throughout the greater part of its area with beds of the Wind River group, pertaining to the Lambdotherium zone.

"2. Mammalian remains are extremely rare or absent from these beds except in two localities in the northern and northeastern part of the basin, viz., along Alkali Creek and between Muddy Creek and the Owl Creek Mountains.

"3. Lying along the northern border of the Tertiary deposits in the northeastern corner of the basin, between the foot hills and the Lambdotherium beds, apparently older than the latter and with the best exposures along Cottonwood Creek, is a series of strata of 350 feet or more, containing a fauna intermediate between the Lambdotherium zone and the Coryphodon zone of the Big Horn Wasatch, the genera all being common to both zones.

"4. Along the southern border of the basin, on the divide between Sweetwater River and Beaver Creek, there is exposed a thickness of 1,100 feet of Tertiary, a remnant of deposits which undoubtedly extended over a large part of the basin at one time. Three distinct faunal levels, as indicated by mammalian fossils, are exhibited, Lower Eocene, Upper Eocene, and Lower Oligocene, the levels being correlated with (1) the ?Coryphodon Zone of the Wasatch, (2) the ?Diplacodon Zone of the Uinta, and (3) the Titanotherium Zone of the White River. An unconformity exists between the Eocene and Oligocene, but no break in sedimentation was detected in the Eocene series.

"5. Between the Coryphodon and Diplacodon levels are several hundred feet of unfossiliferous beds, the lower part of which pertain probably to the Lambdotherium zone of the Wind River group, and the upper part possibly to the Middle Eocene faunal zones of the Bridger Basin."

Granger's study was followed in the succeeding year by a paper by Sinclair and Granger, on the Wind River and Big Horn basins (276: 83-117). They found (p. 88) that Granger's generalized section (87: 238) lacked important parts of the full lithologic sequence in the Wind River Basin, "probably due to thinning out toward the margin of the basin of

accumulation". Their description of the formation was as follows (pp. indicated):

"The extensive badland area between the outcrop of the Cretaceous at Hudson and the base of the Beaver Divide escarpment is carved from a series of red, reddish-purple, and bluish-green shales (the red and bluish-green colors alternating), unconsolidated arkosic sands ..., and one prominent, though local, band of white tuff." (p. 90)

* * *

"Whether the entire thickness of banded beds between the horizon of the Lambdotherium fauna listed above and the outcrop of the Cretaceous at Hudson is to be regarded as Wind River cannot be positively stated and may be open to question in view of the discovery, in the Bighorn Basin, of the conformable superposition of the Wind River on the Wasatch without any lithologic dissimilarity between them.

"The Wind River Shales. -- These might with equal propriety be termed clays as they readily absorb water, swell and become more or less plastic. They occur in lenticular bands of variable extent and thickness and always highly colored ... Locally, an abundance of calcareous concretions of ball or star shape and radiate internal structure may be present ..." (pp. 91-92)

* * *

"The Wind River Sandstone. -- The Wind River sandstones in the vicinity of the Beaver Divide are stream channel deposits of predominantly arkosic character. ... Not all the sandstone beds are in ... perfectly formed channels, but they are all more or less lenticular in cross section and may show slight erosional disconformity with the clays on which they rest although perfectly conformable above with the next succeeding stratum. In one instance small stems of petrified wood were noted, standing erect in the clay and abruptly truncated by the overlying sandstone. The sandstone here referred to lay directly beneath the white tuff described in the next section and contained scattered water-worn pebbles of a similar tuff in a matrix of small sharply angular fragments of feldspar, both orthoclase and plagioclase, often fresh but sometimes slightly kaolinized, quartz grains, biotite and muscovite foils, hornblende needles, splinters of pink garnet, small dark, opaque grains, probably iron ore and masses of kaolin, probably kaolinized feldspars, the whole cemented by calcium carbonate." (pp. 92-93)

* * *

"The Wind River Tuffs. -- Near the mouth of Big Sand Draw ... and on the east side of the draw, a white tuff band, 13 feet thick, is interstratified with the Wind River clays and sandstones at a horizon considerably lower than that affording the fossils. It rests on a heavy brown sandstone containing rolled pebbles of tuff and is overlain by pale greenish shales. The upper four or five feet of tuff is highly pumiceous ..." (p. 93)

Sinclair and Granger then proposed (pp. 104-105) the names, Lost Cabin formation, for the "Lambdotherium zone" of the Wind River, and Lysite formation for the underlying zone. The type locality of the Lost Cabin member is along Alkali Creek and on the divide between Alkali and Poison

creeks, east of the village of Lost Cabin, in the Wind River Basin. The type locality of the Lysite member is on Lysite and Cottonwood creeks, north of Lost Cabin. The following lithologic section of the Lysite zone, was given by Sinclair and Granger (276: 105):

Yellowish and gray sandy shales covered with a heavy mantle of pebbles from the older rocks of the mountains . . . . . 50 feet
Alternating buff sandstones (1 ft. to 5 ft. in thickness) and red and blue-gray shales . . . . . 200 "
Gray and dark brick red sandy shales (red predominating) and gray sandstone . . . . . 100 "
Dull colored, deeply disintegrated clays with some feldspathic sandstone and much gypsum . . . . . ?
Pre-Tertiary rocks of Bridger Range.

In 1914 Granger (88: 201-207) summarized accumulated information on the Tertiary formations of the Wind River and Big Horn Basins. In 1920 Collier (30: 79) estimated a maximum thickness of 500 feet of the Wind River in the vicinity of Big Sand Draw, Fremont County. Condit (33: 16) noted in 1924 that "near the south end of the Wind River Range the earliest Tertiary beds exposed" are apparently the same as the Wind River beds to the north. In 1934 Bauer published a paper on the Wind River Basin and described the Wind River formation in some detail. Bauer's conjectures concerning the thickness of the Wind River formation are of interest:

"The total thickness of Wind River strata exposed in the southeastern part of the basin does not exceed 1200 feet. Inasmuch as the formation was laid down on an eroded surface which, apparently, had reached maturity, this lower zone is variable in thickness. However, its maximum thickness probably does not exceed 2,000 feet in the Wind River basin, which, with 800 feet for the upper zone, makes an estimated maximum of 2800 to 3000 feet for the formation. The Wind River (Wasatch) formation of the northwest extension of the basin has not been measured by the writer, but from casual examination it seems probable that the upper zones are thicker between Crowheart Butte and Dubois so that the entire formation may approximate 4000 feet of sediments in the narrow trough separating the Wind River Range from the Owl Creek Mountains."

In the same year Love (162: 12-17) applied the name, Wasatch, to from 0 to 1,500 feet of arkosic grits, variegated shales and interbedded volcanic extrusive flows, exposed at the west end of the Owl Creek Mountains. These sediments are probably assignable to the Wind River formation. Love's observations have been discussed under the heading, Wasatch group (pp. 139-140).

Big Horn Basin. -- It was shown by the paleontologic notes of Loomis in 1907 (153: 357, 362) that the Wind River formation is present in the Buffalo Basin, a minor depression within the Big Horn Basin, where he collected 5 specimens of *Lambdotherium popoagicum*. According to Sinclair and Granger (276: 109) the upper 325 feet of the upper 1,000 feet of Loomis' section of the "Wasatch" (153: 360), belong to the Lost Cabin stage of

WIND RIVER FORMATION - Areal Distribution and Lithology

the Wind River[1], and the fauna of the Lysite stage "may occur in the 600 feet of sparingly fossiliferous beds between the Lambdotherium zone and the richly fossiliferous Wasatch".

Concerning the lithology of the Wind River formation in the Big Horn Basin, Sinclair and Granger said (276: 109) in 1911 that

"There is no lithologic difference by which the Wasatch and Wind River can be separated. Sedimentation seems to have been a continuous process, the fauna alone changing. A coarse-grained pebbly sandstone occuring at a level above the second specimen of Lambdotherium secured by us is worthy of special mention from the insight it affords regarding the source of the Wind River sediments. It is a feebly coherent rock with much calcium carbonate cement, composed of small pebbles and angular fragments of brown and salmon-pink quartzite, white and black chert, banded chalcedony, micaceous sandstone, quartz-feldspar and mica-feldspar pegmatite, a few fragments of what seem to be a much decayed igneous rock, several flattened pebbles of light-colored shale with dendrites, a small silicified gastropod shell (pre-Tertiary), mica foils, numerous quartz grains angular to round with crystal facets and often doubly terminated, secondary quartz obscuring the original surface of the round grains, abundant feldspar, dull white but not soft and crumbly, many deeply kaolinized particles, and a few splinters of pink garnet, an association of materials derived manifestly, in greater part, from the Palaeozoic rocks of the Bighorn or Bridger-Owl Creek Mountains."

Sinclair and Granger (277: 62) announced in 1912 that the Lost Cabin member of the Wind River is also present in the Big Horn Basin:

"On the north side of the Gray Bull-Fifteen-mile divide southwest of Tatman Mountain the deeper cutting of the former stream has incised its valley in the Knight formation[2] while on the divide and to the south and southwest of it younger beds occur. The Lost Cabin formation is exposed on the Gray Bull -- Fifteen-mile Divide and on all sides of Tatman Mountain where it may be readily located as the uppermost 325 feet, more or less, of red-banded beds immediately beneath the yellow lignitic shales of the Tatman formation. It extends across Buffalo Basin to the south of Tatman Mountain and may be found in a similar position beneath the Tatman formation both to the north, south and east of Squaw Buttes."

The Big Horn Basin exposures of the Lysite member of the Wind River were described by Sinclair and Granger (277: 62) as follows:

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[1]Sinclair and Granger state (276: 109, footnote) that beds No. 4-11 of Loomis' "Wasatch" section (153: 360) = Wind River.

[2]"Knight" formation in the Big Horn Basin = Greybull horizon (see pp. 117-118, ante).

WIND RIVER FORMATION - Areal Distribution and Lithology

" ... the Lysite formation ... forms the great field of badlands to the south of Tatman Mountain. Its thickness ... is probably not in excess of 600 feet and may be less. Like the Lost Cabin formation above it, it can be separated from the older Knight formation [= Greybull] only by the fossils it affords. In the Gray Bull valley it may be found in any of the long draws south and southwest of the McFee ranch about five miles below the YU ranch house where it is represented by brick-red and bluish shales interstratified with sandstone lenses, affording sections indistinguishable from those in the type locality on Lysite Creek and Cottonwood Draw north of Lost Cabin in the Wind River Basin. On the north side of Tatman Mountain south of St. Joe post-office it undoubtedly is represented by all or part of the 600 feet of sparingly fossiliferous beds between the Lambdotherium zone and the top of the Knight formation with its abundant remains of Eohippus. It probably caps the high ridge south of Elk Creek also. At Fenton, the Gray Bull [River] has cut below the base of the Lysite, exposing the Knight."

Sinclair and Granger (277: 63-64) said that gravel lenses interstratified with coarse yellow-brown sandstone in the Wind River formation

"have been seen at many localities in the Lysite and Lost Cabin formations throughout Buffalo Basin where the pebbles seem to increase in size toward the south and southwest, due, undoubtedly, to the fact that we are there approaching the source of supply of the material composing the gravels. These gravels are, unquestionably, channel deposits ... Gravels predominate in the southwestern portion of this trough simply because the Lysite and Lost Cabin formations, in which they occur most abundantly, have been removed by erosion farther east by the deep cutting of the Bighorn ..."

Sinclair and Granger (277: 67) found that the Wind River formation is confined to the southwest portion of the Big Horn Basin and has been removed elsewhere, with the possible exception of the McCulloch Peak area, by erosion.

Southern Wyoming. -- Knight (unpublished manuscript) described exposures of the Wind River formation in south Wyoming in the Cooper Lake Basin region, T's. 18, 19 N., R's. 78, 79 W. The Wind River outcrops, identified by Knight on the basis of unmistakable paleontologic evidence, are shown as "Wasatch" on the 1925 Map of Wyoming of the U. S. Geological Survey. The Arlington terrace outcrops were included in the Hanna formation by Dobbin and co-workers (62: 142-143, pl. 43) in 1929. A representative section of the Wind River exposures in the Cooper Lake Basin region shows the following lithologic characteristics (section measured by Dr. S. H. Knight, Director of the Geological Survey of Wyoming, and published with his permission):

WIND RIVER FORMATION - Areal Distribution and Lithology

Partial Section of the Wind River Formation
As Exposed on the South of Cooper Creek, sec. 12, T.18 N., R.76 W.

Lithology	Thickness (feet)
Terrace gravels	3
Gray, brown, and purplish-red shale	12
Fine-grained gray and brown sandstone	2.5
Variegated, gray to maroon shale	2
Gray to brown massive sandstone	10.75
Gray to white gravel conglomerate	5.5
Gray to brown resistant claystone	10.75
Gray to brown sandy shale	5
Gray, yellow and purplish-red claystone	5.33
Arkose grit and gravel; cross-laminated; *Coryphodon* teeth	7.33
Ferruginous gray shale	4.67
Variegated shale, gray to reddish-purple	12.5
Gray, yellow, and red shale; *Hyracotherium*	6.33
Gray, arkosic friable sandstone	3.5
Purple, red, and gray thinly laminated shale	3
Total thickness	93.91
Basal beds not exposed	

Knight (unpublished manuscript) furnished the additional observations that

"South of the above section beds higher in the succession and aggregating 100 or more feet in thickness, form the terrace between Cooper and Four Mile Creek. Limited exposures of these beds exhibit a succession similar in character to the underlying beds. One of the most characteristic lithological features of the formation is the peculiar purplish red coloring of some of the shale beds. This color is a characteristic feature of the Wind River in its type section. Many of the shale slopes are covered with large crystals of selenite four to six inches in length. A bed of selenite crystals three feet thick is a conspicuous feature in the badland area south of Cooper Creek. Thin seams of yellow jarosite, running parallel to the bedding of the shales are of common occurrence. A bed of carbonaceous shale several feet thick, and containing well preserved plant remains, is exposed in the northwest part of T. 18 N., R. 76 W., south of Cooper Creek."

Sediments unconformably overlying the Hanna formation in the area at the southeast end of the Shirley Mountains, Carbon County, Wyoming, were assigned by Ferren (74: 22) to the Wind River(?) formation. Although a careful search was conducted by Ferren, no fossils were found in these strata. Because of the stratigraphic position and lithologic resemblance

to known Wind River strata, described by Knight, in the region farther south, Ferren tentatively assigned these strata to the Wind River formation. He recorded a thickness of from 0 to 75 feet, and said that the strata "consist chiefly of variegated coarse sandy clays and shales, and irregular, unconsolidated sands and arkoses".

In the eastern part of the Little Medicine district in the northeast portion of the Laramie Basin, Konkel found erosion remnants of Wind River sediments. The maximum thickness recorded by Konkel (142: 24-25) was 314.5 feet. He found the Wind River to consist mainly of "grit, and brown and black carbonaceous shales", and variegated shales.

Extensive exposures of the Wind River formation were found by Peterson in an area extending from the north side of the west rim of Shirley Basin to the north side of Bates Hole, in the region north of the area described by Ferren, and adjacent on the west to the area described by Konkel. Peterson found that in his area the Wind River formation

"consists essentially of alternating layers of conglomerate, arkosic grit, coarse lenticular sandstones and variegated shales or clays. In some localities ... a conglomerate zone was present near, but never at, the base ... This conglomerate contains boulders of ... igneous, as well as sedimentary rocks. Most of the boulders range from 4 to 18 inches in diameter, but in the vicinity of the western rim of Shirley Basin some of them attain a size of five feet in diameter."

Thin surface exposures of the Wind River formation were mapped by Giddings (84: pl. 11) in 1935 in Albany County, northwest of Medicine Bow. The only important outcrop of the Wind River formation in this area extends in a narrow belt from the south-central portion of T. 24 N., R. 75 W., to the north-central portion of T. 25 N., R. 74 W. Diagnostic Wind River vertebrates were not found by Giddings, but the sediments were assigned to the Wind River formation because of stratigraphic and lithologic continuity with Wind River strata identified and mapped by Peterson and Konkel in adjoining areas to the north and northwest. Giddings said (84: 35):

"The Wind River nowhere attains a very great thickness. The thickest exposures are along the west side of the North Laramie River in the north-central part of T. 25 N., R. 74 W. Here the rock is composed of pebbles and cobbles in a white and buff sandy matrix. ... At the surface are granite boulders of great size, 10 to 20 feet in maximum diameter. These become less numerous and decrease in size to the southwestward, where they disappear at a distance of five or six miles. The boulders appear to belong in the Wind River, though the relation they bear to the formation is not certainly known.

"The Wind River ... is very thin, less than 50 feet as seen at most escarpment exposures."

WIND RIVER FORMATION

Stratigraphic and Structural Relations

Wind River Basin. -- In 1911 Woodruff (336: 23) recorded that in the Lander oil field of Fremont Co., Wyoming the Wind River formation "rests unconformably upon the strata below and has been slightly tilted from the horizontal", and that "it was deposited in Eocene time but subsequent to the deformation which warped the Fort Union beds, as determined by the evidence of fossil plants identified by F.H. Knowlton." In the same year Sinclair and Granger (276: 90) found that the Wind River beds "rest unconformably on the Cretaceous and dip beneath the Beaver Divide escarpment at a low angle (about 1° 15')". Hares (93: 247) stated in 1917 that the beds of the Wind River formation "unconformably overlie all the older formations, including the Cambrian".

In 1934, Bauer reviewed the structural and stratigraphic relations of the Wind River formation in the Wind River Basin, where, he said (11: 672-673), the lowest sediments in the Wind River are conglomerates and coarse sandstones. Bauer noted further:

"Although observed contacts between the Fort Union and the Wind River show a discordance in dip of only one or two degrees, this break is seemingly profound; it is general around the basin and probably represents an epoch of considerable diastrophism and erosion. Wherever observed in this area the Fort Union formation has been folded or deformed with the underlying Cretaceous. The Wind River formation is less intensely folded. Apparently in the Wind River basin, orogenic processes resumed activity after Wind River deposition; hence, the structure found in this later formation is a more faintly expressed reflection of the older folds and faults."

Love, who wrote on the western end of the Owl Creek Mountains in 1934 (162: 12-17), found that the "Wasatch" (= Wind River) there rests unconformably on Paleozoic and Mesozoic rocks, and that the relief along the contact is as much as 2,000 feet.

Big Horn Basin. -- In 1911 Sinclair and Grander (276: 108-109) recorded no evidence of unconformity at the base of the Wind River formation in the Big Horn Basin, and found that it is conformably overlain by the Tatman formation. In 1912, however, they said (277: 62) that at the southwest borders of the basin, "we have not been able to find any exposures of the Knight formation [= Greybull] in this area, the Wind River horizons (Lysite and LostCabin) apparently overlapping unconformably on the Fort Union and entirely concealing the Knight". On a subsequent page (p. 67) they said that the "Knight" and Wind River are "conformable throughout".

Southern Wyoming. -- Wherever identified in southern Wyoming the Wind River formation unconformably overlies sediments ranging from Paleozoic to Paleocene in age.

Paleontology, Age and Correlation

In 1861 Meek and Hayden listed fragments of the vertebrates Trionyx

and Testudo, and the invertebrates Helix aff. H. leidyi and a "Vivipara sp.", which they were unable to distinguish from their "V. trochiformis from the Fort Benton Group". In 1876 Hayden (109: 24) was unable to add to this meager paleontologic data:

"The only fossils yet found in this formation are fragments of Trionyx and Testudo, together with the shells of two species of Helix and a cast of a Vivipara. One of these Helices is more like H. leidyi from the White River Group than any of the other species yet known from any of these rocks, while the other is a very large depressed species of southern type, quite unlike any of those hitherto found in any of the other Nebraska rocks. The Vivipara seems to be indistinguishable from our V. trochiformis from the Fort Benton Group, though, as it is a mere cast, it cannot be identified with certainty with that shell."

Meek (199: LXI), in the same year was unable to improve upon Hayden's tentative assignment of the Wind River formation. Meek added the mollusc, "Macrocyclis" spatiosum Meek and Hayden, to Hayden's list, and said that he considered the Wind River wholly or partially equivalent to the Bridger formation.

In 1912 Cockerell and Henderson (29: 231) listed the mollusc Glyptostoma(?) spatiosum (Meek and Hayden)(= Helix spatiosa Meek and Hayden, and Macrocyclis spatiosa (M. and H.) Meek), from "the Wind River beds, five miles west of Buck Spring, Alkali Creek, Wyoming".

In 1920 Collier (30: 78) listed specimens of fossil leaves from the north side of Big Sand Draw, Fremont Co., Wyoming, "just above the Mesaverde-Wind River contact". The list included the following forms, identified by F.H. Knowlton:

Lygodium kaulfussi Heer	Myrica microphylla Newberry
Dryopteris sp., fragment -- new?	Quercus haidingeri Ettinghausen of Lesquereux
Cyperacites or Typha sp., fragments	
Platanus or Liquidambar fruit	

Collier quoted Knowlton's opinion that the plant horizon should be placed "in the approximate position of the Green River, but it may be slightly older, though certainly not much".

By 1890 study of Wind River vertebrates had advanced sufficiently to afford a basis for the following remarks by Scott (in Scott and Osborn 256: 462-463):

"The fauna of the Wind River deposits has been shown by Cope [43: 183-202] to be intermediate between the Wasatch and the Bridger, mingling types which elsewhere are found only in one or the other of these formations with some forms peculiar to itself. Thus such typically Wasatch genera as Coryphodon, Phenacodus, Didymictis, Calamodon and Esthonyx are associated with equally typical Bridger genera, Palaeosyops, Lambdotherium,

Miacis and Microsyops while the earliest and smallest known member of the Dinocerata, Bathyopsis, is confined to these deposits. Thus the Wind River formation occupies the same intermediate position between the Wasatch and Bridger palaeontologically as does the Green River stratigraphically. One is therefore led to infer with Cope that the Green River and Wind River are parts of the same formation, though the entire absence of mammalian fossils from the former renders this determination somewhat uncertain. It may perhaps be objected to this view that in Southwestern Wyoming the Bridger beds lie conformably upon the Wasatch. This conformity is, however, not improbably deceptive ..."

In 1892 Clark (28: 140) said it was "generally conceded that the Wind River group represents the Green River group, although Scott[1] would consider it Lower Bridger in age".[2]

In 1910 Granger published a somewhat detailed study (87: 235-251) of the Wind River formation in the Wind River Basin. The modified table reproduced on p. 159 presents in tabular form the principal lithologic results of his study. In the Wind River at the locality where this section was measured he found (p. 239) a scanty fauna containing Eohippus sp., Phenacodus sp., and Coryphodon ?testis. He called this "Wasatch" the "Coryphodon zone". In the vicinity of Lost Cabin, however, he found that the Wind River section measured from 400 to 500 feet in thickness, and contained in the upper portion ("Lambdotherium zone") a more extensive fauna, with representatives of the genera Lambdotherium, Eotitanops, Coryphodon, Bathyopsis, Phenacodus, Meniscotherium, "Eohippus", Hyrachyus, Pelycodus, Notharctus, Patriofelis, and Esthonyx.

Commenting on the fauna of the "Lambdotherium zone", Granger (87: 241-242) remarked that Hayden's 1200 foot section of Wind River deposits in the western part of the Wind River Basin had been divided by Osborn (219: 44-45) into two zones--Lambdotherium zone below, and Bathyopsis zone above. Incompleteness of collection records had led Osborn to believe that Lambdotherium and Bathyopsis were from different and distinct levels. Granger, however, found unmistakable specimens of both from "the same level" and "in association", thus eliminating the "Bathyopsis zone". Granger stated (87: 243-245) that Meniscotherium had been previously recorded only from the "Wasatch of New Mexico",and Hyrachyus had not been "found before below the Bridger". In addition to the species contained in the lists above, Granger named and described (pp. 249-251) two new genera, of one species each: Shoshonius cooperi Granger, and Parictops multicuspis Granger. Both, he said were from the "Lambdotherium zone" of Alkali Creek.

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[1]Scott's article, to which Clark refers, was cited from American Philos. Soc. Trans., vol. 16, p. 465, 1889.

[2]In 1930 Berry (15: 55-79) described "a flora of Green River age in the Wind River Basin", obtained in beds overlying typical Wind River strata and occupying the stratigraphic position of the "so-called Bridger" described by Sinclair and Granger (276: 94-97) (see discussion of paleontology, age and correlation of Bridger formation, on subsequent pages).

WIND RIVER FORMATION - Paleontology, Age and Correlation

Concerning the fauna of the beds underlying the "Lambdotherium zone", Granger said (p. 246) that his study showed two points of interest:

"First. All of the genera from these beds are common to the Lambdotherium zone and to the Coryphodon zone of the Big Horn Wasatch. Second. The affinities of the species are, in general, closer to those of the latter than of the former zone. The absence in these collections of Lambdotherium, one of the most common forms, and of Eotitanops, a not uncommon genus of the Alkali Creek beds but a few miles distant, clearly indicates that these Cottonwood Creek beds belong to a faunal horizon distinct from the Lambdotherium zone. On the other hand, the absence of equally common Systemodon of the Big Horn Wasatch makes it difficult to correlate the beds with the Coryphodon zone. They appear to be intermediate between the two zones, with none of the characteristic faunal features of either."

At that time Granger proposed no distinguishing names for the two faunal horizons which he had distinguished in the typical Wind River formation. In the following year (1911) Sinclair and Granger (276: 104-105) in a jointly written paper, proposed to call the upper and lower beds the Lost Cabin and Lysite "stages", respectively:

"Granger, has separated certain beds exposed along Cottonwood Creek north of Lost Cabin, characterized by the absence of Systemodon and Lambdotherium, from the typical Wind River along Alkali Creek where Lambdotherium is abundant. They comprise yellow, gray, and brick-red shales or clays with interstratified buff, pale blue, yellow-brown and gray sandstones, dipping at a low angle away from the Bridger Range and passing beneath the bluish shales and gray and yellow sandstones with Lambdotherium along Alkali Creek. These, in turn, lie below the red and blue banded beds, also with Lambdotherium, forming the divide between Alkali and Poison Creeks north of Moneta. Throughout there is conformable superposition.

* * *

"As the beds on Cottonwood Creek lie below and are faunally distinct from the Lambdotherium zone, it seems desirable that they should have a formation name, and, as Cottonwood is pre-occupied, we propose LYSITE, from Lysite Creek where the beds are well exposed. For the Lambdotherium zone which has hitherto been synonymous with Wind River, we propose the formation name LOST CABIN, from the village of that name to the east of which are the main exposures of the beds affording Lambdotherium. Both the Lysite and the Lost Cabin are grouped as stages of the Wind River series, as they are conformable."

In 1909 Matthew (in Osborn 219: 92-95) listed all the known members of the Wind River fauna. In the period 1915-1918 Matthew and Granger (195: 1-103)(196: 429-483)(S.359: 565-657) presented revised faunal lists, with descriptions of many new forms of mammals from the "Wasatch" and Wind River horizons. The first paper cited by Matthew and Granger also contained a brief but valuable review of the history of investigation of these formations.

The following list of associated fossils were found by Sinclair and

WIND RIVER FORMATION - Paleontology, Age and Correlation

Granger (276: 90-91) in "the valley of Beaver Creek, some four or five miles above its intersection with Big Sand Draw":

Glyptosaurus (scutes)	Eohippus ?venticolus
Hyopsodus sp. nov. (not described).	Heptodon calciculus
Hyopsodus	Heptodon ventorum
Didymictis? altidens	Heptodon sp. nov. (not described).
Microsyops sp.	Lambdotherium popoagicum
Eohippus craspedotus	Coryphodon sp.

Sinclair and Granger (276: 108) in 1911 listed the following fossils from the Lambdotherium zone in the Tatman Mountain section in the Big Horn Basin:

Lambdotherium popoagicum	?Stylinodon
Heptodon ventorum	Paramys, 2 species
Eohippus	Crocodile
Hyopsodus cf. H. powellianus	

In 1919 Loomis (157: 217-219) listed the forms Ototriton solidus Loomis, Eohippus kraspidotus, Phenacodus vortmani, Notharctus venticolus, and Paramys bicuspis, associated together in the Lysite exposures of Bridger Creek, Big Horn Basin.

In 1929 Osborn (224: 57) divided the rocks stratigraphically between the base of the Puerco and the top of the White River group into 17 life zones or faunal horizons. Zones 8 and 9 are the Lysite and Lost Cabin stages, respectively, of the Wind River. Concerning the Wind River as a whole, Osborn said (224: 71) that it "marks the end of the lower Eocene, the last period of certain highly distinctive lower Eocene forms like Coryphodon, but it is also prophetic of the middle Eocene in the presence of lemuroids like Notharctus, Anaptomorphus, and Shoshonius". Osborn (p. 69) explained his zoning of the Wind River formation as follows:

"To zone 8 belong the Lysite beds of the Big Horn Basin Wasatch, Wyoming (Big Horn D); the lower level of the Wind River formation (Wind River A); a part of the Knight formation of the typical Wasatch group; and parts of the 'Almagre' and 'Largo' of the New Mexico Wasatch".

"The 'Lysite' or Heptodon zone in the Big Horn Basin is 400 feet thick. Anacodon, one of the arctocyonid creodonts, which has flattened or pavement-like teeth, is characteristic of the Heptodon zone. This zone is faunistically but not lithologically separated from the overlying Lambdotherium zone.

* * *

"To zone 9 belong the typical Wind River of Hayden and of Cope in the Wind River Basin, Wyo. (= the 'Lost Cabin' of Granger and Sinclair); the 'Lost Cabin' (Granger) of the Big Horn Basin Wasatch; part of the Green River lacustrine formation of Wyoming; and the lower level of the Huerfano formation (Hills)[1] of Colorado or Huerfano A. This is the typical Wind

[1]Refers to R.C. Hills, who named the formation in 1888.

River life of all the literature of Cope."

A complete list of genera from the Wind River horizons was given by Osborn (224: 72) in 1929.

Accumulated paleontologic data on the typical Wind River formation has been applied to good advantage by Knight and parties of the Geological Survey of Wyoming in southern Wyoming. From exposures along Cooper Creek, Knight[1] obtained a collection of mammals, identified by G.G. Simpson, containing representatives of the species, Hyracotherium cf. borealis, and Phenacodus intermedius. In the same general area, in section 7, T. 18 N., R. 76 W., Knight found a specimen of Hyopsodus wortmani, identified by Walter Granger.

Ferren found no fossils in the Wind River(?) deposits in the southeast part of the Shirley Mountains. A sparse collection by Konkel contained a single tooth of Lambdotherium and several teeth of Coryphodon.

A collection from the Bates Hole region, in an area previously mapped[2] as White River, yielded the following collection of mammal remains, listed by Knight[1], and identified by Granger:

Coryphodon sp.	Heptodon cf. ventorum
Phenacodus cf. intermedius	Hyracotherium sp.
Hyopsodus powellianus	Cynodontomys scottianus
Hyopsodus cf. minor	Bunophorus sp.
Lambdotherium popoagicum	Phenacolemur sp. nov.

Knight quoted Granger's comment that

> "'Heptodon and Lambdotherium are characteristic genera of the Wind River and such species determinations as I have been able to make are with those Wind River forms. The Phenacolemur has not been previously recorded from the Wind River and the single lower molar in your collection represents a somewhat more advanced form than is found in the Wasatch.'"

A later collection from the Bates Hole region by Peterson (227: 40-41) included representatives of all but one of the species (Hyracotherium borealis) listed by Knight, as well as representatives of the additional species, Hyracotherium index and Phenacodus primaevus.

It was Knight's conclusion (personal communication) that the Eocene outcrops in both the Cooper Creek and north Laramie Basin regions represent the Lost Cabin stage of the Wind River formation.

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[1]Knight: Unpublished manuscript (data published by permission).
[2]U.S. Geological Survey, Geologic Map of Wyoming, 1925.

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MIDDLE AND UPPER EOCENE UNITS

MIDDLE EOCENE GREEN RIVER GROUP

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Group. The type locality is in Sweetwater County, southwest Wyoming, west of Rock Springs along the line of the Union Pacific Railroad.

TYPE DESIGNATION. -- Hayden (104: 190-191) described the Green River group in the type locality in 1873 as follows:

"A little east[1] of Rock Springs station a new group commences composed of thinly laminated chalky shales, which I have called the Green River shales, because they are best displayed along Green River. They are evidently of purely fresh-water origin and of middle Tertiary age. The layers are nearly horizontal and, as shown in the valley of Green River, present a peculiarly banded appearance. When carefully studied these shales will form one of the most interesting groups of the West. ... One of the most marked features of this group is the great amount of combustible or petroleum shales, some portions of which burn with great readiness and have been used for fuel in stoves."

SYNONYMY. -- (See tables, pp. 14, 16, 18-19, 22-23, and pl. 2)

As used by Hayden, Powell and King, in the territorial survey reports, Green River theoretically applied, as originally defined, to beds lying stratigraphically between the Wasatch below, and the Bridger above. Sears and Bradley believed (263: 98), however, that in the Washakie Basin-Sand Wash region the Tipton tongue of the Green River (underlying the interfingered Cathedral Bluffs tongue of the Wasatch) was included in the Wasatch by most writers prior to 1920.

"Green River shales" of most writers, from the territorial survey period to the present, included most of the Green River group.

"Second series" of the Green River Basin Tertiary, described by Engleman (72: 47) in 1858 = Green River, according to Veatch (300: 97).

*Washakie group of Hayden (104: 190) (105: 73) (and other papers) included strata of the Green River group, according to Granger (86: 13-14).

"Fourth Group" of Lesquereux (in Hayden 108: 388-390, 408-419), in his report of 1874 on the fossil flora of the "Lignitic" formation = Green River.

"Green River group" of Lesquereux in 1883 (150: 137) included the "Wasatch", true Green River, Bridger, Uinta and White River formations.

"Green River group" of Lesquereux in 1876 (148: 19) included all Tertiary exposures between Rock Springs and Evanston, Wyoming, according to Veatch (300: 97).

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[1]Obviously an error. The direction should be west. The Green River exposures are first seen in the neighborhood of Rock Springs about 4 miles west of that town.

GREEN RIVER GROUP - Specific Information

SYNONYMY (cont'd).

"Green River" of Comstock in 1873 (in Jones 131: 103, 123) included both the "Wasatch" and true Green River.

"Green River tertiaries" of King in 1870 (134: 455) included all Tertiary beds in the Green River Basin.

"Green River group" as mapped by King in 1876 (135: maps 1-3), is approximately true Green River in most localities. The same is true of the group as described by King in 1878 (137: 377-394), and the Green River group or "series" described by Emmons in 1877 (in King 136: 240-244).

"Wasatch" and "Green River" were used interchangeably by Cope after 1873. He considered them chronologic equivalents, deposited in separated basins, and used the names in various writings in accordance with this belief. Hence his "Green River epoch", "Green River beds", "Green River formation", and "Green River strata" included both Wasatch and Green River in 1873 (39: 279) (in Hayden 107: 589, 625, 627-628), in 1874 (in Hayden 108: 440-441), and in 1884 (44: 7).

Cope's "Wahsatch beds" and "Wahsatch group" in 1872 (in Hayden 106: 350, 352) = Wasatch, not including Green River.

"Green River Group" of Peale in 1877 (in Hayden 111: 156), according to his own statement, included the "Wahsatch group" of Hayden.

"Heliobatus beds" of Marsh in 1886 (172: 6-7)(and other writings)= Green River formation.

"Bridger" of Smith in 1908 (280: 450-451) included Wind River and Green River.

"Wasatch" of Schultz in 1909 (247: 256-282) and 1910 (248: 214-281) included the Tipton tongue of the Green River.

"Cathedral Bluffs member of the Green River" of Schultz (251: 28-29) = Cathedral Bluffs tongue of the Wasatch.

DISTRIBUTION. -- Southwest and west-central Wyoming; northwest and west Colorado; northeast Utah. Bradley (21: 87) summarized the general distribution of the formation in 1929.

NOMENCLATURAL DIVISIONS. -- In southern Wyoming the Green River formation has been divided into the Tipton shale tongue, Laney shale member, "Tower sandstone" lentil, "plant beds", and Morrow Creek member. In the Piceance Creek Basin of Colorado, Bradley differentiated and named (22: 8-14) the following members in 1931: Douglas Creek member, Garden Gulch member, Parachute Creek member. The Evacuation Creek member he named after a stream in Utah.

IMPORTANT REFERENCES. -- Berry (15: 55-79); Bradley (18: 121-131), (19: 203-223), (21: 87-110), (22: 1-56); Brown (25: 279-292); Clark (28: 111-131, 140); Cockerell (S.349: 1-13); Cope (S.348: 807-819), (42: 67-77), (44: 6-11); Eastman (68: 65-75, pls. 1, 2); Emmons (in King 136: 203-204, 210, 213-215, 219-222, 240-244); King (134: 451-473), (137: 377-394); Knowlton (141: 133-137): Powell (229: 63-64, 104-105, 166-167); Reeside (230: 35, 47); Schultz (247: 259), (248: 222, 224-226), (250: 74-76), (251: 22, 24-31, table f.p. 24); Sears (260: 16), (262: 276, 292-294); Sears and Bradley (263: 95, 96-107); Veatch (300: 9-32, 97-107).

GREEN RIVER GROUP

GENERAL INFORMATION

Areal Distribution and Lithology

In 1871 Hayden stated (105: 71):

"Ten miles east of Green River Station, the Green River group disappears abruptly on the south side of Bitter Creek, and the coal formations come up to view. On the north side, the eastern limit of the Green River beds is most sharply marked by a long, high, white bluff, that extends off, far to the northeast, toward the South Pass."

In 1877 Emmons (in King 136: 211), in his report on the Green River Basin, described the group in the Cathedral Bluffs region and adjacent areas as overlying the *Vermilion Creek series (= Wasatch), He said that in this locality the Green River consists of

"about 100 to 150 feet, of an impure concretionary limestone of drab color, having at its summit a seam about 4 inches in thickness of oolitic limestone, which has been, in a great measure, silicified, and changed into a dark-gray chalcedony. These upper calcareous beds represent the base of the Green River group. The oolitic seam is made up of rounded grains from one-thirtieth to one-tenth of an inch in diameter, of a concentric structure, cemented by a cryptocrystalline limy matrix. Examined under the microscope, they ... are seen to be almost identical with the limy sands, which are found on the present beaches of the Great Salt Lake. ...

"Westward from Cathedral Bluffs, as far as Table Rock, extends a less well-defined line of bluffs whose upper beds contain generally some calcareous layers, which are considered to be characteristic of the Green River formation. Table Rock itself is made up of sandstones, and sandy and calcareous shales, with some lignitic seams, and several thin beds of limestone almost completely made up of fresh-water fossils, ... together with the agatized oolitic seam already observed in Cathedral Bluffs."

In the same volume of the 40th Parallel Survey reports, Emmons stated (pp. 213-214) that the most characteristic development of the Green River group in the Washakie Basin occurs in the neighborhood of Pine Bluffs, where he found it to consist of "several hundred feet" of "soft, white, shaly beds" below, and 400 feet of yellowish calcareous sandstone above. On Bitter Creek, 10 miles northeast of Pine Bluffs, he found thin fissile blue calcareous, carbonaceous shales.

In 1878 King noted (137: 385) that

"The surface of the whole Green River outcrop, both of the Washakie basin and of the southern area from Vermilion Bluffs southward to the White River divide, is always characterized by a more marly soil, by infrequent outcrops of solid rock, and by the prevalence among the few actual exposures, of calcareous members, sandy shales, or thin fissile shales, varyingly carbonaceous."

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GREEN RIVER GROUP - Areal Distribution and Lithology

"Along the whole valley of the Little Snake, at Sunny Point, as well as at Godiva Ridge and Elk Gap, the lower horizon of the Green River Group is easily recognized, consisting of calcareous sandstones and impure limestones, resting as usual, upon the brillinatly striped beds of the upper Vermilion Creek [Wasatch]. At Sunny Point particularly there is a thickness of about 950 feet of Green River ..."

In the same year, White, in his report on northwest Colorado, included (in Hayden 119: 19) the note:

"Green River Group. Upper division consisting of irregularly-bedded sandstones, often concretionary, with occasional laminated carbonaceous layers. Lower division consisting of laminated sandy shales or thin-bedded sandstones. Sometimes finely laminated shales which are more or less calcareous, and occasional dark carbonaceous layers are interspersed. Maximum thickness of both divisions about 1,400 feet."

In 1879 Peale noted (in Hayden 114: 637) that the "area between Green River and the Big Sandy is covered with the Green River Group". Clark believed (28: 140) in 1892 that the Green River is typically developed in the Green River Basin of Wyoming and Colorado, where, he said, it "attains a maximum thickness of about 2,000 feet". The areal distribution of the Green River group, as understood by the geologists of the territorial surveys, may be summarized as follows: Peale (in Hayden 109: 147, 156-158) recognized the formation in 1876 between the Colorado (Grand) and Gunnison rivers in Colorado, in 1878 (in Hayden 113: 184) along the Book Cliffs of western Colorado, and (in Hayden 114: 525) in the north and west parts of the Green River Basin. In 1876 Powell (229: 40, 45, 166, 167) described it in the north foothills of the Uinta Mountains. Emmons (in King 136: 203-240) carefully described the occurrence of the group in the Green River Basin in 1877. White (in Hayden 113: 35-37) identified it in 1878 in western Colorado and eastern Utah. Endlich (in Hayden 113: 111) found it in 1878 along the White River in western Colorado, and in 1879 (in Hayden 114: 130) south of the Wind River Mountains in Wyoming.

More recently, Gale, who worked in the Rangely oil district, Rio Blanco County, Colorado, noted in 1908 (78: 26) that shales and sandstones of the Green River group

"are characteristically exposed in escarpments of considerable elevation, among the best examples being those of the Book Cliffs and Cathedral Bluffs, south of Raven Park. These steep scarps stand at elevations of 1,500 to 2,000 feet above the neighboring valleys, and are almost everywhere characterized by the chalky-white appearance of the weathered cliffs as seen at a distance. ...

"In detail the Green River formation is composed of sandstones and thin-bedded slaty shales, with layers of limestone and calcareous shale. Many beds of oolitic or pisolitic limestone occur, and at some localities they form the major part of the harder beds which the formation contains."

The Green River group in Lincoln County, Wyoming was studied by

Schultz, and described in 1914. Schultz (250: 74-75) stated that in Lincoln County the group

"consists of light-colored shale, a few sandstones, light-colored calcareous limestone, and some bands of red or purple calcareous shale. Near the south end of the field the Green River formation can readily be differentiated from the underlying Knight formation, for here light-colored sandstones of the Green River overlain by calcareous layers and fissile shale rest conformably on the soft variegated beds of the Knight formation.

* * *

"Farther north, however, some difficulty was experienced in locating the contact. The white calcareous limestone of the Green River, which is so characteristic near the southern part of the field and which yields the well preserved fish and plant remains ... loses its identity toward the north and more and more of the white limestone appears in the Knight formation."

In his paper of 1920, on the Baxter Basin gas field, Schultz noted (251: 24) that Green River beds are extensively exposed along the west side of the Rock Springs dome and are traceable from there across the north end of the dome into the Red Desert to a point about 20 miles southeast of the Antelope Hills, at the south end of the Wind River Mountains. He recorded similar beds south and southeast of the Rock Springs dome and throughout the area between the Union Pacific Railroad and the Uinta Mountains. In this report Schultz included beds now known as the Cathedral Bluff's tongue of the Wasatch in the Green River group.

Still later (1929) the areal distribution of the Green River was summarized in general terms by Bradley (21: 87), who stated that the Green River formation "is a series of lake beds of Middle Eocene age which occupies two large intermontane basins, one in Colorado and Utah, the other in Wyoming. The formation averages about 2,000 feet in thickness and covers an area of more than 25,000 square miles."

"Upper" and "Lower" Green River "groups". -- Powell, in his report of 1876 on the Uinta Mountains, divided the Green River formation into upper and lower members, which he called groups. The type locality of the lower member was along Green River, near the town of Green River, Wyoming. Powell (229: 45) gave the following description of the lower member:

"This group is well exposed along the Green River from Green River Station southward for ten miles ... It is also well exposed in many of the escarpments of the Quien Hornet Mountain. We again find it well exposed in the escarpments a few miles northeast from the head of Vermilion Canon. Fine exposures are seen on the Snake River six miles above the northern foot of Junction Mountain. The elevated ledges known as Pine Bluffs, near the sources of the eastern tributaries of Vermilion Creek, are capped with limestone and bituminous shales of this group."

On subsequent pages of the same report, Powell offered an additional note on the lithology of the lower member (pp. 63-64):

GREEN RIVER GROUP - Areal Distribution and Lithology

"The Lower Green River beds represent a period when minutely laminated bituminous shales and more massive limestones were deposited, the limestones prevailing as you descend in the series. These beds are all fresh water and are separated from those below by an abrupt plane of stratification which marks a change in the character of the sediments. The lower beds are soft, friable, and highly colored bad-land sandstones."

The divisibility of the Green River into upper and lower members was also remarked by other territorial geologists. White, in his studies in northwest Colorado, noted (in Hayden 113: 36) that the group is lithologically separable into two divisions, but that these are not "severally coordinate with the other recognized Tertiary groups". White added:

"The lower division consists mainly of siliceous and sandy shales, and laminated and thin-bedded sandstones, with, in some places, especially in the western part of this district, frequent layers of hard, dark-colored carbonaceous shales. In some places the strata are also quite calcareous, occasional layers being nearly pure, compact, finely laminated limestone. ... The general aspect of the strata as seen exposed at a distance is light gray."

Endlich, in his report on the geology of the White River district remarked (in Hayden 113: 83):

"Geognostically and lithologically speaking, we can distinguish the two groups of Powell very readily. While the eastern two-thirds of the Green River area are composed entirely of the shales, the western third contains the younger sandstones. These shales generally show very light shades of color upon exposures, which alternate with narrow dark bands ..."

Emmons (64: 203-204) in his studies of the Green River Basin observed:

"The beds of the Green River series contrast with those of the other two groups /Wasatch and Bridger/ by the relative prevalence of calcareous material, and the fineness of their sediments. ... They consist of a lower series of calcareous sandstones and impure limestones, containing some lignite seams, overlaid by a great thickness of remarkably fissile, calcareous shales abounding in remains of fish and insects, which reach an aggregate thickness of about 2,000 feet, and are characterized throughout by their prevailing white color."

Beds now believed to be equivalent to the lower Green River of Powell were included by Schultz (247: 259)(248: 222) in the "Wasatch". In a later report (251: 22) he included them in the Green River (see tables, pp. 18, 22-23, and plate 2). As developed in the area of the Rock Springs dome, the equivalent of Powell's lower Green River consists of the Tipton shale tongue of the Green River, the overlying, intercalated Cathedral Bluffs tongue of the "Wasatch", and the Laney shale member of the Green River group.

Powell also distinguished an upper member in the Green River formation

(229: 45). His general description of the member (229: 63) was as follows:

"These beds are interpolated between the Bridger and Lower Green River ... only in a portion of the country where the latter two occur. The Tower Sandstone which forms the base of the Upper Green River Group is laid down unconformably on the Lower Green River, the unconformity being represented by gentle valleys of erosion; and there seems to have been a period of erosion or dry land conditions separating the Tower Sandstone from the Plant Beds of the Upper Green River also, and during this dry land period the sands of the Tower Sandstone were eroded by rains and drifted by winds. After the deposition of the sands, the bottom of this great Green River lake was left bare for a time and the sands drifted in dunes."

The type locality of Powell's upper member was in the general neighborhood of the town of Green River.

White observed in 1878 (in Hayden 113: 36) that in northwest Colorado the Green River was lithologically separable into two subdivisions and that the

"upper division consists mainly of sandstones that are coarser, as well as less thinly and distinctly bedded, than those of the lower division. In some parts it is shaly, and in others carbonaceous. Much of its sandstone is ferruginous in aspect, instead of having the gray tint that the lower division has. Sometimes certain beds of its sandstones are earthy and easily disintegrated, often leaving weathered out of the mass, spherical concretions of hard sandstone that vary in size from a fraction of an inch to two or three feet in diameter."

White recorded a thickness of about five hundred feet for this upper division. F.M. Endlich, in his report on the geology of the White River district, Colorado, recorded that the thickness of the upper division in that region locally varied between 1,000 and 1,200 feet.

Emmons recognized two divisions of the Green River formation in the Green River basin, the upper of which, he said (in King 136: 203-204), consisted of "a great thickness of remarkably fissile calcareous shales abunding in remains of fish and insects".

The upper and lower members of the Green River of Powell were recognized by Schultz in 1920 (251: 25), in the Rock Springs dome region.

In 1914 Woodruff and Day (337: 11) represented 1,600 to 2,625 feet of Green River present in northwest Colorado and northeast Utah. They divided it into lower, middle and upper Green River. The lower member consists of sandstone, shale and oolite; the shale is locally calcareous or bituminous and the colors range through brown, gray, or faint green. The middle member consists of thin-bedded shale (sometimes bituminous), and calcareous sandstone; colors brown, gray, or faint green. The upper member consists of sandstone, sandy shale and some clay shale with pre-

vailingly brown and gray colors; evenly bedded and containing fossil leaves in the sandstone.

In 1931 Bradley described (22: 14) two types of facies in the Green River:

"A shore and delta facies of the Green River formation constitutes the Gray Hills, north of the White River in Colorado. ... as none of the lithologic units recognized south of the White River have been surely identified north of the river, the exact equivalence of the facies is unknown. Two complete sections north of Deep Channel Creek are about 1,100 and 1,175 feet thick. The shore facies in that locality is a little less than one-half as thick as the section measured about 15 miles farther south along Piceance Creek, and probably therefore some of the upper part has been eroded, although the relative thinness of the shore facies is probably also to be explained by breaks in sedimentation.

"Nearly 50 per cent of the shore facies north of Deep Channel Creek is sandstone. ... The shale is monotonously uniform, being either gray or grayish-buff, soft, flaky, and prevailingly sandy. A little of it is hard and platy.

* * *

"There are several noteworthy algae reefs in the upper part of this facies, but beds of limestone and oolite are rare. Most of the limestone beds are brecciated."

Stratigraphic and Structural Relations

Powell (229: 64), in 1876, noted an abrupt plane of stratification, marking a change in lithology, separating the base of his Green River group from the underlying Wasatch, in the area south of the town of Green River, along Green River. He also noted an unconformity, within the group, separating what he called the "Lower Green River group" from the overlying "Tower sandstone" member, in the base of his "Upper Green River group". Schultz later (1902) recorded (251: 27) a similar unconformity at the same horizon at Laney Rim.

In 1877 Emmons recorded (in King 136: 213) southeastward dips of 4° to 5° in Green River exposures at Pine Bluffs in the Washakie Basin. He noted, however, that these small dips are well within the range of depositional inclination and in general are in the direction of the centers of the basins or depressions in which the sediments were deposited. Emmons noted also that (p. 218):

"The line of elevation of the Cherokee Ridge ... marks a comparatively sharp fold in the beds of the Green River series, which has doubtless been accompanied with considerable faulting. The movement which produced this fold would seem to have been continued since the deposition of the [overlying] Bridger beds, as indicated by the angle of 7° at the southern edge of this basin already mentioned, if these beds really belong to the Bridger series."

GREEN RIVER GROUP - Stratigraphic and Structural Relations

According to King (137: 385), the Green River beds are always found resting unconformably on the Wasatch. Peale (in Hayden 113: 637), however, made exactly opposite observations in the same year (1878). He stated:

"Whenever seen the group rests conformably on the Wahsatch. It is seen dipping with the latter where it rises on Meridian Ridge and in the Ham's Fork Plateau, but when upturned it appears to have been very easily eroded, so that it generally ends in a bluff face just east of the steeper inclination. This often makes it resemble an unconformability; but it is only apparent, for the Wahsatch beds are always seen in position beneath the Green River Group, dipping in the same direction at the same angle."

King believed that there was evidence of large-scale post-Green River faulting. He said (137: 386):

"It is noticeable that the line of strike of this steeply southward-dipping Green River series at Elk Gap would carry it directly into the northern edge of Brown's Park, where beds also assigned by us to the Green River series hold the same position, dipping 25° to the south. It would seem, therefore, that a long line of displacement has occurred here, with a downthrow to the south. Provided the upturned beds in Brown's Park are, as we suppose, Green River[1], there is a vertical displacement of 5,000 feet between them and the series of the same horizon north of the Archaean mass on Red Creek, the Brown's Park being the depressed member."

Endlich observed (in Hayden 113: 83) that in the White River district of Colorado

"Stratigraphically the Green River Group ... is remarkably simple. Its strata partake to a slight extent of the flexures extending southward from the northern more distrubed district, but their effect is soon lost, and the former resume their normal position. As such, a slight dip, varying from 1° to 6° a little west of north may be regarded. It is noticeable wherever the strata are exposed, and only slight variations of the angle were observed. Both the upper and lower groups are perfectly conformable in this."

Gale examined the Green River formation in northwest Colorado and northeast Utah. He reported (79: 83-84) in 1910 that the Green River is well exposed in the Roan or Book Cliffs, Gray Hills, Citadel Plateau, Cathedral Bluffs, the walls of the White River Canyon below Raven Park, and the canyons of Evacuation Creek. He said that the beds are found in "a nearly horizontal position or with only slight inclination, and within the bordering escarpment rims they form high mesa or plateau surfaces occupying the undisturbed interiors of the great structural basins."

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[1]The supposed Green River beds in the Browns Park region = Browns Park formation (see Sears 261: 279-304).

In some areas, however, Gale found folded strata and he stated (p. 84):

"Both the Wasatch ... and Green River formations were involved in the folding that produced the uplifts ... ... This is shown in certain favorable localities where beds of the younger groups are tilted in the same structure with the older beds. One of the best illustrations is found on the eastern face of Escarpment Peak, north of Keystone Basin. At this place the variegated clays of the upper part of the Wasatch are clearly exposed in a badlands wash at the foot of the Green River escarpment. Although quite steeply tilted in the valley and at the foot of the main slope, the dip gradually decreases higher up the ridge. The apparent conformity of all the beds at this place is even more clearly revealed in perspective by a view from the valley to the south, where this escarpment is seen to be situated approximately on the axis of flexure."

Winchester also found structural features in the Green River in southwest Wyoming. He stated (329: 191) in 1910:

"That part of southwestern Wyoming lying between the Uinta Mountains on the south and the Wind River Mountains on the north is a broad structural basin which is separated into several smaller basins by north-south uplifts.

* * *

"Beds of the Green River formation are only slightly tilted in any part of the area ... Along the western rim of the Southern Red Desert Basin the oil shale at its outcrop dips as much as 11° NE., but it flattens rapidly toward the center of the basin. Along the east and west sides of the main Green River Basin the oil-yielding shale shows dips not exceeding 3° or 4°, but in some places along the north flanks of the Uinta Mountains the beds of the Green River formation are tilted at greater angles angles. The oil shale of the Fossil syncline is practically horizontal at every point examined.

"Faults in the Green River shale were noted in only one area, but they may be present at many other places within the area here described. West of Green River, near the center of T. 15 N., R. 108 W., there is an area perhaps half a mile wide and extending an unknown distance to the west, where the rocks are crumpled and cut by east-west trending faults. On both sides of this disturbed zone the strata are apparently unaffected.

"The channel sandstone of Lee [S.369: 74], which is the Tower sandstone of Powell, forms vertical cliffs in the vicinity of Green River, Wyoming, where it rests on an irregular surface of shale and is itself very much distorted, whereas the shale beneath is not deformed."

Cope's observations in southwest Wyoming early led him to believe that the Green River and Wasatch formations were synchronous facies deposited in separated basins. He thus came to use the names interchangeably, as he explained in 1872. He repeated his opinions in 1874, in his report on the vertebrate paleontology of Colorado (in Hayden 108: 440-441), where he said:

"The Ham's Fork Mountains form the divide between the waters of Green

and Bear Rivers respectively, and are passed by the Union Pacific Railroad at the west of Aspen station, as is described by Dr. Hayden, (Annual Report for 1870, p. 149). He here points out that the distinctness of the two basins was marked during the Tertiary period, and hence names the deposits of the western area the Wahsatch group, regarding it at the same time as synchronous with those of the Green River epoch. The writer has attained the same opinion on paleontological grounds, and has hence employed the same name for both areas, namely the Green River epoch."

Cope (40: 38-39) repeated this conclusion verbatim in 1875. Again, as late as 1884, he stated (44: 7) that, petrographically, the Wasatch "has two divisions, the Wasatch proper and the Green River beds; the latter name having sometimes been given to the entire formation as well as the former".

In 1908 Schultz, in his paper on central Uinta County[1], Wyoming, showed (246: 366) a generalized section of rocks in which he represented 200 feet of Green River formation, conformably overlying the Knight member of the Wasatch, and consisting of thin-bedded shales, sandstones and limestones of light colors and occupying the top of the stratigraphic column.

The stratigraphic relations of the Wasatch and Green River groups in south Wyoming and northwest Colorado were described and illustrated by Sears in 1925 (260: 294, fig. 23). These relations had been more fully described by Sears and Bradley in another report (263: 94-107) in the previous year. Their interpretation of the relations of the Wasatch and Green River groups differed markedly from those of earlier writers. The following passage (263: 98-99) is indicative:

"The early explorers believed that the Green River formation is not only different from the Wasatch in lithology but is also distinctly younger throughout. Such a belief is justified in the Bridger Basin, where the Wasatch was followed by continuous Green River deposition. Farther east, however, in the Washakie-Sand Wash depression, this belief led them to draw the boundary at the base of the beds later named Laney shale member by Schultz, thus including in the Wasatch the deposits here called the Tipton tongue of the Green River formation and the Cathedral Bluffs tongue of the Wasatch formation. The boundary was drawn at the same horizon by Schultz [(247: 256-282) (248: 214-281)] in his reports on the coal fields of the Rock Springs uplift. In a later report, however, Schultz [251: 25, 28-31] described the northwestward gradation of his Cathedral Bluffs red beds member into shale of Green River type and suggested that his Tipton shale member might die out toward the southeast, causing an interfingering of the two formations. He believed that the Green River west of the Rock Springs uplift is the time equivalent of all beds east of the uplift between the base of the Tipton tongue and the base of the Bridger, and

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[1]Since 1912, due to relocation of boundaries, the area described has been in eastern Lincoln County.

hence he treated the Tipton tongue and the Cathedral Bluffs tongue as members of the Green River formation.

"Although the time equivalence suggested by Schultz is essentially correct, the writers believe that his classification does not adequately express the time and depositional relations of the Wasatch and Green River. The interfingering of these formations, now proved to exist, may be better indicated by the use of the term 'tongue' ... The names Cathedral Bluffs tongue of the Wasatch formation and Tipton tongue of the Green River formation are therefore here used to replace the members of Schultz."

Later (1930) Berry (15: 56, 57) expressed the views that

"The Green River formation, as developed in the Green River Basin, is a thick series of deposits showing a variety of lithologic phases of sedimentation, for the most part lacustrine, and it is quite possible, as Cope thought, that the typical banded beds of the Wind River formation, which underlie the 'so-called Bridger' of Sinclair and Granger in the Wind River Basin, may also be of Green River age. This seems even probable, but I have no data for expressing an opinion on this point."

* * *

"As Bradley has shown [28: 121-131], when the Green River is traced by lithology from its area of maximum development toward the margin of its basin of deposition it is found to thin and gradually disappear, thus bringing the Wasatch and Bridger into contact. It seems to be a legitimate supposition that deposition contemporaneous with that which formed the typical Green River was taking place in the Wind River Basin and elsewhere in Wyoming, and that at least the Wind River formation in the Wind River Basin, a part of the 'so-called Bridger' of Sinclair and Granger, and perhaps the upper part of the Wasatch of the Wind River Basin represent the time equivalent of the maximum Green River of the Green River Basin."

In 1912 Schultz and Cross published a paper on the potash-bearing rocks of the Leucite Hills of Wyoming. In that region, they stated (252: 15):

"The volcanic activity which forced the leucite-bearing rock out toward the surface is certainly younger than the Green River formation, as the leucite-bearing rock at Pilot Butte and Steamboat Mountain rests as surface flows upon that formation. It appears that after the fresh-water beds of the Eocene had been laid down there was a long epoch of erosion in which the entire region was reduced to a peneplain or nearly level surface. This was succeeded by mild volcanic activity, during which the leucite-lava flows north and west of Rock Springs were poured out on a planed off, nearly level surface, formed by the truncation of the underlying rocks."

Economic Products

Much has been written on the oil shales of the Green River group. It is impracticable to present a brief review of all that has been written on the subject. The following passages from Winchester's report of 1916 on the oil shales of northwest Colorado and adjacent areas, however, indicate

the general lithology, distribution, and productivity of the oil shale. Winchester said (329: pp. indicated):

"The economic study of the oil shale of Colorado and Utah was begun in 1913 by Woodruff and Day, and the results of their preliminary work showed that the shale of the Green River formation in Colorado and Utah will yield oil in commercial quantities when subjected to destructive distillation. ... The thickest and richest beds of shale are exposed along the southern margin of the /Uinta/ basin ... An examination of the same formation in southwestern Wyoming in 1915 indicates that in that area there are no thick beds of rich shale." (pp. 140-141)

* * *

"The maximum yield, 90 gallons to the ton, was obtained from a thin bed near Watson, Utah. Samples ... from Wyoming, yielded less than 30 gallons ...

"As these quantities compare favorably with those obtained from the oil shale of Scotland, it seems probable that in time the distillation of oil from the Green River shale may become as important an industry in this country as the distillation of oil from Carboniferous shale has become in Scotland, or if richer raw material can be found here in abundance it may even exceed the present shale-oil industry abroad." (p. 142)

* * *

"The Green River formation, of early Tertiary (Eocene) age, consists predominantly of shale. It exhibits on the weathered outcrop more or less white color, but closer examination reveals an alternation of gray, bluish gray, and white bands. The shale that yields the most oil when subjected to distillation is that which weathers into massive benches of grayish-blue color but which is dark brown to black on a freshly broken surface." (p. 162)

Bradley studied the occurrence and origin of analcite and meerschaum in the Green River formation. He stated (20: 1) in 1929:

"Thin beds that consist almost wholly of euhedral analcite crystals occur at five or more horizons in the upper half of the Green River formation of Utah and Colorado, a series of Eocene lake beds that contain large deposits of oil shale. Most of these beds contain also minute crystals of apophyllite. The analcite crystals in some beds are cemented only by chalcedony, but in other beds that have less analcite the matrix is tuffaceous and consists of chalcedony in which are embedded splinters of feldspar, hornblende, and quartz, laths of biotite, and euhedral crystals of sanidine, apatite, and zircon. Analcite occurs plentifully also, disseminated in many of the oil shale beds, and locally makes up as much as 16 per cent of weight of the rock. In those beds the analcite is accompanied by apophyllite, euhedral crystals of sanidine and orthoclase, angular fragments of quartz, and a little volcanic glass. The rocks associated with the beds of analcite and analcite-bearing oil shale contain salt-crystal cavities, that strongly suggest the former presence of glauberite and anhydrite.

* * *

"Meerschaum, or fibrous sepiolite, occurs in several thin beds near the top of the Green River formation in Duchesne County, Utah. It is mixed with structureless organic matter like that in the oil shale and apparently formed in place on the lake bottom."

GREEN RIVER GROUP

Paleontology, Age and Correlation

The fauna of the Green River group consists chiefly of fishes, turtles, crocodiles, mollusks and insects. In this respect the Green River fauna differs markedly from that of the Wasatch group and Bridger formation, both of which have yielded specimens of the same organic groups, and, in addition, have furnished fine collections of mammal material. The Green River fish are characteristic Eocene types, of which a few genera, according to Clark (28: 140) range from the Wasatch into the Bridger. Most of the fossil fish were figured and described by Cope in several different publications: in 1877 (S.348: 807-819), in 1878 (42: 67-77), and 1884 (44: 49-100). Veatch (300: 98) listed the following species of fish, collected from the Green River near the town of Fossil:

Phareodus (Dapedoglossus) testis Cope
Phareodus (D.) aequipenis Cope
Diplomystus densatus Cope
Diplomystus analis Cope
Diplomystus humilis (Leidy)
= Chipea pusilla Cope
Diplomystus altus (Leidy) Cope
Diplomystus pectorosus
Amphiplaga brachyptera Cope
Asineops pauciradiatus Cope
Mioplosus abbreviatus Cope
Mioplosus labracoides Cope
Mioplosus beani Cope
Mioplosus sauvageanus Cope
Priscacara serrata Cope
Priscacara cypha Cope
Priscacara oxyprion Cope
Priscacara clivosa Cope
Priscacara pealei Cope
Priscacara liops Cope

According to Cockerell (quoted by Knowlton 141: 148) there are 296 species of insects known from the Green River group.

Bradley made a detailed study of the algae reefs and oolites of the Green River, the results of which were published in 1928. Bradley's report included (19: pl. 28) sections showing the vertical distribution of these structures in the formation. His map (pl. 31) showed the geographic distribution of the algae reefs. Concerning the reefs and oolites he said (19: 203-204):

"Reefs or beds and isolated nodules of fresh-water algal limestone are abundant in several parts of the Green River formation of Wyoming, Colorado, and Utah. Locally they constitute more than 8 per cent of the basal member of the formation and occur in single reefs or groups of reefs as much as 5.5 meters (18 feet) thick. Oolitic limestone and algal pebble beds are also plentiful but thinner.

* * *

" ... the algae reefs of the Green River formation, although formed in inland lakes during the middle part of the Eocene epoch, are remarkably similar to those found in the Miocene lake beds of the Rhine Valley in Germany. The same species of alga has been the chief agent in forming the reefs in each of these two widely separated localities, and, so far as the writer is aware, deposits with a comparable internal structure are elsewhere unknown.

* * *

GREEN RIVER GROUP - Paleontology, Age and Correlation

"The algae reefs of the Green River formation are most plentiful in shore phases of the formation, as between White and Yampa Rivers in Moffat and Rio Blanco Counties, Colo., and in the northeastward extension of the Bridger Basin in Sweetwater County, Wyo. In both these areas the formation consists of silty shale, sandstone, ostracode and oolitic limestone, and shell marl ... In these areas bedlike algae reefs are irregularly distributed through the entire thickness of the formation, but elsewhere in the Green River formation algae reefs are confined almost wholly to the basal member, whose lithology is similar to that of the shore phases.

* * *

"But these lakes, despite their enormous area and slight depth, must have been fairly stable water bodies, for some of the thicker algae reefs required, according to the writer's estimate, at least 355 years to form."

The fossil plants of the Green River group have been the subject of study from the time of the first work of the territorial surveys to the present. Leo Lesquereux figured and described many specimens in his reports on "the Lignitic formation and its fossil flora" (in Hayden 108: 388-390, 408-419) in 1874, on the "Tertiary flora" (148) in 1876, and on the "Cretaceous and Tertiary flora" (150) in 1883. In the latter report he stated (p. 127):

"In my preceding Reports I have referred to the Green River Group a limited number of species of fossil plants obtained from different localities mentioned below, and which were formerly considered as pertaining to the same geological stage. Now this group includes four members: the lower, the Wasatch, of which the Green River is an upper member; then, in ascending order, the Bridger, the Uinta, and the White River with the Oregon Beds [John Day?]."

Knowlton (141: 147), from a consideration of the flora in the Green River Basin, concluded that the Green River group contains representatives of two ecologic groups--a lowland flora of warm-temperate environment and an upland flora, including Salix, Myrica, Juglans, Quercus, Rhus, Acer, and Ilex, that may have lived in a cooler environment.

In 1929 Brown presented (25: 279) the following general statement:

"The most abundant plant fossils are found in the upper part of the formation and are most readily collected at the test pits made by oil-shale prospectors. The principal localities where fossil plants have been found are Green River and Alkali Station, Wyo.; Cathedral Bluffs (20 miles west of Rio Blanco post office); the Smith ranch (on Greasewood Creek 40 miles southwest of Meeker); and on Carr Creek and Brush Creek Utah."

Knowlton's paper of 1922 (141: 133-137) was a careful assemblage of scattered information on the Green River flora which had been published up to the time of his paper. Cockerell (S.349: 1-13) added a number of new species to Knowlton's list. Brown's paper contained lists and descriptions of the latest additions to the flora of the group and added 48 species to the known flora of the Green River. Most of them were new species.

GREEN RIVER GROUP - Paleontology, Age and Correlation

In 1929 Osborn (224: 48) assigned the Green River formation to the upper lower Eocene, correlating it with the lower Ypresian of the European standard section.

Berry (S.350: 35) believed in 1924, however, that the flora indicates a somewhat younger age. He compared the flora of the Green River to that of the Claiborne of the Gulf Coast, and suggested a possible partial correlation with the lower part of the Jackson also. He at first regarded it as equivalent to the European Bartonian. In 1925 Berry (S.351) expressed the opinion that the Green River formation is to be correlated with the Auversian stage of the European section, thus making it a part of the middle Eocene of this country. Five years later, Berry (15: 57, 59) remarked:

"Although Osborn ... correlated the Wind River with the upper Wasatch of the Big Horn Basin and the lower Huerfano of Colorado, I believe all three are somewhat younger than the position usually assigned to them by vertebrate paleontologists, and this point comes within the province of paleobotanic correlation when the Green River section is compared with that of the Atlantic Coastal Plain and with the standard European section.

"The general stage of development of the Green River flora, the stage in the evolution of Tertiary climates in North America, and a few identical species indicate that the flora is of about the same age as that of the Claiborne group of the Gulf Coastal Plain. The Claiborne, which I at first thought was of Lutetian age, is now rather definitely correlated with the subsequent Auversian stage of the European section, and I believe this to be the approximate age of the Green River flora and the flora from the Wind River Basin described in the present contribution. The Wind River formation may be Lutetian, but I much doubt if it is any older. At any rate, the Green River is well up in the middle Eocene.

* * *

"The Green River formation contains an abundance of fishes at certain horizons in the Green River Basin. Other layers are packed with plant remains, and the oil shales contain innumerable bacteria, blue-green algae and fragments of other algae, sporophytic fungi, mosses and fern-spore exines, and pollen of the higher plants. Coniferous pollen has been found in the oil shales and might have been brought into the area of sedimentation by the wind from higher altitudes or even from a great distance, as such pollen which must have come from the continent of Europe, is found at the present time in Svalbard (Spitzbergen)."

Shufeldt recorded (267: 619) in 1915 that "a number of years" previously, Eastman had described, "in the Geological Magazine of London ... one of the most interesting and complete skeletons of a fossil bird that we have in this country". The specimen, Gallinuloides wyomingensis Eastman, had been taken from "the Green River shales of Wyoming, near the town of Fossil".

Bradley (22: 14) said in 1931 that north of White River in Colorado

GREEN RIVER GROUP - Paleontology, Age and Correlation

"There are several noteworthy algae reefs in the upper part of this [shore and delta] facies, but beds of limestone and oolite are rare. Most of the limestone beds are brecciated.

"Ostracodes are abundant in some of the sandstone beds. The shale contains a few fragmentary leaves and stems and locally also ostracodes and Estheria? shells. Some of the thin limestone beds consist largely of gastropod shells. Scattered crocodile and turtle bones, garpike scales, and the bones and teeth of other fish were also found."

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MIDDLE EOCENE TIPTON SHALE TONGUE

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- The Tipton shale was ranked by Schultz, in the original designation, as a member of the Green River group. In 1924, however, Sears and Bradley (263: 98-99) showed that it is a tongue, which appears as a wedge in the Wasatch in the neighborhood of the Washakie Basin. This conclusion was repeated by Sears in 1925 (260: 293-294) and 1926 (263: 16). The type locality is south of Tipton Station on the Union Pacific Railroad T. 19 N., R. 96 W., Sweetwater County, Wyoming.

TYPE DESIGNATION. -- The unit was named by Schultz in 1920 (251: 30):

"On both the east and west sides of the [Rock Springs] uplift the beds immediately overlying the Black Rock coal group consist of fissile shale, conglomerate, oolitic limestone, shale, clay and sandstone. Some of the greenish-white shale of these beds is very fissile and closely resembles the shale in the lower part of the Green River formation in the Green River Basin. At the south end of the dome and in the area between the Rock Springs uplift and the Washakie Basin traces of coal were found near the base of these beds, but throughout the northern part of the field no coal was seen in them. To this member of the formation the name Tipton shale member is here given ..."

DISTRIBUTION. -- East, north and west borders of the Washakie Basin; south, west and north borders of the Rock Springs uplift.

SYNONYMY. -- The Tipton shale (then unnamed) was included in the Wasatch formation by Schultz in 1909 (247: 259), and in 1910 (248: 222, 225-226). The same is true, in general, of the geologists of the territorial surveys, according to Sears and Bradley (263: 98). In a 1920 report Schultz (251: 22, 30-31) included the Tipton tongue in the Green River group.

IMPORTANT REFERENCES. -- Sears (260: 276, 292-294); Sears and Bradley (263: 95, 98-99); Schultz (247: 259), (248: 222, 225-226), (251: 22, 30-31, table f.p. 24).

TIPTON SHALE TONGUE

GENERAL INFORMATION

In 1920 Schultz summarized (251: 30-31) the distribution and lithology of the Tipton tongue, as he had observed it:

"South of Tipton station the country rises in a series of steps or terraces, the first of which is formed of the whitish shales, clays, and sandstones of the Tipton member, which extends parallel to the railroad toward Wamsutter, on the east, where they swing southward and extend nearly to the edge of the cliffs west of the valley of Little Muddy Creek, approximately 8 miles east of Washakie or Flat Top Mountain, and thence south to Little Snake River. The beds in this part of the field are 200 to 250 feet in thickness. Southwestward from Tipton station, these shales ... may be followed along the west base of the Laney Rim past Pine Bluffs to the Kinney Rim and Lookout Mountain and southwestward to Pine and Bishop mountains. The fissile Tipton shale continues along the road south of Rive's ranch ... In Canyon Creek there are great escarpments of yellow sandstone, about 200 feet high, containing a small amount of conglomerate. The largest pebbles here are but a few inches in diameter. Upstream on Ruby Creek toward the mountains the percentage of conglomerate and the size of the pebbles rapidly increase. Within a mile boulders as large as 2 feet are encountered. These include gray and yellow quartzite and sandstone ...

"At a point 14 miles southeast of Pine Butte along the Kinney Rim the fissile Tipton shales are typically exposed. ... The Tipton shale is here 300 feet thick, and the fissile Laney shale, overlying the red beds, is about 600 feet thick. ... Toward the south the Tipton shale is not well exposed ...

"North of Tipton station the Tipton shale has been removed by erosion over the greater part of the Great Divide Basin. The beds have been traced along the north side of this basin from Steamboat Mountain northeastward to the southeast end of the Wind River Mountains."

In 1924, Sears and Bradley stated (263: 98):

"North of Baggs, Wyo., the Tipton tongue of the Green River enters in the midst of the Wasatch beds, thickens northward, and, encircling the north end of the Washakie Basin, unites with the Tipton to the west. Thus the outcrop of the Tipton tongue has the shape of the letter U with the open side toward the south. The Tipton lake may have extended southward to a line between Baggs and East Fork of Vermilion Creek; and there is a possibility that much of the Cathedral Bluffs tongue of red beds, deposited as this lake retreated, was derived from the east and southeast."

Sears observed (260: 293) in 1925:

"Above the Wasatch are beds of gray fissile shale and oil shale, thin sandstones and limestones, oolitic beds, and alga reefs, which are correlated with the Green River formation. ... The Tipton tongue appears as a wedge between the two parts of the Wasatch in sec. 4, T. 10 N., R. 100 W., and thickens toward the north and northwest. Still farther northwest, beyond the limits of the field, the Cathedral Bluffs tongue of the Wasatch loses its identity and the Tipton tongue merges with the overlying Green River shales."

TIPTON SHALE TONGUE - General Information

In the following year Bradley remarked (18: 123) that in north Sweetwater County, Wyoming,

"Light-brown to buff finely laminated shale, ostracode-bearing limestone, oolite, and sandy limestone make up the bulk of the Tipton tongue of the Green River formation in this area. Sandstone, however, is locally conspicuous, either in persistent well-stratified beds or in massive or cross-bedded lenses. Calcareous alga reefs are numerous in the Tipton tongue. At the base of the Tipton tongue throughout this area and beyond there is a very persistent limestone in which ostracodes are in places so abundant as to compose most of the rock. In the southwestern part of this area and to the south along White Mountain the Cathedral Bluffs tongue of the Wasatch formation is not represented, and the southern continuation of the Tipton beds is more appropriately termed the Tipton shale member of the Green River formation."

Bradley noted also (p. 123) that shells of Goniobasis and Unio were in almost constant association with the persistent limestone, sandy limestone and oolite, and that above the persistent limestone there were observable lithologic variations in the Tipton tongue from place to place. Bradley also remarked (p. 126) that plant remains, "such as the impressions of Equisetum stems and the leaves of higher plants ... are of sporadic occurrence in the Tipton tongue". In sec. 30, T. 25 N., R. 101 W., he noted "the mingling of the bones of aquatic and terrestrial vertebrates in a thin but persistent grit", which he believed "is a beach deposit in the Tipton tongue of the Green River formation". Bradley recorded also that petrified wood is rather abundant near the top of the Tipton tongue.

The Vermilion Creek gas area of southwest Wyoming and northwest Colorado was examined by Nightingale who reported in 1930 that "a few outliers and most of the rocks around the west, north, east, and southeast borders of the structural area belong to the Tipton shale".

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MIDDLE EOCENE LANEY SHALE MEMBER

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Member of the Green River group. The type locality is along Laney Rim, south of Tipton Station on the Union Pacific Railroad, Sweetwater County, Wyoming.

TYPE DESIGNATION. -- The member was named and described by Schultz in 1920 (251: 27-28):

"The second member [from the top] of the Green River formation, herein named the Laney shale member, from typical exposures along the Laney Rim, lies unconformably below the 'Tower Sandstone' [lentil]. On the east side of the dome the beds consist of white and green fissile shale, limestone,

and sandstone similar to those so characteristic of the lower member, or Tipton shale, of the Green River formation in this part of the field and to the entire Green River formation in other parts of the Green River Basin.

"These beds in places lie unconformably upon the third member of the formation, the Cathedral Bluffs red beds[1], and the relations along this contact indicate that there was an erosional interval in which channels were cut into the red beds before the overlying shale was deposited. In other parts of the field the beds are apparently conformable and seem to grade upward into the shales without a break, although the contact is everywhere well marked by means of a color line.

* * *

"The series of red beds [Cathedral Bluffs tongue] that mark the escarpment around the Washakie Basin ... is overlain nearly everywhere by this series of fine, fissile, Laney shales, 100 to 800 feet thick, which in turn is capped in places, as at Pine Bluffs, by reddish or cream-colored coarse-grained sandstone that is probably equivalent to the 'Tower Sandstone' ..."

SYNONYMY. -- Emmons (in King 136: 211) considered the base of the Laney shale the base of the Green River proper.
Powell (229: 63-64) and others regarded the Laney shale as the upper portion of the "lower" Green River group (see pl. 2).
The unnamed lower member of the Green River of Schultz (247: 259)(248: 222, 225-226) = Laney shale (see table, p. 18).

IMPORTANT REFERENCES. -- Emmons (in King 136: 211, 212); Powell (229: 45, 63-64, 166); Schultz (251: 27-28), (247: 259), (248: 222, 225-226).

GENERAL INFORMATION

The beds in the region of Laney Rim, later chosen by Schultz as the type exposures of the Laney shale member, were described in 1877 by Emmons (in King 136: 211-212). In this locality, Emmons said, the red beds (Cathedral Bluffs tongue)

"are capped by about 100 to 150 feet of an impure concretionary limestone of drab color, having at its summit a seam about 4 inches in thickness of oolitic limestone, which has been, in a great measure, silicified and changed into a dark-gray chalcedony. These upper calcareous beds represent the base of the Green River group (as mapped by King). The oolitic seam is made up of rounded grains from one-thirtieth to one-tenth of an inch in diameter, of a concentric structure, cemented by a cryptocrystalline limy matrix. Examined under the microscope, they show no evidence of organic origin and are seen to be almost identical with the limy sands which are found on the present beaches of the Great Salt Lake. A partial analysis of the agatized portion of this seam gave 74.818 per cent of silica,

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[1]The Cathedral Bluffs "redbeds" are no longer included in the Green River group, but are recognized as an intercalated tongue of the "Wasatch" (see pp. 157-158, pl. 4).

the remainder being principally carbonate of lime, with some alumina, oxide of iron, and magnesia."

In 1931 Bradley found (22: 9) that in the type locality the Laney shale is divisible into two nearly equal units, "of which the lower contains more marlstone and sandstone than the upper and weathers a rather somber gray. The upper unit is nearly all finely laminated marlstone, shale, and oil shale and weathers stark white. A thin but very persistent buff zone separates the two units".

Schultz (251: 28) said that the beds in general dip slightly toward the center of the Washakie Basin, and that, in the vicinity of Flat Top (Washakie) Mountain, they are nearly horizontal.

Sears (260: 293) found that in Moffat County, Colorado and southern Sweetwater County, Wyoming,

"the Laney shale ... is persistent and makes up the bulk of the [Green River] formation; southeastward from the neighborhood of Lookout Mountain this member is the actual base of the formation.

In an earlier paper (1924) Sears and Bradley, who examined the Laney shale in Moffat County, stated (263: 98) that in T. 8 N., R. 96 W., Godiva Ridge "is capped by the main body of the Green River formation, which in this area is the Laney shale member". They remarked further (p. 98):

"On the rim of the Washakie-Sand Wash depression the main body of the Green River formation (Laney shale member) undergoes a very gradual northward change. Near the mountains it is prevailingly buff and much of its shale is limy and poor in oil-yielding organic matter. Although sandstones are numerous, only one conglomerate was observed. This conglomerate, about 5 feet thick, contains small subangular pebbles of black and green chert and of coarse-grained red quartzite, some grains of glassy quartz, and a few compact clay balls. The pebbles average a quarter of an inch in diameter; a few pebbles of black chert are an inch in diamter. This conglomerate lens, near the top of the Laney shale member in T. 9 N., R. 100 W., passes rapidly northward into a coarse-grained sandstone with a limy cement. Just west of Little Snake River, near the center of T. 8 N., R. 97 W., two or three thin beds of coal and numerous beds of partly humified plant remains occur in the Laney shale several hundred feet above the base. The coal beds are bony and very lenticular, ranging from a few inches of carbonaceous material to beds 3 feet thick."

Bradley recorded (18: 123) in 1926 that northeast of the town of Green River, in the region of White Mountain, "the deposits overlying the Tipton tongue belong to the Laney shale member, which here consists entirely of finely laminated shale, oil shale, and limestone." He found also that in "this area the Laney shale member thins and disappears completely toward the north and east". He stated (p. 125), moreover, that

"The Laney shale member of the Green River formation thins northward

from about 200 feet in sec. 31, T. 24 N., R. 104 W., to less than 50 feet, and finally by the introduction of more and more thin fingers of green clay it loses its lithologic identity and passes over in sec. 3, T. 25 N., R. 102 W., into the typical fluviatile deposits of the Cathedral Bluffs tongue of the Wasatch formation."

Bradley added (p. 127):

"This member consists entirely of exceedingly fine-grained sediments which contain in addition to the clastic mineral matter varying proportions of organic matter. The organic content ranges from almost none in the barren limy shale to as much as 36 per cent in the richest oil shale found in this area. On distillation this rich shale yielded oil at the rate of 35.5 gallons to the short ton."

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MIDDLE EOCENE — MORROW CREEK FORMATION and TOWER SANDSTONE LENTIL

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- The Morrow Creek member is here ranked as a member (probably of formational rank) of the Green River group. The Tower sandstone is a lentil in the Morrow Creek formation. The type locality of the Morrow Creek is in the valley of Morrow Creek, northern Sweetwater Co., Wyoming. The type locality of the Tower sandstone is the region of "The Towers", a local name applied to the cliffs in the vicinity of the town of Green River, Sweetwater County, Wyoming.

TYPE DESIGNATION. -- The Morrow Creek formation was named by Bradley (18: 123) in 1926:

"The Tower sandstone ... occurs ... in the vicinity of the town of Green River, Wyo. In the northern part of Sweetwater County it appears to be replaced by the lower part of the plant-bearing beds herein designated the Morrow Creek member of the Green River formation, because of their extensive exposures in the valley of Morrow Creek. ... The Morrow Creek member is a distinct lithologic unit easily traceable from this area southward along the top of White Mountain to the Union Pacific Railroad and thence westward to Green River. It consists largely of buff sandy limestone and buff sandstone, which contrast rather sharply with the underlying bluish-white Laney shale member. Poor bedding and chippy fragments are characteristic of the exposures of these beds. In addition to the sandstone and limestone there is a small amount of light-brown paper shale and an occasional alga reef or pisolite. Locally plant impressions are abundant. The Morrow Creek member ranges in thickness from 100 to 300 feet."

SYNONYMY. -- "Upper Green River Group" of Powell (229: 45, 63, 104-105, 167) = the Tower sandstone and "Plant beds", which in turn are equivalent to the Morrow Creek member and Tower sandstone lentil of Bradley.

MORROW CREEK FORMATION and TOWER SANDSTONE LENTIL - Specific Information

SYNONYMY (cont'd).
Tower sandstone of Powell (229: 45) and others, according to Bradley (22: 9), is a lentil, included by definition in the Morrow Creek member of the Green River group.
"Plant beds" of Powell (229: 45) = Morrow Creek member of the Green River.
"Channel sandstones" of Lee (S.369: 74) = Tower sandstone lentil.

DISTRIBUTION. -- Since the Morrow Creek formation corresponds in general to the "upper Green River" of Powell and others, it is probably represented wherever the "upper" member has been described (see pp. 180-183). The writer knows of no publication, however, in which the distribution and correlation of the Morrow Creek member, as such, has been considered in detail. The member was described by Bradley only in the northwest quarter of Sweetwater County. The writer has identified extensive exposures of the member in north Sweetwater County, extending for a distance of at least 20 miles east of the Oregon Buttes locality mentioned by Bradley (18: 125).

IMPORTANT REFERENCES. -- Bradley (18: 121-131), (22: 8-19); Emmons (in King 136: 203-204, 210, 213-215, 219-222, 240-244); Powell (229: 45, 63, 104-105, 167); Schultz (247: 259), (248: 222-223, 226), (251: 24-28, 45-64).

GENERAL INFORMATION

Bradley said (22: 9) in his paper of 1931:

"The Morrow Creek member, nearly all crudely bedded sandy and limy shale or shaly marlstone that weathers yellowish brown, forms the upper part of the formation and at the type locality of the Green River formation includes the Tower sandstone lentil."

The Tower sandstone had been previously described in 1876 by Powell who said (229: 45):

"The Tower Sandstone is well shown in the Cliffs at Green River Station and in that vicinity, especially up and down the river for several miles. This sandstone is also well exposed on the eastern side of the Green River, below the mouth of Currant Creek."

A subsequent page of Powell's report contains the remarks (229: 63):

"The Tower Sandstone which forms the base of the Upper Green River Group is laid down unconformably on the Lower Green River, the unconformity being represented by gentle valleys of erosion; and there seems to have been a period of erosion or dry land conditions separating the Tower Sandstone from the Plant Beds of the Upper Green River also, and during this dry land period the sands of the Tower Sandstone were eroded by rains and drifted by winds."

MORROW CREEK FORMATION and TOWER SANDSTONE LENTIL - General Information

Powell (229: 45) described the *Plant beds in the following terms:

"The Plant Beds of this group are well exposed to the north of Green River Station, and between that point and Alkali Stage Station in many gulches and canons. They are also well exposed in the cuts of the Union Pacific Railroad between Green River Station and Bryan. Another good exposure can be seen in the escarpments on either side of Henry's Fork, commencing about five miles above its mouth and continuing up the stream for several miles."

Schultz observed (251: 25-26) in 1920 that on the west side of the Rock Springs uplift, beds overlying the Laney shale member

"here tentatively included in the Green River formation consist of massive, irregularly bedded sandstone, sandy limestone, and shale that are well exposed along the crest of White Mountain north of Wilkins, a station on the Union Pacific Railroad a few miles west of Rock Springs; on Wilkins Peak, south of the Union Pacific Railroad, in the vicinity of the town of Green River; in Fire Hole Basin; and at other points along Green River. These beds were designated by Powell 'plant beds and Tower Sandstone', but his 'Tower Sandstone' was not clearly defined and is not a geographic name. As these beds were not studied in detail, it is not proposed to define them here and introduce a geographic name or names for them.

* * *

"Powell's names are ... tentatively used, and the beds are also tentatively retained in the Green River formation, where they were placed by Powell, although there is a possibility that they may prove to belong to the overlying Bridger formation. The 'Tower Sandstone' forms vertical cliffs and in many places, as in the vicinity of the town of Green River, it rests on irregular surfaces of shale and is itself very much distorted, whereas the shale beneath it is not deformed. Beds of the same sandstone are present in small outliers on the east side of the dome in the vicinity of Pine Butte.

* * *

"As further studies are made of these beds in the areas where they are well exposed it will probably be found that they are contemporaneous with the Bridger beds and represent local deposits laid down under peculiar conditions near the margin of the Bridger Lake."

Reeside, who examined the geology of the Green River Valley between the towns of Green River, Wyoming, and Green River, Utah, stated (230: 35) in 1923:

"Most of the part of the Green River Valley lying between Green River, Wyo., and Henry's Fork is cut in rocks assigned to the Green River formation (lower Eocene). This formation includes a lower division of whitish, gray, and greenish fissile shale, light-colored limestone, and sandstone and an upper division of massive, irregularly bedded brown sandstone with some sandy limestone and shale -- the 'Tower Sandstone' and 'plant beds' of Powell. Over much of the way the 'Tower Sandstone' caps

the bluffs along the river, and the gray mass of shaly beds beneath it forms steep slopes. The dips of the beds are low, usually so low that they are not apparent to the eye."

Sears (260: 294) found in 1925 that in Moffat Co., Colorado,

"The upper boundary of the Green River formation around Sand Wash Basin is difficult to locate with precision, as the uppermost 100 to 150 feet contains beds typical of both the Green River and the Bridger. Near Sand Wash the boundary chosen is the base of a deep-green gritty sandstone, above which are the predominantly light-gray clay shales of the Bridger; the bottom of this sandstone is an uneven plane, apparently marking a small local unconformity. The transition zone at the top of the Green River is possibly equivalent to the "Upper Green River" ('Tower Sandstone' and 'plant beds') of Powell."

Bradley (18: pp. indicated) observed that in north Sweetwater County, Wyoming,

"In this area the Laney shale member thins and disappears completely toward the north and east. The overlying member of the Green River formation, which Powell called the 'Upper Green River,' continues eastward to Steamboat Mountain and northeastward to Oregon Buttes and Continental Peak, beyond which it was not traced. In Powell's definition of the 'Upper Green River' he included a basal sandstone, which he designated the Tower sandstone, and the overlying plant beds. The Tower sandstone was so named because it forms the tops of the weathered rock masses known in the vicinity of Green River as The Towers. It is lenticular and is therefore herein designated the Tower sandstone lentil of the Green River formation. It consists of cross-bedded and massive beds of medium to coarse grained brown sandstone which is firmly indurated by a limonitic cement. The Tower sandstone is not present in the area described in this report but occurs farther south, in the vicinity of the town of Green River, Wyo. (p. 123)

* * *

" ... the Morrow Creek member of the Green River formation, which itself becomes sandy and thins northward from more than 300 feet to about 100 feet in Oregon Buttes, in sec. 12, T. 26 N., R. 101 W., rests directly upon the Cathedral Bluffs tongue.

* * *

"Calcareous alga reefs, oolites, pisolites, and ostracode-bearing limestones are present in abundance in the Tipton tongue and Morrow Creek member of the Green River formation in this area ... (p. 125)

* * *

"Near the top of both the Tipton tongue and the Morrow Creek member of the Green River formation petrified wood is rather abundant." (p. 126)

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SPECIFIC INFORMATION

The following four members of the Green River formation have been differentiated and named in Colorado and Utah. The names have not been applied to strata in Wyoming, but the type designations are included here for reference purposes.

Douglas Creek Member

TYPE DESIGNATION. -- The Douglas Creek member was named by Bradley, who said in 1931 (22: 9-10):

"The rocks making up the high ridge which separates the drainage basin of West Douglas Creek from that of Trail and East Salt Creeks are typical of the basal part of the Green River formation east of Bitter Creek. Because this group of beds, which constitutes a distinctive and mappable unit, is so thick and so well exposed at the head of Douglas Creek, especially in the east half of T. 5 S., R. 102 W., Garfield County, Colo., the writer proposes to call it the Douglas Creek member of the Green River formation.

"The beds of this member are characteristically buff or yellowish brown and in most places contrast markedly with the underlying drab or variegated mudstone of the Wasatch formation and the overlying gray or bluish-gray marlstone and oil shale. The member ranges in thickness from about 200 feet on Piceance Creek to nearly 800 feet near the head of Trail Creek. It differs from the bulk of the formation in having relatively large proportions of sandstone, limestone, algae reefs, and oolite. Moreover, the marlstone and shale beds are notably different from those in other parts of the formation, as many of them are silty and interbedded with very fine-grained sandstone. The amount of oil shale is negligible.

* * *

"Ostracode-bearing shale and marlstone are characteristic rocks of the Douglas Creek member and in many places are associated with oolite. Locally ostracodes make up considerable masses of rock. Gastropods and pelecypods are also locally plentiful but are not so characteristic of the basal member in this area as west of Bitter Creek or in Wyoming. Vertebrae, finrays, and other fragments of small fish skeletons are surprisingly abundant in the southwestern part of the Piceance Creek Basin."

Garden Gulch Member

TYPE DESIGNATION. -- The name, Garden Gulch member, was proposed by Bradley (22: 10, 11) in 1931:

"In most places east of Bitter Creek the transition upward from the Douglas Creek member is abrupt and marked by a change from yellowish brown or buff to light gray, as well as by a distinct change in lithology. The overlying member will be designated herein the Garden Gulch member because it is so thick and so fully exposed in the bluffs near the mouth of Garden Gulch, a short gulch tributary to Parachute Creek in secs. 7 and 8, T. 6 S., R. 96 W., Garfield County, Colo. The rocks of this member

weather either to a smooth slope or to one interrupted only by low, rounded, and discontinuous benches. Its topographic expression is thus noticeably different from that of either the Douglas Creek member, which makes steeper slopes broken by low but precipitous ledges, or the overlying oil shale bearing rocks, which generally make steep and rather high but broken cliffs. The thickness of this member ranges from a little more than 200 feet in Hells Hole Canyon, near Watson, Utah, to about 700 feet in the Parachute Creek Canyon, north of Grand Valley, Garfield County, Colo."

* * *

"Ostracodes occur only sparingly in this member in thin limestone or lean paper-shale beds. Garpike scales are not numerous, and only a few skeletons of small fish were found. A few plant remains, mostly stem impressions and leaf fragments, were found in the sandstone and siltstone."

Parachute Creek Member

TYPE DESIGNATION. -- The Parachute Creek member of the Green River group also was named by Bradley (22: 11) in 1931:

"The member next above the Garden Gulch member is distinguished from other parts of the formation by its content of oil-shale beds. It contains all the large groups of rich beds, most of the individual rich beds, and a very large proportion of the low-grade oil shale. As the oil-shale facies of the Green River formation reaches its maximum thickness and probably also its maximum richness in the vicinity of Parachute Creek, Colo., it seems particularly appropriate to name this unit the Parachute Creek member. This member ranges in thickness from about 175 feet in the vicinity of Watson, Utah, to a little more than 1,000 feet in the vicinity of Parachute Creek. It is predominantly a cliff-forming unit, and its top is marked by a soft limy sandstone which is conspicuous because of its bright ocherous color. This sandstone makes the top of the highest cliffs in the canyon of Parachute Creek and its tributaries. For convenience of description and discussion the oil-shale beds of the Parachute Creek member have been grouped into three units, designated here the lower oil-shale group, the transitional beds, and the upper oil-shale group."

Evacuation Creek Member

TYPE DESIGNATION. -- The Evacuation Creek member of the Green River formation was named by Bradley (22: 14) in 1931

"The uppermost lithologic unit of the Green River formation is the Evacuation Creek member, so named because of the excellent exposures on Evacuation Creek, Utah, and because in that locality it is a definite and readily mappable unit. In the vicinity of Piceance Creek it is at least 840 feet thick and is overlain by about 400 feet of beds that are dominantly sandy. No fossils have been found in these uppermost sandy beds, but they are lithologically and stratigraphically equivalent to the basal part of the Bridger formation of the Uinta Basin and are here tentatively assigned to that formation. In the Uinta Basin the Evacuation

Creek member is also a definite unit and along the White River in Utah is about 530 feet thick.

"This member consists chiefly of barren shale and marlstone that weathers brown or brownish gray, and in most places it makes gently rounded slopes broken by irregular and discontinuous ledges. Most of the shale is limy, thin bedded, and platy or irregularly chippy. Locally it is sandy. ... The Evacuation Creek member also contains a few thin beds of rich oil shale similar to those in the Parachute Creek member. ...

"Along Parachute Creek in Colorado and the White River in Utah the Evacuation Creek member contains numerous salt cavities. Many of the oil-shale beds and a few of marlstone and muddy sandstone show contorted bedding, but shale breccias, mudstone lumps, and mud cracks are not so abundant as in the Garden Gulch member. At one place near the top of the section on the White River in Utah mud cracks were found on the upper surface of a bed of low-grade oil shale, and in another place mud cracks occur on a bed of sandstone marked with oscillation ripples. ...

"Most of the finely preserved adult insects and leaves of the Green River formation came from the lower part of the Evacuation Creek member. Larvae-bearing beds are also abundant in the lower part."

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UPPER(?) EOCENE — RAMSHORN VOLCANIC SERIES

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Rank uncertain; probably a formation. The type locality is in the Absaroka Mountains, R. 4 W., T. 8 N., Fremont County, Wyoming.

TYPE DESIGNATION. -- The Ramshorn volcanic series was named by Love (162: 21-22) in 1934:

"Ramshorn volcanic series. - Resting unconformably on the uneven erosional surface of the /"post Green River"/ agglomerates and breccias is a thick succession of coarsely bedded light-colored soft andesite tuffs, which have been stripped far back from the resistant underlying agglomerates. In general the texture is fine, although there are some angular fragments a foot in diameter, which are usually so badly decomposed that they crumble readily. The tuffs are light colored but upon close examination numerous small crystals of pyroxene and hornblende can be seen. The bedded structure is so massive that it is not apparent unless the tuffs are viewed from a distance. The individual beds are between 20 feet and 100 feet in thickness and the succession has a maximum thickness of 600 feet in this area. To the north this succession of tuffs is much thicker.

"Lying on the white tuffs is a series of tuffs, pink andesite flows and breccias. In places the texture of the breccias is so coarse that they resemble agglomerates, which are sufficiently resistant to form a protective capping to the soft underlying tuffs. In the northeastern corner of

RAMSHORN VOLCANIC SERIES - Specific Information

the area and extending for miles farther north can be seen alternating layers of white tuffs and pink andesite flows of similar character. This series of light colored andesitic tuffs and flows is here named the Ramshorn volcanic series. The name is taken from the The Ramshorn, which is located twelve miles west of this area. The Ramshorn is a mountainous ridge made up of rocks of this volcanic series which also extends for miles to the north and east of the area mapped and forms many of the prominent peaks of the region.

"The only fossils found in the agglomerates are a few massive tree stumps. Therefore, all that can be definitely said of the age of this series of volcanic rocks is that they are post-Green River."

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EOCENE PINYON CONGLOMERATE

SPECIFIC AND GENERAL INFORMATION

RANK AND TYPE LOCALITY. -- Formation. The type locality is at Pinyon Mountain, Yellowstone National Park, Wyoming.

TYPE DESIGNATION. -- The formation was named in 1896 (306: 5) by Weed, who said that the strata of the Pinyon conglomerate

"occupy limited areas and are found only in the southern end of the Park. They have been designated the Pinyon conglomerate from the name of the mountain where they are best exposed. They consist of a series of conglomerate beds with local intercalations of sandstone, the formation resting unconformably upon the upturned Laramie (Cretaceous). The conglomerate is almost wholly made up of pebbles, sometimes as large as 10 inches in diameter, of vari-colored quartzites, carrying occasional fragments of gneiss, and still more rarely a few polished pebbles of porphyry. The quartzite pebbles are mostly light-colored, but are associated with others of widely contrasting shades of red, purple, and green. They are well rounded and polished, and show indentations and sheared surfaces that are the result of pressure and movement. The pebbles are cemented by a matrix of coarse sand, which passes in places into lenticular beds of sandstone. This sandstone is coarse and loosely compacted, and shows strong cross-bedding."

GENERAL NOTE. -- The Pinyon conglomerate has had very little mention in geologic literature. Hague (92: 2) offered the following observations in 1896:

"Between the blocking out of the mountains at the close of the Laramie and the pouring out of vast eruptions of igneous rocks there were deposited certain strata, which in the /Yellowstone/ Park are limited to the southeast corner (Lake sheet). Here are found, resting unconformably upon the tilted and eroded sandstones of the Laramie epoch, a series of nearly horizontal beds which have been designated the Pinyon conglomerate, named from

the mountain where they are best exposed, on the divide between Wolverine and Gravel creeks. Nine-tenths of this material consists of waterworn pebbles mingled with sand and gravel; associated with them are fragmentary pieces of rock derived from the underlying Mesozoic strata, with occasional well-rounded pebbles of volcanic origin, together with granite and gneiss. This material has accumulated to a thickness of nearly 600 feet, and is clearly a shallow-water, in-shore deposit, as it is far too coarse to have been transported to any great distance. As regards their age, these conglomerates have been provisionally referred to the Eocene period, since they were deposited subsequent to the Laramie upheaval and must have preceded the accumulation of volcanic rocks ... These gravels are the northern extension of much larger areas occurring in the Wind River Mountains."

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EOCENE CANYON CONGLOMERATE

SPECIFIC AND GENERAL INFORMATION

RANK AND TYPE LOCALITY. -- Formation. The type locality is along the Lamar River and in the Grand Canyon of the Yellowstone, Yellowstone National Park, Wyoming.

TYPE DESIGNATION. -- Weed named the conglomerate in 1896 (306: 5):

"Rocks of the Neocene period occupy still more restricted areas than those of the earlier Tertiary deposits. The Canyon conglomerate is named from its occurrence in the Grand Canyon of the Yellowstone, and consists of thinly bedded conglomerates and gravels, exposed only in stream cuttings along the Lamar River and the Grand Canyon. The beds are light-colored and are composed of well-rounded pebbles of Archean gneisses and andesitic material, derived from the underlying breccias, the latter greatly predominating. At both localities the beds are capped by recent basalt."

GENERAL NOTE. -- Hague (92: 2) made the general observation:

"The only other strictly sedimentary formation of Tertiary age in the Park [besides the Pinyon conglomerate] are beds of waterworn congomerate and friable sands exposed in the walls of the Grand Canyon and in the valley of Lamar River, in both cases overlain by basalt. In the Grand Canyon they are both overlain and underlain by basalt. They were deposited after the outbursts of andesitic breccia, but before the great flows of rhyolite which covered the country were poured out, so that their geological position with reference to the igneous rocks is well determined. They are of slight importance in themselves, seldom exceeding 50 feet in thickness, and they cover limited areas."

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SECTION OF THE BRIDGER FORMATION (*WASHAKIE FORMATION)
IN THE WASHAKIE BASIN (after Granger)

(Section measured from east end of summit of Haystack Mountain down to basal sandstone at Tadpole Stage Station on the Overland Trail)

	Top	Thickness (feet)
22.	Very coarse and very hard greenish sandstone, weathering brown. Not fossiliferous. This layer breaks up into enormous blocks weighing many tons each which are found strewn over the side of the mountain.	15
21.	Gray, green, slamon colored and purple sandstone and sandy shales with a few thin bands of clay shales. To the westward the salmon tints give way to pink. From Cope's description it was apparently in this division a few miles to the west that he found the skull of Eobasileus cornutus.	150
20.	Light gray (nearly white) coarse sandstone, cross-bedded and of only local occurrence.	20
19.	Gray and brown sandy shale and loosely compacted gray sandstone. On approximately this level and in very light gray sandstone, on the northwestern face of the mountain, was found the skull of Dolichorhinus hyognathus.	45
18.	Light brown clay shale.	8
17.	Very coarse loosely packed gray sandstone, containing pebbles and clay pellets in layers. Except in the uppermost and lowermost strata this is the most constant layer found in these beds. To the westward it is of a pale yellowish green color and can be traced around the point of the mountain and then to the southwest until it is lost under the mountain and then to the southwest until it is lost under the plain. The type skull of Metarhinus earlei and the skull of an undescribed species of Limnocyon are from this stratum.	15
16.	Gray sandy shale, with one thin band of gray sandstone.	5
15.	Gray, greenish and yellowish sandy shales and soft sandstones. Represented to the westward chiefly by light gray and pink sandstone.	50
14.	Green and blue-gray sandstone, weathering vertically.	15
13.	Greenish gray sandy shale and soft sandstone. The disintegrated material on the surface of this stratum is a foot or more deep.	50
12.	Hard, fine, green and greenish gray sandstone.	2

SECTION OF THE BRIDGER FORMATION IN THE WASHAKIE BASIN (after Granger[1])
(Continued)

11.	Light gray sandy shale, weathering white. This was a rather conspicuous stratum and quite constant at the east end of the mountain. To the west the stratum passes under the plain.	4
10.	Gray and greenish gray sandy shales, a harder layer at the top forming a bench.	15
9.	Flinty hard greenish sandstone. A bench of considerable extent is formed by this layer.	2
8.	Gray sandy shale, with two layers of nodular sandstone.	35
7.	Hard, brittle, shaly sandstone, weathering brown.	1
6.	Gray and greenish sandy shale alternating with gray, brown-weathering sandstone, the lower twenty feet having thin bands of mottled clay weathering red.	60
5.	Area of one half mile covered with sage brush; represented at other localities by numerous layers of gray nodular sandstones (weathering rusty color) interstratified with gray sandy shales. Fossils fairly abundant.	75
4.	Gray sandy shale.	10
3.	Brown sandstone (local).	10
2.	Gray sandstone, bluish and gray sandy shale and hard fissile shale. The fissile shales are pale green in places, particularly near La Clede Station and toward the Kinney Spring. Remains of the smaller mammals are rather abundant in the division.	40
1.	Hard sandstone, weathering rusty brown, nodular in places and very uneven as to thickness. In some places it consists of several thin layers separated by sandy shale, in others of a single solid stratum. This is the Lower Brown Sandstone of the Amer. Mus. Expedition of 1893 and 1895. It extends in a nearly continuous rim around the Basin and marks the limits of the Washakie formation. Rich in mammalian remains, especially of Uintatheres and Titanotheres.	15
	Total thickness	642

[1]Granger, Walter (86: 20), Faunal horizons of the Washakie formation of southern Wyoming: Am. Mus. Nat. History Bull., vol. 26, 1909.

THE FLORA OF GREEN RIVER AGE IN THE WIND RIVER BASIN

Comparative Tabulation Showing Range of Species (after Berry[1])

	Green River formation	Denver formation	Fort Union formation	Clarno formation	Puget group	Atlantic Coastal Plain			Arctic Tertiary	California
						Wilcox group	Claiborne group	Jackson group		
Equisetum tipperarense	-	-	-	-	-	-	-	-	-	-
Salvinia preauriculata	-	-	-	-	-	X	-	-	-	-
Danacea coloradensis	X	-	-	-	-	-	-	-	-	-
Dryopteris weedii	-	-	X	-	-	-	-	-	-	-
Asplenium serraforme	-	-	-	-	-	-	-	-	-	-
Asplenium eoligniticum	-	-	-	-	-	X	-	-	-	-
Lygodium kaulfussii	X	-	X	X	X	-	X	X	-	-
Typha sp	-	-	-	-	-	-	-	-	-	-
Sparganium antiquum	X	-	-	-	-	-	-	-	-	-
Sabalites florissanti	X	-	-	-	-	-	-	-	-	-
Sabalites powellii	X	-	-	-	-	-	-	-	-	-
Geonomites haydenii	X	-	-	-	-	-	-	-	-	-
Musophyllum complicatum	X	-	-	-	-	-	-	-	-	-
Juglans alkalina	X	-	-	-	-	-	-	-	-	-
Juglans occidentalis	X	-	X	-	-	X	-	-	-	-
Myrica ludwigii	X	-	-	-	-	-	-	-	-	-
Salix sp	X	-	-	-	-	-	-	-	-	-
Dryophyllum wyomingense	-	-	-	-	-	-	-	-	-	-
Ficus wyomingiana	X	-	-	-	-	-	-	-	-	-
Ficus ungeri	X	-	?	-	-	-	X	X	-	-
Fagara wyomingensis	-	-	-	-	-	-	-	-	-	-
Sapindus dentoni	X	-	-	-	-	-	X	X	-	-
Sapindus obtusifolius	X	-	-	-	-	-	-	-	-	-
Sapindus winchesteri	X	-	-	-	-	-	-	-	-	-
Negundo fremontensis	-	-	-	-	-	-	-	-	-	-
Zizyphus wyomingianus	-	-	-	-	-	-	-	-	-	-
Ampelopsis tertiaria	X	-	-	-	-	-	-	-	-	-
Grewiopsis wyomingensis	X	-	-	-	-	-	-	-	-	-
Laurus fremontensis	-	-	-	-	-	-	-	-	-	-
Aralia whitneyi	-	-	X	-	-	-	-	-	-	X
Aralia browni	-	-	-	-	-	-	-	-	-	-
Aralia notata denticulata	-	?	?	-	-	?	-	-	-	-
Diospyros mire	-	-	-	-	-	-	-	-	-	-
Sambucus? winchesteri	X	-	-	-	-	-	-	-	-	-
Nordenskioldia borealis	X	-	-	-	-	-	-	-	X	-
Carpites newberryanus	X	-	-	-	-	-	-	-	-	-
Antholithes anceps	-	-	-	-	-	-	-	-	-	-
Antholithes browni	-	-	-	-	-	-	-	-	-	-
Antholithes fremontensis	-	-	-	-	-	-	-	-	-	-
Carpolithus browni	-	-	-	-	-	-	-	-	-	-
Carpolithus bridgerensis	-	-	-	-	-	-	-	-	-	-
Sporophyllis	-	-	-	-	-	-	-	-	-	-

[1] After Berry, E. W. (15: 60), A flora of Green River age in the Wind River Basin: U. S. Geol. Survey Prof. Paper 165-B, 1930.

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation. The type locality is in the Bridger Basin, north of the Uinta Mountains in Uinta County, southwest Wyoming.

TYPE DESIGNATION. -- The Bridger formation was named and first described by Hayden in 1869 (104: 191):

"The next group commences not far west of Bryan, and is doubtless a prolongation upward of the Green River shales ...

"The sediments are composed of more or less fine sands and sandstones, mostly indurated, sometimes forming compact beds, but usually weathering into those castellated and dome-like forms which have given such celebrity to the 'Bad Lands' of White River. Church Buttes, near Fort Bridger, is an example of this group, and shows the style of weathering to which I refer. I have called this series of beds the Bridger group, from the fact that it is best developed in this region. It has already yielded remarkably fine species of Unio, Melania, Planorbis, Vivipara, Helix &c., with a great variety of turtles and mammalian remains."

SYNONYMY. -- *Washakie group of Hayden (104: 190) (105: 73) (and other papers) = Bridger formation plus parts of the "Wasatch" and Green River formations, according to Granger (86: 13-14).

"Dinoceras beds" of Marsh in 1877 (171: 355) (and various other writings) = Bridger formation plus Green River in some cases.

*Bitter Creek group of Powell in 1876 (229: 45-47, 64-65) included the Bridger formation in some localities.

"Third group" of the Tertiary series, described by Lesquereux (in Hayden 108: 387-388) = Bridger formation.

"Green River group" of Lesquereux in 1876 (148: 19) and in 1883 (150: 137) included the Bridger formation.

"Bridger" of Eldridge in the Wind River Basin in 1894 (69: frontispiece) = largely Wind River

"Wasatch" of Endlich in 1879 on the Sweetwater Divide (in Hayden 114: 110) included the "Bridger".

"Bridger" of Darton in 1906 at the southern end of the Big Horn Mountains (57: 70) may = Wind River.

"Wasatch" of Darton in 1908 in the Wind River Basin (59: 463) probably includes the so-called Bridger.

"Bridger" of Smith in 1908 (280: 450-451) included Wind River and Green River as substages.

"Orohippus and Uintatherium zone" of Osborn in 1912 (220: 235) = Bridger formation.

"Life Zones" 10-14 of Osborn (224: 9, 57, 58, 82-90) = Bridger formation (including the *Washakie).

"Green River formation" at the west end of the Owl Creek Mountains, described by Love (162: 17-19) in 1934, is probably equivalent to the strata of the Wind River Basin from which Berry (15: 55-79), in 1930 described a "flora of Green River age". These deposits were believed by Berry, and Sinclair (Berry 15: 56) to be in the stratigraphic position of the "so-called Bridger" of Sinclair and Granger (276: 83-117) in

the Beaver Divide section. Love has stated (personal communication), moreover, that since his paper was written, remains of a distinctive Bridger mammal have been found in the upper portion of his "Green River". For these reasons the Wind River Basin-Owl Creek Mountain partial equivalent of the Green River formation is discussed in the present paper in connection with the Bridger formation.

DISTRIBUTION. -- Southwest Wyoming, principally in the Green River, Bridger and Washakie basins. A portion of the Tertiary section in the Beaver Divide (Sweetwater escarpment) on the south border of the Wind River Basin, Wyoming has been tentatively called Bridger. Also doubtfully identified in the Big Horn Basin. In Utah the Bridger is present along the north flank of the Uinta Mountains, east of the Wasatch mountains, and in the Uinta Basin south of the Uinta Mountains. Scattered outcrops have been reported in west and northwest Colorado and in Wasatch Co., Utah.

IMPORTANT REFERENCES. -- Bauer (11: 675-676); Berry (15: 55-79); Clark (28: 142); Darton (57: 70); Emmons (in King 136: 204-205, 210, 215-218, 238-239); Hay (98: 327-342); Hayden (104: 191), (105: 58, 144-145); King (137: 394-405); Love (162: 17-19); Marsh (172: 1-243, pls. 1-56); Matthew (in Osborn 219: 95-100); Osborn (219: 48-54), (224: 9, 57, 58, 82-90); Scott and Osborn (255: 223-225); Sinclair and Granger (276: 94-97), (277: 62-63, 66-67); White (in Hayden 113: 37).

GENERAL INFORMATION

Areal Distribution and Lithology

Southwest Wyoming; adjacent parts of Colorado and Utah. -- In 1871 Hayden (105: 144), writing on the Bridger formation in the type locality, noted that

"From Bryan we pass over a peculiar region, differing again in its surface features from any previously seen on our route. Far distant to the southward the singular, dome-like appearance of what we have usually styled the 'bad lands' is visible, their brown and indurated sands and clays having weathered into remarkable forms. One of these singular hills forms a noted landmark along the old stage road, which has received the name of 'Church Buttes' ... To this formation I have given the name of the 'Bridger Group' ..."

In 1876 Powell (229: 45) recorded a few typical exposures:

"This group can be well studied in the vicinity of Fort Bridger, at Church Buttes, and in the Cameo Mountains. It has an extensive development in this region, i.e., west of the Green River and north of the Uinta Mountains, and is usually well exposed. An outlying patch can be seen between Vermilion Creek and the Snake River, on the north side of the Dry Mountains. It can also be finely studied at Haystack Mountain."

BRIDGER FORMATION - Areal Distribution and Lithology

Peale, in his report of 1879 on the Green River Basin, remarked (in Hayden 114: 639) that the largest area of Bridger exposures

"extends northward from Ham's Fork toward Slate Creek, breaking off in low bluffs in which the sombre clays and sands of the group are exposed. Between the mouth of the Big Sandy and the Green, on the east side of the former, there are variegated sands and marls much like those of the Wahsatch Group. They are, however, above the Green River shales, and have therefore been referred to the Bridger Group. They weather in Bad Lands. On the east side of the Big Sandy north of the Green there appeared to be isolated patches of the beds, but they do not extend far to the northward."

In 1869 Hayden (104: 190) designated certain beds in east-central Sweetwater County, in the northern edge of the Washakie Basin, the *Washakie group. He said:

"From Creston to Bitter Creek there are a series of purely fresh-water beds, with some beds of impure lignite, with vast quantities of fossils belonging to the genera Unio, Melania, Vivipara, Helix, &c. This group I regard as middle tertiary, and the strata are very nearly horizontal. I have regarded these beds as separated from the lower tertiary or true lignite group, and have designated them by the name of the Washakie group."

Two years later, however, Hayden (105: 73) remarked that

"Between La Clede and Barrel Springs the strata are very nearly horizontal. The surface is less rugged; still to the south of the road are high, rather abrupt ridges, and in the distance are quite pointed ridges three hundred feet high, composed of the somber, hard, indurated, rusty, arenaceous clays which characterize the Bridger group. Indeed, from its form and style of weathering, and the color of its sediments, it could not be distinguished from the high ridges of the Bridger beds west of our road from Henry's Fork to Green River Station. Although I have hitherto regarded the group of beds which I have denominated the 'Washakie group,' as separated from those of Green River to the westward, yet I am now inclined to believe that the upper series is either an extension eastward of the Bridger group or synchronous with it."

According to Granger (86: 13-14) the *Washakie, as defined by Hayden, included strata which belong to the Wasatch and Green River formations. Osborn said (224: 8) that the Washakie "was contemporaneous with the upper two-thirds of the Bridger formation, and the name Washakie is now abandoned by the United States Geological Survey for the name Bridger". In view of this decision, the *Washakie beds will be treated here in conjunction with the Bridger formation proper, although the validity of this procedure is not admitted by all stratigraphers, Sinclair (272: 25-27) was of the opinion, for example, that petrographic evidence contradicts the faunal testimony and indicates that the Washakie formation is distinct from the Bridger.

Cope summarized the distribution of the Bridger in 1884 (44: 11-12):

BRIDGER FORMATION - Areal Distribution and Lithology

"The distribution of the Bridger formation is limited, and is, so far as I am aware, restricted to three areas, whose mutual connection is as yet uncertain. Its principal mass is in the Bridger basin, which extends from the northern base of the Uinta Mountains to the latitude of the mouth of the Big Sandy River northward. In this area it reaches a depth, according to King, of 2,000 or 2,500 feet. A second district is also in Wyoming, and lies east of Green River between Bitter Creek and the northern boundary of Colorado, in what is called by King the Washakie basin. ... The third region is in Western Colorado, where it loses much of its importance."

Clark, in 1892, summarized (28: 142) available information of the distribution of the Bridger:

"The deposits of the Bridger group are found chiefly in southwestern Wyoming, on the northern flanks of the Uinta Mountains, and on both the east and west banks of the Green River. To the east of this region the strata appear also in portions of western Colorado. The larger area, to the west of the Green River, has been termed the Bridger Basin; the smaller, to the east, the Washakie Basin."

In 1912 Lupton (164: 605-606) reported small exposures of Bridger and Uinta(?) in the Blacktail (Tabby Mountain) coal field of Wasatch County, Utah, and gave detailed sections of the Bridger and Uinta(?).

In 1878 White (in Hayden 113: 37) had noted that there are minor outcrops of Bridger strata in northwest Colorado:

"Strata of the Bridger Group are found to occupy only a comparatively minute portion of the surface in this district, the only locality at which they appear being in the valley of Red Bluff Wash, between Raven Ridge and White River, in the southwestern part of the district, where these strata rest upon those of the upper division of the Green River Group, and are covered in turn by those of the Uinta Group. The strata of the Bridger Group exposed there reach only about one hundred feet in thickness, and probably represent those near the base of the formation."

Woodruff and Day (337: 11), in their report on the oil shales of northwest Colorado and northeast Utah, showed 600 feet of the Bridger formation, consisting mostly of irregularly-bedded loosely cemented fossiliferous sandstone, sandy shale and a few conglomerates, prevailingly pink, gray and brown in colors. Winchester reported on the same general area in 1916 and also found (329: 165) that the Bridger formation is there represented. Sears and Bradley (263: 97) identified the Bridger formation in northwest Colorado, in the Sand Wash Basin.

In 1931 Bradley (22: 19, 21), in his paper on the Green River group, noted that

"In the Piceance Creek Basin, Colorado ... the writer believes that the uppermost 400 feet of sandy beds in the center of the basin are litho-

logically and stratigraphically equivalent to the Bridger formation, and he has tentatively assigned them to that formation. No fossils have yet been found in these beds. ...

"In the eastern part of the Uinta Basin a thick series of brown massive or cross-bedded medium to coarse grained sandstone beds overlies the Green River formation. It forms a rough and rather steep southward-facing slope interrupted by many benches of harder sandstone. This unit is about 800 feet thick, contains a small amount of hard greenish-gray sandy mudstone interbedded with the sandstone, and in most places rests with evident conformity on the Green River formation." (p. 19)

* * *

"Winchester found fossil insects similar to those of the Green River formation in a thin mudstone bed of this large sandy unit and therefore included it in the Green River formation. Osborn and Peterson, however, regard this series of sandstone beds as a part of the Bridger formation, having found bones of Bridger mammals in it.

* * *

"Because this sandstone series contains vertebrate fossils of Bridger age and because the very distinct lithologic change from regularly laminated marlstone and shale to medium-grained massive or cross-bedded sandstone indicates an abrupt change from lacustrine to fluviatile conditions, the writer prefers to regard it as a part of the Bridger formation ...

"It is somewhat puzzling that the vertebrate fossils found near the base of the sandstone series indicate middle or late Bridger time. This suggests that, as there appears to have been no significant break in sedimentation between the Green River and Bridger formations, the uppermost portion of the Green River formation is perhaps of Bridger age. In other words, if the boundary between the Green River and Bridger formations were to be determined wholly by the vertebrate fossils it apparently should be placed at some indefinite horizon below the present lithologic boundary. According to this definition of the boundary, lakes seem to have persisted longer in the Uinta Basin than in the Green River Basin of Wyoming, where all of the Bridger epoch is represented by fluviatile deposits." (p. 21)

Veatch (300: 99) remarked in 1907 that in the type locality in southwest Wyoming, the strata of the Bridger formation have, in places

"a marked greenish cast and contain persistent white calcareous bands, filled with fresh-water shells that are identical in appearance with those found in the Green River and upper Wasatch beds. ... Its outcrops are for the most part limited to the area east and south of Muddy Creek. On Hams Fork Plateau ... are two hills capped by Eocene beds that are very different from the underlying Green River, and it is possible that they represent outlying Bridger areas. These outcrops have a rather reddish cast, not like typical Bridger, and the suggested correlation is based more on their position above the typical Green River than on their lithologic resemblance to the Bridger of the type locality."

In 1912 Osborn (220: 235) represented a general section of the Tertiary of southwest Wyoming with 1,800 feet of Bridger unconformably lying on the

Green River. He also applied to the Bridger the term "Orohippus and Uintatherium zone".

In 1905 Hay (98) had advocated that the Bridger formation is a result of deposition in a fluvial, rather than lacustrine, environment, as advocated by Cope, Powell, Emmons, King and others. In 1929 Osborn (224: 78-80), however, remarked that in the type locality the Bridger

"consists of a great series of deposits of volcanic ash and dust, solidified into tuffs, which weather into picturesque and in places highly colored 'badlands'. Apparently the greater part if not all of these tuffs were distributed from unknown eruptive volcanic centers by wind; but at four periods they were deposited in great shallow playa lakes and partly worked over by stream delta, and flood-plain deposition.

* * *

"... the Bridger rocks are largely tuffs, perhaps modified in part by sufficient transportation to add the numerous grains of quartz they contain, and ... these grains may be of sedimentary origin, although the material of the tuffs is mostly andesitic.

* * *

"Thus the Bridger is composed chiefly of dacite tuff, of altered dacite, and of glass tuff containing irregular grains of quartz, feldspar, and hornblende, which are at some places contained in a groundmass made up entirely of coarse angular particles of stringy glass full of bubbles. The Huerfano formation of Colorado, which is in large part older than the Bridger, is composed largely of glass tuff. The deposits in the Washakie Basin, east of the Bridger Basin, are composed chiefly of dacite and glass tuffs.

* * *

"Conspicuous features of the Bridger formation are four hard, 'white layers,' which were laid down at intervals in the series of beds. Some of these 'white layers' have been traced over many square miles. They are composed of tuffaceous shale and marl or of calcareous shale and are in places filled with fresh-water shells. They mark periods during which the deposition of volcanic dust was less rapid, when the Bridger Basin was temporarily base-leveled and the waters rose into wide, shallow playa lakes, in which sedimentation was slow. That these four relatively thin 'white layers', which are variously known geographically as the 'Cottonwood white layer', and 'Burnt Fork white layer,' the 'Lone Tree white layer,' and the 'upper white layer,' correspond with long periods of geologic time is shown by the marked faunal differences that separate them, which indicates that extensive migration occurred before and after the deposition of each of these layers, but expecially the first, which separates the lower from the upper Bridger life zone."

In 1909 Granger (86: 20) published a detailed lithologic section of the Bridger formation in the Washakie Basin. This section has been reproduced in the form of a table on pages 106-107. Commenting on the sediments of the upper part of the Bridger formation in the Washakie Basin, which are represented in the detailed section, Granger said (86: 20):

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"There is no evidence of a break in sedimentation from the base to the summit of the Washakie series but the beds seem to fall into two horizons; the lower 250 feet and the upper 400 feet. ... the upper horizon is characterized by coarse white, pink and salmon-colored sandstones and by the extremely coarse green sandstones, or feldspar conglomerates; the lower horizon is characterized by the rusty brown nodular sandstones. The fine green tuff-sandstones occur in both horizons. In general appearance the lower beds are dull and somber while the upper ones are bright and often highly colored. Stratum No. 11, a nearly white sandy shale, was selected, for the purpose of field labelling, as dividing the lower from the upper beds, which were termed respectively horizons A and B. Fossils found immediately below stratum No. 11 (Manteoceras and Sinopa) pertain to that phase of the fauna which more nearly resembles the fauna of the Bridger, while the first fossils found, about 60 feet above the datum plane, pertain to the Uinta phase. The layer was selected because it was continuous and easily recognized. Most of the subdivisions recognized in the section given above do not exist, with any uniformity of character, over any great area. It is possible that the strata Nos. 12 and 13 (55 feet) should be included in the lower horizon."

In the same year (1909) Sinclair (272: pp. indicated) was of the opinion that

"petrographic examination of the Washakie rocks ... affords valuable evidence for the separation of the Washakie from the Bridger as a distinct formation. The Bridger rocks ... are composed of rhyolitic ash interstratified with shell marls and thin lignitic bands of lacustrine and swamp origin respectively, while the ash comprising the mass of the formation has been distributed, apparently, by both wind and running water.

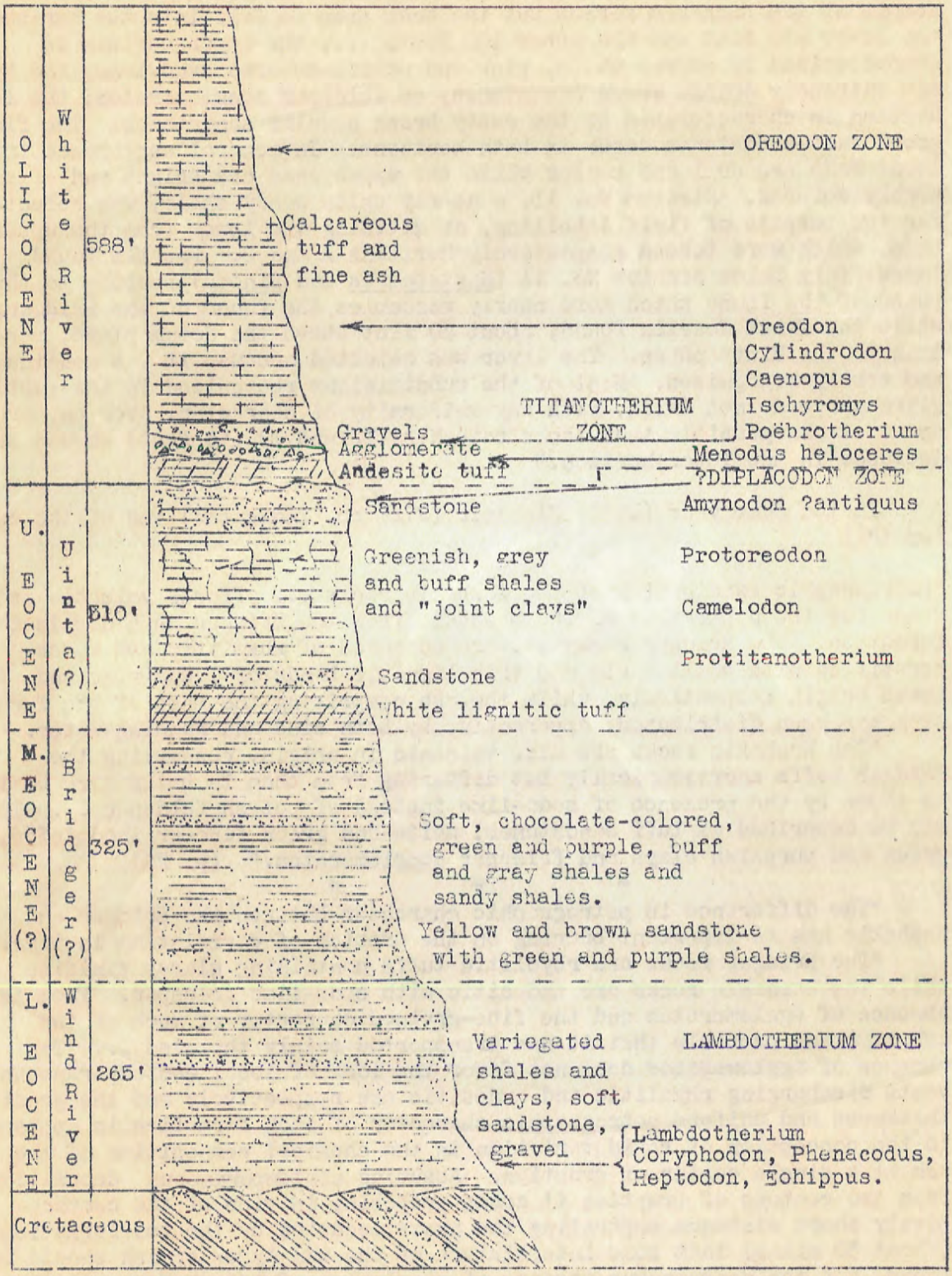
"The Washakie rocks are also volcanic in origin, resembling the Bridger tuffs macroscopically but differing from them in being more basic as shown by the presence of soda-lime instead of potash feldspar ... They may be described as tuff sandstones, white and green fine-grained tuffs, green and purplish clays and feldspar conglomerates." (p. 25)

* * *

"The difference in petrographic character between the Bridger and Washakie has an important bearing on the problem of correlation in time.

"The Bridger rocks are rhyolitic tuffs containing glassy sanidine while the Washakie rocks are andesitic with soda-lime feldspar. From the absence of agglomerates and the fine-grained character of much of the ash it seems probable that it was transported mainly the wind ... The absence of agglomerates does not favor the idea of local contemporaneous vents discharging rhyolitic and andesitic ash respectively and the great thickness and uniform petrographic character of each formation is opposed to the conception of rapid variation in the chemical composition of the ash at a single center of eruption. Assuming contemporaneous deposition from two centers of eruption it seems probable, in view of the comparatively short distance separating the areas occupied by the two formations (about 50 miles) that some intermixture of the two types of ash should be found, but the conspicuous absence of plagioclase feldspar from all the

Generalized Section of the Tertiary Rocks Exposed at Green Cove And Wagonbed Spring on the Beaver Divide, Southwest Border of the Wind River Basin, Fremont County, Wyoming[1]



[1]From data by Osborn, H.F. (224: 76), The titanotheres of ancient Wyoming, Dakota, and Nebraska: U.S. Geol. Survey Mon. 55, vol. 1, p. 76; Sinclair and Granger (276: fig. 2a, 3), Eocene and Oligocene of the Wind River and Big Horn Basins: Am. Mus. Nat. History Bull., vol. 30, art. 7, pp. 88, 89.

Bridger tuffs and its presence in all those of the Wasahkie shows that this has not occurred. The lithologic evidence, therefore, does not favor the idea of contemporaneity for any part of the Bridger or Washakie.

"The faunistic evidence of contemporaneity of the Lower Washakie and Upper Bridger is therefore in contradiction to the lithological evidence." (pp. 26-27)

Wind River and Big Horn Basins.-- In 1906 Darton (57: 70) tentatively assigned to the Bridger formation certain strata at the south end of the Big Horn Mountains. In this region, he said, the "Bridger" formation overlaps against the mountains, and

"It extends to a moderate height up the slopes of the ridges in the vicinity of Badwater and Bridger Creeks and occupies a wide area on the northern side of the saddle separating the Bighorn and Bridger ranges. In this saddle the deposits are over 800 feet thick, and consist of sands, clays, and sandstones ranging in altitude from 6,200 to slightly over 7,000 feet. Near the base there are several members of hard, massive sandstones; next above are light-colored sandy clays, mostly of yellowish color; and in the upper part are brown sandstones in deposits 15 to 20 feet thick in light-gray clays, sometimes containing considerable chert. Smaller deposits also extend up some of the valleys, especially along Sioux Creek and near the headwaters of No Wood. The formation also skirts the southern slope of the Bridger Range, overlapping the granites and schists in ranges 91, 92, 93. No special study was made of these Tertiary deposits, nor is it even certain that they consist entirely of the 'Bridger' formation."

Sinclair and Granger examined the geology of the Beaver Divide in the Sweetwater escarpment. In 1911 they described the "Bridger" in that region as follows (276: pp. indicated):

"About 375 feet of sandstone, shale and tuff lying between the red-banded clays of the Wind River and the Uinta shales have been referred doubtfully by Granger [87: 238, 239] to the Bridger. Although repeatedly examined during two seasons, no fossils have been found in these beds, the age determination depending entirely on stratigraphic relationships." (p. 94)

* * *

"The Basal Arkose. -- The first formation overlying the Wind River clays at the base of the Beaver Divide escarpment is an unconsolidated or slightly consolidated pale yellow-colored arkose containing an abundance of water-worn gravels occurring both scattered through the finer matrix and in more or less well-defined lenses. Pegmatite pebbles two or three inches in diameter or even more abound in these gravels. Quartz, feldspar, black chert and sandstone are also represented. The matrix is composed of subangular quartz and feldspar grains, with a few foils of biotite, rather numerous particles of chlorite and a little kaolinized material." (p. 95)

* * *

BRIDGER FORMATION - Areal Distribution and Lithology

"The White Lignitic Tuff. -- Owing to ... landslides, the contact between the variegated shales or clays and a bed of white lignitic tuff which overlies them has been either concealed or so dislocated at every exposure discovered that we have not been able to ascertain whether it rests conformably on the clays or not. From its absence in the Green Cove section [see table, p. 159], and also to the northeast about the headwaters of Muskrat Creek, the tuff bed is evidently lens-shaped. Exposures were examined for a mile and a half or more north of Wagon-bed Spring ... ... The tuff is a white, thin-bedded harsh-feeling rock varying in degree of cementation from pulverulent to compact, and contains frequent lignite beds varying in thickness from six inches to a foot. It shows no admixture of fluviatile material such as clay, sand or gravel and is possibly a lacustrine deposit." (pp. 95-96)

* * *

" ... the white tuff and underlying soft shales are absent at Green Cove, their place being taken by a twenty-foot blue-gray stratum of arkose, clay pellets and clay. This is harder than the beds below it, from which it is separated by a slight disconformity, and weathers out in relief as a prominent cliff and terrace.

* * *

"In the field, the plane of demarcation between the so-called Bridger and the Uinta was arbitrarily placed at the top of the white lignitic tuff in the Wagon-bed Spring section, as no structural break could be detected between it and the overlying shales with Amynodon and other Uinta fossils.

"Wherever exposed, the lignitic tuff is conformably overlain by a rust-colored, fine-grained silt, frequently concretionary, owing its color to the yellow staining of multitudes of cottony grains ..., evidently representing kaolinized or sericitized material." (p. 97)

In 1934 Bauer (11: 676) summarized the lithology of the "Bridger" formation in the Wind River Basin. Summarizing its distribution, he said (p. 677):

"Some of the best exposures of Bridger are found along the bluff and in the high butte east of Sand Draw. The formation thins out in a short distance to the east and to the west of the head of Sand Draw. It is absent along the road up the escarpment from Lander to Rawlins. It is absent at the head of Muskrat Creek. At Chalk Springs there is much slumping along the foot of the bluff; however, here about 150 feet of beds similar in character to the Bridger have been so classified."

Love (162: 17-19), on the basis of paleobotanic evidence, assigned to the Green River formation a sequence of strata exposed in the west end of the Owl Creek Mountains. Love described these strata as follows (pp. 17-18):

"The Green River formation of this locality presents the following distinctive features:

1. It is separated from previously known Green River sediments of the formation by the Wind River Mountains.

BRIDGER FORMATION - Areal Distribution and Lithology

2. There is evidence of an interval of andesitic igneous activity during Green River time.
3. The formation is separated from the underlying Wasatch by an erosional unconformity.
4. The formation in this locality is coarser than in the Green River Basin to the south.

"Between the close of Wasatch time and the beginning of Green River sedimentation in this locality there was a period of profound erosion, which entirely removed the Wasatch sediments from some parts of the area. The land surface was still in a state of high relief when the basal Green River sediments were deposited. In some places there was a vertical rise of a hundred feet in a horizontal distance of three hundred feet. The basal beds consist, for the most part, of conglomerates and sandstone, although in a few places the entire basal member is made up of reworked Wasatch shales.

"The conglomerates are local, probably marking stream channels, and are lenticular in shape. The pebbles are well rounded, vary in size from one quarter inch to about three inches, and are composed largely of Wasatch rhyolites. The matrix of the conglomerate is a soft sand composed usually of small fragments derived in part from the Wasatch rhyolites. Few of the individual lenses are more than three feet thick.

"Wherever studied the sandstones show a striking similarity. A hand specimen from one locality cannot be distinguished from one taken several miles away. In most places the sandstones are greenish-buff in color. Some are cross-laminated, but most of them have plain stratification. The sand grains are of nearly equal size, contain many rhyolite fragments and are firmly cemented by volcanic ash. The beds are so well consolidated that they form small projecting cliffs. The thickness of the individual sandstone beds varies from a few inches to nearly seventy feet, although the average is about fifteen.

"By far the greater part of the Green River formation consists of shales, which are also of very uniform character and can be easily differentiated from the underlying Wasatch. Almost all are green, varying from fine-grained bright-green hard shale to soft dull grayish-green shale. There are a few white shales and a few brown carbonaceous bands, but they are not common. Some of the gray shales near the top of the succession are so soft that on weathering, their appearance is similar to that of the gray Wasatch shales.

"The green shales are usually compact, thinly laminated, pale-green, hard and brittle. Ripple marks are a common feature and there is a great abundance of plant impressions. Most of the plants are either Sparganium or Equisetum."

The strata described by Love as "Green River" are apparently a more extensive development of beds from which Berry (15: 55-79) obtained a collection of Green River plants in the Wind River Basin. The strata from which Berry's collection came are in the same stratigraphic position as the "so-called Bridger" of the Beaver Divide section, described by Sinclair and Granger (276: 94-97). There is evidence that the strata

described by Love and Berry probably are in part equivalent to the Green River group of southwest Wyoming. The Bridger of southwest Wyoming, however, also appears to be in part correlative with the Green River of the same area. Paleontologic evidence recently publicized by Wood, Seton and Hares (S.366: 68-69) indicates that the strata overlying the Wind River formation in the Wind River Basin are of Bridger age, and that the contained flora, similar to that of the Green River formation, was much longer-ranged than contemporary mammal faunas. For the purposes of the present paper therefore, it is considered desirable to discuss these strata in the Wind River Basin with the Bridger formation. It would seem, however, that the proposal of an entirely new formation name for the horizon would be a preferred future procedure. The problem and the evidence are more fully discussed in the section on the paleontology, age and correlation of the Bridger formation.

Strata in the Big Horn Basin which are presumed to be of Bridger age have been named Tatman formation, and are separately discussed on subsequent pages.

Stratigraphic and Structural Relations

Southwest Wyoming; adjacent parts of Colorado and Utah. -- Hayden (105: 58) remarked in 1871 that in the type locality of the Bridger formation, his stratigraphic divisions were "somewhat arbitrary" since there were no well-defined lines of demarcation and "there seems to be no unconformability, and the different beds pass into one another gradually". Powell (229: 63) likewise found that the change from the "indurated sandstones and limestones" of the Green River formation to the "green sands and badland rocks" of the Bridger is transitional. King also had difficulty in determining the relations of the Green River and Bridger, though he considered the preponderance of evidence to point toward an unconformity. King said (137: 395):

" ... the Bridger beds are usually found in the middle of basins, in a nearly horizontal position. These areas of Bridger rocks are surrounded ... by groups of the Green River formation, which pass under the Bridger at angles so slight as to leave it somewhat uncertain whether they are strictly unconformable. On this point, however, all the positive evidence is in favor of a true nonconformity."

King (137: 399-400) also noted that along the base of the Uinta Mountains the Bridger formation

"consists of a series of soft, sandy, and clayey beds, for the most part covered with soil, or obscured beneath unconformable deposits of Pliocene conglomerates, and wherever distinctly seen it is found to dip at gentle angles to the north ... within the probable limit of the original deposition.

* * *

"Throughout the middle of the Bridger Basin it rests in positions of complete horizontality, and throughout its whole extent shows no evidence

of orographical disturbance, such as could be registered in local changes of angle. The aggregate thickness of the beds of this group is estimated as between 2,200 and 2,500 feet."

Winchester, in his report of 1916 on the oil shales of the Green River, said (329: 165):

"In northwestern Colorado ... north of White River and only a few miles west of the Colorado-Utah line the Bridger formation rests unconformably on the Green River as well as older formations, and along the northern edge of the Uinta Basin in Utah the Bridger obscures the entire outcrop of the oil shale. The Bridger formation also occupies the central part of the Green River basin in southwestern Wyoming and west of Burnt Fork and south of Carter overlaps the Wasatch formation, covering the outcrop of the Green River."

In 1924 Sears and Bradley (263: 97) noted that in northwest Colorado

"An erosional window in the Browns Park formation, in T. 9 N., R. 100 W., exposes the Bridger resting with marked angular unconformity upon Mancos and older Mesozoic rocks dipping northeastward on the flank of the Uinta Mountain arch. The Bridger is very conglomeratic, the boulders consisting largely of gray cherty limestone containing carboniferous fossils. Inasmuch as a few miles farther north there is no angular unconformity between the Bridger and Green River, the fact that in T. 9 N., T. 100 W., the Bridger rests directly upon Mesozoic rocks seems to show that the Wasatch and Green River were not deposited this far south, and that the Bridger was laid down as an overlap beyond the margins of the older Eocene beds."

Osborn (224: 78) noted that in southwest Wyoming the sediments at the base of the Bridger

"pass gently into the Green River shales, and the lower levels of Bridger A show gradual transition from lacustrine to flood-plain conditions. The Bridger formation attains its maximum thickness of 1,875 feet near the Uinta Mountains and thins out northward. Beyond the margins of the Green River lacustrine deposits the Bridger overlies upper members of the Wasatch group."

In 1931 Bradley, in his paper on the Green River formation, noted (22: 19, 21) that in the east part of the Uinta Basin, a sandstone sequence about 800 feet thick, which he assigned to the Bridger formation, "in most places rests with evident conformity on the Green River formation".

Wind River and Big Horn Basins. -- Sinclair and Granger (276: 95) reported that in the Beaver Divide section, at the south edge of the Wind River Basin

"this so-called Bridger is conformable with the underlying Wind River. There may be an erosional disconformity with the Uinta, as the white lignitic tuff band and the soft clay shales beneath it, observed at Wagon-bed Spring, are absent four miles farther south at Green Cove, their place

being taken by a twenty foot layer of a peculiar sandstone and clay mixture."

Bauer (11: 676) reported an "erosional and structural unconformity between the Bridger formation and the Wind River formation" in the area of Sand Draw in the Wind River Basin. He remarked further (p. 677) that slumping is common along escarpment exposures.

In a paper on the Heart Mountain thrust fault of the Big Horn region, published in 1920, Hewett (121: pp. indicated) stated:

"The recognition in 1919 of blocks of Madison limestone (Mississippian) overlying beds of the Bridger epoch (middle Eocene) in the McCulloch Peak region, 12 miles east of Cody, Wyoming, shows that the overthrust fault recognized by Dake in 1916 [194] is much more extensive than first suspected." (p. 536)

* * *

" ... Dake was able to conclude that the overthrust took place after the deposition of his Fort Union(?) (early Eocene) beds and before the outbursts of the 'early basic breccias (Neocene or upper Miocene)' described by Hague. The McCulloch Peak outliers show that the overthrust is probably post-Bridger (middle Eocene).

* * *

"It is concluded that the overthrust took place after the deposition of the 'early acid breccias' and before the outbursts of 'early basic breccias' and is, therefore, middle Eocene or early Oligocene in age." (p. 537)

* * *

" ... there can be little doubt that the blocks of limestone in the vicinity of South Peak are parts of a layer of limestone that was thrust from the west, probably from the region near Sheep Mountain between the north and south forks of Shoshone River, 28 miles west. It is impossible to imagine that the McCulloch Peak blocks are somehow related to another overthrust or to some obscure and complex structure, for the structure of the beds between the peaks and Sheep Mountain is completely shown in the canyon of Shoshone River.

"The recognition of mammalian fossils characteristic of the Bridger formation of western Wyoming under the blocks of Madison limestone shows conclusively that the period of overthrust was no older than these beds." (pp. 552-553)

Paleontology, age and correlation. -- Concerning the mammalian fossils referred to in the last paragraph of the above quotation, Hewett (121: 550) quoted Granger, who studied the specimens, as follows:

> "'These three specimens seem to represent a fauna intermediate between that of the upper Wind River and that of Bridger B. It may belong to the base of the Bridger (Hor. A), the mammalian fauna of which is practically unknown, correlation with the upper Huerfano being made on a single specimen of Titanothere. In any event the McCulloch Peak horizon is close to the border line between the Lower and Middle Eocene.'"

BRIDGER FORMATION - Paleontology, Age and Correlation

Hewett (p. 549) quoted J. W. Gidley's analysis of the specimens to the effect that, apparently, "'the three specimens represent a Bridger fauna, although the Eohippus tooth suggests Wasatch rather than Bridger affinities.'"

In 1871 Hayden (104: 144-145) predicted that the then newly discovered Bridger beds were "destined to yield a fauna second only to that of the 'Bad Lands' of Dakota. So far as yet known, all the remains appear to be of middle tertiary age. Among these fossils those of turtles are especially numerous." Subsequent discoveries have borne out Hayden's prediction. Cope (in Hayden 108: 430) noted that in Colorado

"Fresh-water strata of probable Eocene age were ... detected by both Dr. Hayden's party and my own in the South Park. These consist of laminated argillaceous shales of soft consistency, in which great numbers of fishes and plant impressions are preserved. The fishes are referable to only two species, Amyzon commune and Rhineastes pectinatus ... They are nearly related to the species of the Elko shales and Bridger formation, and I suspect that their age is Eocene."

In 1877 Marsh (171: 354) remarked that the strata "which have been termed the Green River and Bridger Series, may be designated as the Dinoceras Beds, as the gigantic mammals of this order are only found here."

Emmons (in King 136: 246) reported in 1877 that from the beds in the region of Grizzly Buttes and "along the northern borders of the valleys of Henry's Fork, have been obtained most of the remains of Eocene vertebrates for which this basin is renowned". White (in Hayden 113: 37), on the other hand, said in 1878 that in northwest Colorado "the only fossils obtained from these strata were a few fragments of chelonian and mammalian bones". In 1890 Scott (in Scott and Osborn 256: pp. indicated) remarked:

"The faunal lists of the two basins [Bridger and Washakie] seem to show that the Bridger contains slightly older deposits than the Washakie, though the two may be in part contemporaneous. Some of the differences to be noted are, no doubt, due in part to the fact that the Bridger basin has been much more frequently and thoroughly explored than the Washakie, and others probably to conditions of preservation ..." (p. 464)

" ... it is difficult to believe that these differences are to be explained by geographical considerations, while on the other hand the stratigraphical relations of the Washakie beds to the underlying Green River series present objections to the assumption that the latter could have been a land surface for any great length of time." (p. 465)

* * *

"From present knowledge, we are therefore justified in making a threefold subdivision of the Bridger epoch, with the Wind River beds at the base and the Washakie at the top, and in regarding the Dinocerata as the group characteristic of the entire epoch. It is interesting to note that

where the fauna of the Washakie basin departs from that of the Bridger basin, it does so in the way of resemblance to the Uinta." (pp. 465-466)

In 1891 Marsh (172) described in great detail the Bridger mammals of the order Dinocerata, a group which, as already noted, he considered so characteristic of the Bridger formation that he frequently called it the "Dinoceras beds". Osborn (216: 163) commented in 1904:

"The most surprising discovery by the American Museum expedition of 1903 was that of the presence of true Dasypoda or Armadillos in the Middle Eocene or Bridger formation of Wyoming.

"Mr. Walter Granger ... announced the discovery as that of an Edentate; the four specimens ... prove indeed to be closely related to modern armadillos ..."

* * *

"Unfortunately these Armadillos, on the basis of less perfect material, have already been placed /by Wortman[1]/ under another name /Metacheiromys/ and group."

In 1909 Granger (86: 23) summarized his conclusions that

"the genera of the Lower Washakie are, almost without exception, found in the Bridger, and, it may be added, are represented by species closely allied to Upper Bridger species and in some cases identical with them. None of them excepting Hyopsodus and Paramys pass through to the Uinta.

"The genera of the Upper Washakie are mostly distinct from those of the Lower Washakie or Bridger and are represented in the lower horizons of the Uinta by closely allied or identical species. Two Bridger genera of Carnivora, Harpagolestes and Limnocyon, are represented in the Upper Washakie and not in the Lower, but the species differ widely from those of the older horizon.

"The entire absence from the Washakie of such a group as the Hyracotheres can be accounted for only by the fact that fossils ... are comparitively rare there; that the animals existed there at that time but that their remains have not yet been discovered.

"So far as discoveries have gone, however, they tend to show that faunally the Lower Washakie corresponds with the Bridger C and D (Middle Eocene) and the Upper Washakie with the Uinta A and B (Upper Eocene)."

The known fauna of the Bridger and Uinta (complete to 1909) was listed by Matthew (in Osborn 219: 95-100).

The following sketch by Osborn (224: pp. indicated) is of interest:

"The Washakie Basin lies about 50 miles east of the Bridger Basin ... The basin was described by Hayden in 1869-70, and more fully by Cope in 1873. Its faunistic levels were studied by the Princeton expedition and by expeditions of the American Museum of Natural History, under Wortman

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[1]Osborn cited Wortman from Am. Jour. Sci., vol. 16, pp. 345-352, 1903.

(1893, 1895) and Granger (1906). Granger gave the first complete and accurate description of the geology of the Washakie Basin in his 'Faunal horizons of the Washakie formation of southern Wyoming'. King treated the deposits of the Washakie Basin as of Bridger age and of lacustrine origin. Osborn favored the theory of separate deposition, and Scott showed that where the fauna of the Washakie Basin departs from that of the Bridger it approaches that of the Uinta. The discovery of the true upper Bridger fauna in horizon A of the Washakie Basin was due to the American Museum expeditions of 1893, 1895, under Wortman.

" ... Haystack Mountain ('Mammoth Buttes' of Cope), a long ridge of badlands near the north end of the basin, which in places rises 400 feet above the plain forms the northern border of an extensive semicircular 'central basin' that has the appearance of a gigantic crater." (p. 85)

* * *

"The 'lower brown sandstone' of the Washakie Basin, known as Washakie A, contains the fauna of the Uintatherium-Manteoceras-Mesatirhinus zone. It was deposited contemporaneously with the upper Bridger, to the west, and probably with the non-fossiliferous Uinta A, to the south. Its contemporaneity with Bridger D is established through the common presence of ... /a number of species of mammals/.

"This fauna of the Uintatherium zone occurs in 260 feet of Washakie A ...

"The 'lower brown sandstone' layer yields a rich fauna of uintatheres. This layer forms a persistent bench, which constitutes the lower rim of the basin on its northern border. This 'lower brown sandstone' passes at a low angle southward beneath the floor of the basin. Below it, and apparently conformable with it, lie gray sandy shales, which are provisionally referred to the Green River, but which were probably laid down in lower Bridger time. As these deposits show no marked evidence of erosion it seems probable that the Washakie Basin was filled with a lake in Green River time while Bridger A was being deposited to the west."

(pp. 85-87)

* * *

"The great life division known as Washakie B, 380 feet in thickness, contains a new and dominant fauna, which is not represented at all in Bridger D or Washakie A. It is significant that this unit is divided into two zones by its fauna, exactly as Uinta B is divided into two zones ..."

(p. 89)

In 1931 Bradley (22: 19-21) tentatively assigned to the Bridger formation, a thickness of about 800 feet of sandstones and mudstones which conformably overlie the Green River group in the east part of the Uinta Basin. Because of the presence of certain fossil insects in these strata, Winchester had previously assigned them to the Green River. Bradley stated that

"Osborn and Peterson, however, regard this series of sandstone beds as a part of the Bridger formation, having found bones of Bridger mammals in it. The lower part of this sandstone unit, about 500 feet in thickness, contains few fossils, but according to Peterson the type specimens of Metarhinus and Sphenocoelus were found near the base. The upper part is

more fossiliferous and according to Riggs contains Metarhinus, Dolichorhinus, Telmatherium, Mesatirhinus superior, Rhadinorhinus, Eobasileus, Triplopus, Mesonyx, and Harpagolestes, all of which are Bridger fossils."

In 1930 Berry (15) announced significant paleobotanic findings in the Wind River Basin of Wyoming. His remarks are of sufficient signifi- to warrant quotation in some detail. He explained that the flora consists of 41 identified species, and stated (pp. indicated):

"Osborn correlated the Wind River formation with the upper part of the Wasatch of the Big Horn Basin and with the lower part of the Huerfano formation of Colorado. As no fossil plants are known from the Huerfano or Bridger, and as those collected from the Wasatch have been confused with the Fort Union, it is impossible to check these correlations by means of the fossil plants.

"Except for the forms listed below, identified by F. H. Knowlton and reported by Collier /30: 78/, no fossil plants have been recorded from the Wind River Basin.

Lygodium kaulfussi Heer	Myrica microphylla Newberry
Dryopteris sp., new?	Quercus hardingeri Lesquereux
Cyperacites or Typha sp.	Platanus or Liquidambar fruit

(p. 55)

* * *

"The material that forms the basis of the present preliminary report was collected for me by Mr. N. H. Brown, of Lander, Wyo. ... The collection contains a few specimens from Crow Heart Butte and Lenore, but the bulk came from the vicinity of Tipperary, Fremont County, Wyo., in the SW., ¼ sec. 18, T. 6 N., R. 4 W., Wind River meridian. ... Above the typical red-banded beds of the Wind River formation is about 25 feet of dark sandy clay, overlain by 40 to 50 feet of coarse cross-bedded buff sandstone. Above the sandstone is a thin bed of plant-bearing shale, overlain by 15 feet of thin-bedded sand, a second plant-bearing shale, and soft thin-bedded sandstone. So far as I know the Bridger has never been recognized in this area. .... I am of the opinion that the plants described in the present paper are stratigraphically in what Sinclair and Granger /276: 83-117/ termed 'so-called Bridger,' and this conclusion is confirmed by Sinclair." (pp. 55-56)

* * *

"The most abundant types in the flora as a whole are Salvinia, Lygodium, Sparganium, Sabalites, Juglans, Sapindus, Zizyphus, and Aralia."

(p. 56)

* * *

"The appended table /reproduced, p. 108/ gives the occurrences of the flora in other areas. The following are not known elsewhere:

Equisetum tipperarense	Aralia browni
Asplenium serraforme	Diospyros mira
Typha sp.	Antholithes anceps
Dryophyllum wyomingense	Antholithes browni

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Fagara wyomingensis	Antholithes fremontensis
Negundo fremontensis	Carpolithus browni
Zizyphus wyomingianus	Carpolithus bridgerensis
Laurus fremontensis	

"These 15 peculiar species constitute about 37 per cent of the known flora, or slightly more than one-third. Of the 26 species with an outside distribution 21, or 81 per cent, are common to the Green River formation. Two others, Asplenium eolignitiicum and Salvinia preauriculata, that are not found in the Green River Basin occur in the Wilcox group of the Gulf Coastal Plain, and both are more common in the Wind River Basin, at what I believe to be a later horizon, than they are in the Coastal Plain. One or possibly two other species also occur in the Wilcox group, 3 are common to the Claiborne group, and 3 to the Jackson group of the Gulf Coastal Plain. Four are recorded from the Fort Union formation of the west, 1 from the Clarno formation and 1 from the Puget group of the Pacific coast region, and 1 from the Arctic Tertiary.

"The most common species ... is the climbing fern of the genus Lygodium, which in the Atlantic Coastal Plain section characterizes the late middle and upper Eocene Claiborne and Jackson. It would therefore not be inappropriate to name the horizon the Lygodium zone." (p. 56)

* * *

"The Green River flora of the Green River Basin ... consists of about 80 species, of which 21 occur in the deposits in the Wind River Basin. It is legitimate to suppose that if the Wind River region were more thoroughly known, a great many more identical species would be brought to light. The only really conspicuous Green River plant not discovered in the present small collection from the Wind River Basin is Acrostichum hesperium Newberry, and this is found in the upper Claiborne of the Mississippi embayment.

"Of the 21 species common to the Wind River Basin and the Green River Basin, 15, or about three-fourths, are not known to occur anywhere else than in these two areas, which are not geographically remote. The conclusion seems to be reasonably well established that these deposits in the Wind River Basin are of very nearly the same age as those containing the Green River flora in the Green River Basin."

* * *

"It seems to be a legitimate supposition that deposition contemporaneous with that which formed the typical Green River was taking place in the Wind River Basin and elsewhere in Wyoming, and that at least the Wind River formation in the Wind River Basin, a part of the 'so-called Bridger' of Sinclair and Granger, and perhaps the upper part of the Wasatch of the Wind River Basin represent the time equivalent of the maximum Green River of the Green River Basin.

* * *

"The few invertebrates associated with the plants in the Wind River Basin are either Green River or Bridger species, but they are of little significance as time indicators." (p. 57)

On a subsequent page Berry listed the following invertebrates, identified by H. A. Pilsbry and said by Berry to be "closely comparable with

forms from the Green River and Bridger formations":

Physa bridgerensis Meek
Planorbis cirratus White
(or a closely related form)
Unio washakiensis Meek (probably identical with U. tellenoides or U. shoshonensis
Unio sp. of the group U. tellenoides Hall
Unio shoshonensis White
Oreohelix sp.

Important evidence substantiating Berry's suggested correlation of these strata with the Bridger formation has recently (1935) transpired. An abstract of a paper by Wood, Seton and Hares (S.366: 68), read before the 48th Annual Meeting of the Geological Society of America, contains the following notes:

"In the northwestern part of the Wind River Basin, northeast of Dubois, near the Duncan Ranch, a sparingly fossiliferous horizon contains the following fauna: Palaeosyops robustus, skull and partial skeleton, Patriofelis ferox, right ramus with P_3-M_1, and Hyrachyus cf. modestus (progressive variant), Uintatherium cf. mirabile, Telmatherium cf. cultridens, Telmatherium cf. validum and cf. Tillotherium. This unmistakably Upper Bridger assemblage is closest to Bridger C. Several hundred feet lower, the following fauna suggests Lower Bridger age, possibly equivalent to Bridger A: Desmatotherium guyotii, Eotitanops borealis, Palaeosyops cf. paludosus, Palaeosyops cf. major, Patriofelis sp. Phenacodus teeth, still lower, near variegated beds of typical 'Wind River' aspect, indicate a Lost Cabin horizon. The first demonstrably middle Eocene in Central Wyoming underlies beds correlated with those containing a flora of Green River aspect at Tipperary, Lenore, and Crowheart Butte, whereas the type Green River underlies the Bridger. Additional field study in the northern part of the Basin shows that the shales containing a Green River-like flora near Schoening interfinger with the Lysite, and extends the area of the former shallow lake containing the leaves several miles. The Green River flora was much longer lived than any of the contemporary mammalian faunas. Near Badwater, on the northern edge of the Basin, the Lost Cabin overlies the Lysite conformably. The unfossiliferous Green Cove ('so-called Bridger') overlies the Lost Cabin, as at Beaver Divide, on the southern edge of the Basin. The fossil molluscs (Planorbis spectabilis, Physa bridgerensis and Vivipara wyomingensis) from Sand Draw are probably from the 'Uinta' above, which contains also: Amynodon advenus, Camelodon arapahovius, Protoreodon ?parvus and ?Diplacodon."

The geographic data accompanying the following list of molluscs, given by Henderson (119: 39) from "the Eocene formations of southwestern Wyoming", indicates that they may have come from exposures of the Bridger and *Washakie beds:

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Unio clinopisthus[1] White. Washakie. [Apparently ranges from Greybull through *Washakie time]
Unio grangeri Cockerell. Haystack Mountain. [From the *Washakie beds]
Unio haydeni Meek. Ham's Fork. [From the Bridger formation]
Unio leanus[2] Meek. Church Buttes. [Probably occurs in both the Bridger and *Washakie]
Unio shoshonensis White. Alkali (north of Green River City) [Bridger]
Unio tellinoides (Hall)[3]. Barrel Spring, Muddy Creek. [Bridger ?]
Unio washakiensis Meek[4]. Washakie, etc. [Both Bridger and *Washakie]
Holospira leidyi (Meek). Near Fort Bridger. [Bridger]
Vertigo arenula (White). Henry's Fork. [Supposedly only in the Green River]
Vertigo atavuncula (White). Henry's Fork. [Supposedly only in the Green River]
Pupa? incolata White. Henry's Fork. [Supposedly only in the Green River]
Succinea papillispira White. Alkali. [Supposedly only in the Green River]
Viviparus paludinaeformis (Hall). Henry's Fork, Ham's Fork, etc. ["Wasatch", Green River and Bridger]
Goniobasis tenera (Hall) and vars. Alkali, Barrel Springs, Sage, etc. [Apparently ranges throughout Eocene. Varieties may have restricted ranges]
Lymnaea vetusta Meek. Ham's Fork. [Green River and Bridger]
Lymnaea similis Meek. Ham's Fork. [Green River and Bridger]
Planorbis spectabilis Meek. Ham's Fork and Big Sand Draw. [Green River and Bridger]
Planorbis spectabilis utahensis Meek. Ham's Fork.
Physa bridgerensis Meek. Pacific Springs, Church Buttes, etc. [Bridger]

Scattered information on the Bridger and *Washakie formations, as developed in the Bridger and Washakie basins of southwest Wyoming, and on other exposures assigned to the Bridger formation, was carefully reviewed and summarized by Osborn (224: 77-91) in 1929. Osborn, chiefly on the evidence of titanothere remains, divided the Bridger into five major faunal zones; some of these were in turn subdivided into lesser zones. Osborn also zoned the Bridger beds (*Washakie formation) of the Washakie Basin. Careful study of the Bridger formation appears to have been prosecuted chiefly in the centers of the basins, or in the regions of its most extensive and typical development. It is apparent, it seems to the writer, that comparatively little exact information is available concerning the stratigraphic relations of the Bridger formation with other Eocene sediments around the margins of basins, away from the centers of deposition. The relations of the Bridger and Green River formations, particularly, offer a fertile field for future investigation.

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[1]Henderson listed this species from the Greybull horizon of Park County, Wyoming and then stated, apparently inconsistently, that it is "known only from the Eocene of southwestern Wyoming and northwestern Colorado".

[2]Unio "leai" = synonym of U. leanus.

[3] = "Mya" tellinoides Hall.

[4]May be identical with Unio haydeni.

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UPPER(?) EOCENE TATMAN FORMATION

SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- The unit was designated as a formation. The type locality is at Tatman Mountain, in the central part of the Big Horn Basin, Wyoming.

TYPE DESIGNATION. -- The formation was designated by Sinclair and Granger (277: 59, 62-63) in 1912:

"... the lignitic beds which we propose to call the Tatman formation overlying the Wind River on Tatman Mountain, are not present on McCulloch Peak.

* * *

"We propose the name Tatman formation for a hitherto unnamed series of yellowish shales, yellow-brown and gray sandstone and lignite beds overlying the red-banded Lost Cabin clays typically developed on Tatman Mountain, but occurring also on Squaw Buttes and on the divide between Fifteen-mile and Gooseberry Creeks both to the north, south and west of the buttes. Wherever the contact is exposed, the Tatman formation appears to be conformable with the Lost Cabin beds below. It has not been found north of the Gray Bull River and seems to have been entirely eroded from this portion of the basin. Its thickness is estimated by Fisher as about 600 feet.

"Microscopic examination of the coarser Tatman sediments suggests that their source was the same as that of the underlying Eocene horizons, but that depositional conditions were different is shown by the scarcity of channel sandstones, the absence of color-banding and the abundance of impure, gypsiferous lignite at many horizons in the shales. Some of the thicker lignite beds have attracted attention among the local ranchmen as a source of blacksmith's coal.

"With the exception of a few scraps of bone, no vertebrate fossils have been found in the Tatman formation. The invertebrates suggest that its age is probably Eocene and possibly Bridger."

SYNONYMY. -- Writers who observed prior to the naming of the Tatman formation by Sinclair and Granger usually included the Tatman formation in the "Big Horn Wasatch".

DISTRIBUTION. -- Confined, so far as known, to the type locality.

IMPORTANT REFERENCES. -- Fisher (76: 34); Sinclair and Granger (276: 109-117), (277: 59, 62-63).

GENERAL INFORMATION

Fisher appears to be the first investigator to have recognized the possibility that the beds, now known as the Tatman formation, might constitute a distinct formation. In 1906 he described them as follows (76: 34):

"Capping some of the highest areas in the central part of the

TATMAN FORMATION - General Information

Bighorn Basin, especially that part lying south of Gray Bull River, are brown, leaf-bearing, sandy shales and gray sandstones, which have a total thickness of about 600 feet. Thin coal seams sometimes occur in these beds, and in one locality on the southern side of Tatman Mountain some prospecting has been done in a seam which has a thickness of about 18 inches. A number of fossils were collected from the sandstones of this formation in the vicinity of Squaw Buttes. These have been examined by Dr. T.W. Stanton, who makes the following report:

"'The small collection contains many internal casts of fresh-water fossils belonging to the genera Unio, Viviparus, and Goniobasis. Of the last named there are imprints of the exterior which permit identification with G. tenera Hall, an Eocene species. The Unio has about the size and proportions of U. haydeni Meek and the Viviparus resembles V. wyomingensis Meek, but in neither case can specific identification be positively made with such material ... I think that the horizon is Eocene, but I am unable to determine from these fossils whether it is Wasatch or Bridger.'

"These beds are extensively exhibited in Tatman Mountain and Squaw Buttes. They have been represented with the Wasatch on the geologic map."

Sinclair and Granger, in their paper of 1911 on the Wind River and Big Horn Basins, stated (276: 110) that

"Poorly preserved remains of ostracods and phyllopods have been found by Professor G. van Ingen in a specimen of pale pink shale collected near the base of this formation on Tatman Mountains. ... That they may correspond to the Bridger is possible, and they are, perhaps, to be correlated with the so-called Bridger of the Beaver Divide section. They are separated from the gravels capping Tatman Mountain ["Tatman Mountain gravels"] by about 30 feet of unconsolidated, highly micaceous, greenish sandstone containing abundant foils of chloritized biotite, decomposed muscovite, many quartz grains and both fairly fresh and kaolinized feldspar. From its stratigraphic position this sandstone may possibly be Uinta, but the assumption is entirely unconfirmed by palaeontological data. Only small remnants of both the lignitic shales and the greenish sandstone capping Tatman Mountain, Squaw Buttes and other high points have been spared by erosion. So far as at present observed, the sandstone seems to be conformable with the lignitic shales."

In 1912 Sinclair and Granger were able to add only general comments to the previously obtained paleontological data. Their observations on the physical geology of the formation (277: 67), however, were significant:

"The Tatman formation is overlain by andesitic gravels of doubtful age, of which but a remnant on the top of Tatman Mountains is preserved in place. Deformative stresses have acted on the basin filling after the deposition of the Tatman formation, flexing it into marginal anticlines and synclines and increasing the centripetal dip of the beds."

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SPECIFIC INFORMATION

RANK AND TYPE LOCALITY. -- Formation. The type locality is in the Uinta Basin, Utah.

TYPE DESIGNATION. -- The Uinta formation was described by Emmons in 1877 in Volume 2 of the King Survey reports (in King 136: 307, 314), as follows:

"The examinations of the Tertiary beds of this basin have been extremely cursory, being confined principally to the line of travel along the immediate foot-hills of the range."

* * *

"Below the upper bend of Red Fork, a sulphur spring issues from the sandstones overlying the coal.

"To the eastward, the beds of the Triassic, Jurassic, and Cretaceous pass under the almost horizontal Tertiaries of the Uinta Eocene, which cover the whole region along the headwaters of the Uinta. These Tertiaries are exposed in great thickness, and consist mostly of coarse buff and chocolate-colored sandstones and loose gravelly conglomerates, attaining a thickness of several thousand feet. They have been deeply cut through by the streams which flow into the Uinta River, and in some places, notably at the junction of Kern Creek and where the Uinta River cuts through the southern end of Kern Ridge, beyond the limits of the map, isolated outcrops of unconformable upturned beds, limestones and sandstones, are exposed."

Volume 1 of the King survey reports, written by King himself, was published a year later than Volume 2. Passages from King's descriptions are usually quoted as the type designation, and the name, Uinta formation, is commonly attributed to him. The fact, however, that the name was proposed by Emmons, and was so considered by King, is indicated by King's statement (137: 449) that "Marsh, and Emmons who worked out what we of the Exploration know of the stratigraphy of this region, by accident gave the same name -- Uinta -- to the group."

RESTRICTIONS. -- In 1878 King (136: 405-407) recapitulated the stratigraphic scope of the name, Uinta formation:

"Flanking all the alluvial valleys of the streams [south of the Uinta Range] are bluffs and ridges formed of Tertiary strata, the lower members being chiefly rough, gritty conglomerate, passing up into finer-grained sandstones, and at certain points developing creamy, calcareous beds. The strata apparently form an unbroken line from the region of the Wahsatch eastward throughout the length of Uinta Valley, and across Green River into the valley of White River."

* * *

"... the most recent Eocene group, as developed in White River Valley, is unconformable with all the earlier Eocene groups. It is a shallow deposit, of which not over four hundred feet are seen, and in all probability is the sediment of a very restricted post-Bridger lake, wholly south of the Uinta Range, and the last member of that remarkable series of Eocene

UINTA FORMATION - Specific Information

lakes whose great deposits are piled unconformably over one another in the region. To this group alone should the term Uinta be applied."

SYNONYMY. -- "Diplacodon beds" and "Uintah Group" of Marsh in 1877 (171: 354) (and in various other writings) = Uinta formation. According to Osborn (224: 91) the "Diplacodon zone" is equivalent to only a part of the Uinta, i.e. his own "Uinta C".

King said in 1878 (137: 407) that "as provisionally used on the Fortieth Parallel Atlas, Uinta group was a term stretched for convenience to cover all the Tertiaries south of Uinta Range, of whose true subdivisions we were ignorant."

"Uinta formation" was used by Powell (229: 41-42, 61, 141-145) in his report of 1876 on the geology of the Uinta Mountains, as the name of a sequence of 12,500 feet of sandstones, shales and quartzites, which underlie his "Lodore group" of the "Carboniferous" system. Reeside (230: 40) commented on this usage:

> "Red Canyon may be considered to extend down the river from Hideout [Utah] to a point several miles below Red Creek ... ... perhaps the only uniform character is the constituent rock, the mass of dark-red to red-brown sediments called by Powell the 'Uinta group' and by most later geologists the 'Uinta quartzite' or 'Uinta formation', though by King and Emmons mistakenly identified as Weber sandstone. The name Uinta is more correctly applied to the very much later Tertiary formation that occurs in the Uinta Basin, to the south of the mountains ..."

"Uinta group" of White in 1878 (in Hayden 113: 37), at the east end of the Uinta Mountains = Browns Park formation.

In 1907, Weeks (308: 434) in a paper on the stratigraphy and structure of the Uinta Mountains, stated that, by decision of the U.S. Geol. Survey Committee on Formation Names, it had "recently been decided to retain the name Uinta for the Tertiary strata which form the plateau region east of the Wasatch and south of the Uinta ranges. The decision was made on the grounds of priority and general usage."

The "Uinta sandstone" defined by Powell (229: 41-42, 61, 141-145), was called the Weber quartzite by King, who correlated it with a formation of the same name in the Wasatch Mountains. King's name has been retained.

"Life Zones" 13-15 of Osborn (224: 57) = Uinta formation.

Osborn said (224: 91) that "the sediments in the Uinta Basin between the Diplacodon zone and the Green River formation were classified by White as Bridger, although no fossils were found in it, and were treated as contemporaneous with the Bridger deposits".

Browns Park formation, named by Powell (229: 62-63, 168-169) has been generally treated as an equivalent of the Uinta formation, and the names were used interchangeably by many geologists. It seems, however, that the Browns Park corresponds at most only to part of the Uinta, and it would therefore seem best to retain the distinction between the two units.

UINTA FORMATION - Specific Information

DISTRIBUTION. -- The true Uinta formation is confined to the Uinta Basin, south of the Uinta Mountains, in Utah. The name, however, has also been applied to sediments in the Beaver Divide on the southern and eastern rims of the Wind River Basin.

IMPORTANT REFERENCES. -- Emmons (in King 136: 304-307); King (137: 405-407); Matthew (in Osborn 219: 98-100); Granger (87: 237-241); Osborn (224: 84-101); Scott (254: 15-121); Scott and Osborn (256: 461-572); Sinclair and Granger (276: 88-90, 97-99).

GENERAL INFORMATION

Areal Distribution and Lithology

Uinta Basin and adjacent areas. -- White (in Hayden 113: 19, 37) tersely noted in 1878, concerning the Yampa region of northwest Colorado:

"Uinta Group. Fine and coarse-grained friable sandstones, with intermixed gravel in some places, forming a conglomerate; distinctly or obscurely stratified; the materials composing the strata in some places nearly or quite incoherent. General aspect gray or dull brownish red. Unconformable by sequence upon the other Tertiary, and several of the older groups in the district. Thickness about 1,200 feet."

* * *

"The group consists of fine and coarse sandstones, with frequent layers of gravel, and occasionally cherty and calcareous layers occur. The sandstones are sometimes firm and regularly bedded, and sometimes soft and partaking of the character of badland material. The color varies from gray to dull redish-brown, the former prevailing north of the Uinta Mountains and the latter south of them."

In 1890 Scott (in Scott and Osborn 256: 466) noted briefly that the Uinta deposits "are composed of sandstones and clays much like those of the Bridger in appearance", and that the beds "are of no great thickness and are best developed in the valley of the White River, a tributary of the Green, in eastern Utah and western Colorado".

Later (1895) Osborn (214: 73-74), in an account of an expedition of 1894 to the Uinta Basin, described the typical Uinta formation in greater detail:

"Conformably overlying the Green River shales is a series of hard brown sandstones of the same character as sandstones which are found capping these shales north of the Uinta Mountains. Alternating with this brown sandstone are clay layers of a greenish-gray color, and this whole series reaches a thickness of about 800 feet. Specimens were found in the sandstone ledges of this series which represent true Bridger types. Overlying this series is a well-marked stratum of a light reddish color about 20 to 40 feet thick. This is especially noticed in the eastern part of the basin where the most satisfactory stratigraphical sections can be obtained.

UINTA FORMATION - Areal Distribution and Lithology

"The most important and faunally rich series of sediments in the Uinta basin immediately overlies and conformably succeeds the last mentioned reddish clay stratum. These beds are about 350 to 400 feet thick, and are composed of coarse brown sandstones with alternating clays. The largest part of the vertebrate collection secured by the party is from this level, and is of great interest owing to its transitional relationship between the true Bridger and the Uinta fauna.

"We now reach the true Uinta or Brown's Park beds of a fine-grained soft material much the same in appearance as the characteristic Bad Lands of South Dakota, with the exception of the color which is of a brick red; in fact, the reddish tinge holds good throughout the entire Uinta sediment. At a distance these beds present a ferruginous aspect, and are about 600 feet thick. This uppermost strata of the Uinta Basin has hitherto been reported as resting unconformably upon the underlying Bridger Sedi sediment, but no observable breaks are found to distinguish the true Uinta from the underlying Bridger sediment. So the writer found it necessary in collecting fossils to divide the beds overlying the Green River shales into three different levels, which are here arranged alphabetically in ascending position:

"Horizon C.--True Uinta beds 600 feet thick. Sandstones and clays brownish and reddish, ferruginous. The strata are sometimes evenly bedded and firm, but often irregular and friable, and present the characteristic Bad Land appearance where the erosion has been most complete. This is the level in which the Yale College and the Princeton expeditions have made their explorations, and it contains the true Uinta fauna.

"Horizon B,--300 feet thick. Soft coarse sandstones and clays.

"Horizon A.--800 feet thick. Hard brown sandstones immediately overlying the Green River Shales."

Some years later (1929) Osborn (224: 71) said that the Uinta sediments are

"composed mainly of altered eruptives, probably dacite tuffs, as indicated by analyses ... The rocks of the lower levels, described as 'brown sandstones' comparable in lithologic appearance to Washakie A, contain a large element of tuff and consist microscopically of irregularly broken and rounded fragments of quartz, lime-soda feldspar, hornblende, biotite, and fragments of andesite or basalt in a brown gound-mass, which is chiefly chlorite but contains some calcite. On the lower levels (in Uinta A) brown is the prevailing color, as in Washakie A. In Uinta B sediments of this color pass into pinkish-brown and reddish-brown sediments, and in Uinta C into pale-green and gray fine-grained rocks containing considerable glass. Many rocks that look like sandstones prove under the microscope to resemble flow breccias."

Central Wyoming. -- Granger (87: 247) recorded in 1910 that along the southern border of the Wind River Basin,

"on the divide between Sweetwater River and Beaver Creek, there is exposed a thickness of 1,100 feet of Tertiary, a remnant of deposits which

undoubtedly extended over a large part of the basin at one time. Three distinct faunal levels, as indicated by mammalian fossils, are exhibited, Lower Eocene, Upper Eocene, and Lower Oligocene, the levels being correlated with (1) the ?Coryphodon Zone of the Wasatch, (2) the ?Diplacodon Zone of the Uinta, and (3) the Titanotherium Zone of the White River. An unconformity exists between the Eocene and Oligocene ..."

Granger (87: 237) gave the following lithologic details of the upper Eocene (so-called Uinta):

White River group
Erosional unconformity
7. Coarse greenish sandstone . . . . . 10 ft.
6. Yellowish green and olive coarse, loosely compacted sandy stones . . . . . 55 ft.
5. Gray and yellowish clay . . . . . 27 ft.

The following year Sinclair and Granger published a paper on the Wind River and Big Horn Basins. They said (276: 98-99) that the so-called Bridger of the Wind River Basin is conformably overlain by

"the so-called 'joint-clays' of the Uinta with Amynodon, etc., light cream-colored to pale greenish shales with the same association of minerals as in the yellow silts below, but with the kaolinized material of finer grain. As the specimen examined showed no tendency to become plastic when soaked in water, even after the large amount of calcium carbonate present had been removed by treatment with acid, the term 'clay' is hardly applicable. The shales are irregularly jointed, readily crumbling, when exposed to the weather, into small fragments ..."

* * *

"The sandstone is a medium-grained, greenish-colored rock which, in addition to vast numbers of kaolinized fragments ranging in size from fine dust to particles a third of a millimeter in diameter or thereabouts, white, rusty red or purplish pink in color ... contains abundant angular fragments of orthoclase, water clear or slightly cloudy, an occasional plagioclase,... quartz grains, hornblende splinters, biotite foils and abundant magnetite sand. ... The ... rock is so hard that it readily breaks across the quartz grains when a hand specimen is trimmed."

* * *

"In the section at the head of Muskrat Creek a fine-grained, bluish gray shale occupies the position of the Uinta below the Oligocene gravels which here rest upon it.

"... the total thickness of the Uinta varies much as does that of the individual elements which, also, change character from place to place."

Stratigraphic and Structural Relations

King (137: 406) recorded in 1878 that at Wonsits Ridge, northeast Utah

UINTA FORMATION - Stratigraphic and Structural Relations

"These beds consist of earthy sandy beds, having many coarse chocolate-colored sandstone members. A still higher dip is observed in these same rocks along the upper branches of Ute Fork, where an inclination of 25° is sometimes seen."

Bradley (22: 6) said in 1931 that

"The Uinta formation, of upper Eocene age, comprising the youngest rocks of the basin, took part in the major deformation, which is therefore post-Eocene. It may perhaps have been later than early Miocene and coincident with a partial collapse of the east end of the Uinta Mountain arch, which faulted and in places strongly flexed beds of the Browns Park formation that are probably of late Oligocene or early Miocene age."

Sinclair and Granger (276: 97) noted in 1911 that in the region of the Beaver Divide the Uinta rests conformably on the Bridger.

Bauer (11: 678), also said that in the Wind River Basin

"The strata are essentially parallel with the Bridger below and the Oligocene formations above, although there is much evidence of erosional unconformity at the top of the Uinta and little indication of unconformity at its base, wherever the Bridger formation is present."

Paleontology, Age and Correlation

Marsh (171: 354) noted in 1877 that the "Uinta Group is especially well characterized by large mammals of the genus Diplacodon, and hence may be termed the Diplacodon Beds". Emmons, in his report of 1877 on the Green River Basin, noted (in King 136: 307) briefly that

"... Professor Marsh and his assistants, who followed them [the Uinta beds] from below the mouth of the Ashley Creek, up the valley of White River, south of the limits of this exploration, succeeded in securing a very valuable suite of vertebrate fossils from the latter locality.

"The following are some of the principal forms collected and determined by him:

Diplacodon elatus
Orohippus Uintensis
Agriochoerus pumilus
Diceratherium advenum
Orohippus gracilis

"Although some of the forms collected have a generic resemblance to those of the Bridger beds, others again have somewhat of a Miocene facies; the preponderance being in favor of the former, he has regarded the whole, while representing a later period than that of the Bridger beds, as probably of Middle or Upper Eocene age."

King (137: 406, 407) observed in 1878:

UINTA FORMATION - Paleontology, Age and Correlation

"it is certain we have now not only established a complete faunal transition from the Bridger and Washakie beds upon the one side, to the true Uinta level or Horizon C upon the other, but have demonstrated a closer connection between the fauna of this basin and that of the lowest White River Miocene."

Osborn (p. 76) then proposed a division of the Uinta formation into three distinct faunal levels, as follows:

"C.--Upper level. True Uinta. Diplacodon elatus beds. This is the level of the Princeton and probably the Marsh explorations. It is distinguished by the presence of three genera -- Diplacodon, Protoreodon, Leptotragulus--which have thus far not been found below. It contains, however, several species which have also been found in the middle level. It is apparently distinguished by the absence of Uintatherium.

"B.--Middle level. Transitional. Telmatotherium cornutum beds. This is a rich faunal level, hitherto unknown. Telmatotherium cornutum is very abundant. This is related to the White River or Lower Miocene by the presence of an ancient species of Elotherium, and probably of Hyaenodon. It is related to the upper level, C, by similar species of Mesonyx, Amynodon and Epihippus, but is distinguished from C by the presence of Uintatherium. It is related to the eastern or Washakie Basin by the presence of Telmatotherium hyognathum and Achaenodon insolens, and apparently to the Bridger by Helaletes guyotii and Mesonyx obtusidens, both of which determinations are however somewhat doubtful.

"A.--Lower level. Base. Telmatotherium megarhinum beds. This level has been comparatively little explored. It contains T. megarhinum, also found in the Washakie, besides Amynodon, Triplopus and Uintatherium.

"We have now to ascertain what type of Uintatherium existed as a contemporary of Telmatotherium cornutum. Judging from the limbs, it was a very large animal, and will not improbably be found to belong to the Uintatherium cornutum Cope, which was obtained at the summit of Haystack Mountain, or the very top of the Washakie beds."

In the paper above quoted, Osborn listed, described and illustrated (214: 71-115) all the then known members of the Uinta mammal fauna, and included type descriptions of a number of new genera and species.

In 1929 Osborn (224: pp. indicated) presented the following summary:

"The deposits of horizons A and B of the Uinta basin are not those of the typical Uinta formation of Marsh, of King, or of Scott and Osborn, all of which belong to Uinta C, the Diplacodon zone; they form the lower part of the section (Uinta A and Uinta B), determined by the American Museum expedition of 1894 under Peterson and successively explored with remarkable results by Peterson, Douglass, and Riggs, whose observations and exact records of the vertical distribution of genera and species have firmly established the stratigraphy of the Uinta Basin section ...

"Uinta A as now defined is entirely unfossiliferous but is here correlated with ... horizon A of the Washakie Basin (Uintatherium zone).

UINTA FORMATION - Paleontology, Age and Correlation

"Uinta B 1 (in some previous reports included in Uinta A) contains a rich river-border fauna, like that of Washakie B 1.

"Uinta B 2 (formerly constituting all of Uinta B) contains a larger land and river-border fauna, like that of Washakie B 2.

"Uinta C contains the typical Uinta (Diplacodon) fauna.

* * *

"... We now know that the sediments that form Uinta B were certainly laid down after Bridger C and D had been deposited, but they may have been contemporaneous with the unfossiliferous Bridger E." (p. 91)

* * *

"To zone 15 belong the Uinta of King and Marsh, the 'Brown's Park beds' of Powell and the Uinta (?) of the Beaver Divide, Wind River Basin. This zone (Uinta C 1) is correlated with the European stage that was named the Ludian ..." (p. 94)

* * *

"The fauna found near the base of the true Uinta thus includes a considerable light-limbed meadow and plains element, transitional to the plains fauna of the lowest Oligocene of the White River group. The occurrence of this fauna near the base of the Uinta C indicates that the Uinta formation probably passes up into lower Oligocene time. The beds represent a considerable change in local physiographic conditions from those of Uinta B. The fine-grained soft material, composed of altered eruptives, probably dacite tuffs, is of much the same texture as the characteristic 'Titanotherium beds' (Chadron formation) of South Dakota, except as to its color, which is brick-red; in fact, a reddish tinge prevails throughout the sediments of Uinta C." (p. 95)

* * *

"Titanotheres have thus far been determined from only the lower 100 feet of Uinta C. They are at present only partly known. When fully known we shall probably find close generic if not specific correlation between the upper fauna (now unknown) of Uinta C and the fauna of the lower levels (Chadron A) of the White River group. The passage from Eocene to Oligocene time probably occurs within the period of Uinta C (true Uinta) deposition. Scott is disposed to put all of Uinta C in the Oligocene." (p. 99)

Osborn's correlation of the Browns Park formation with "Uinta C", is, of course, tentative, since the meager paleontologic evidence which has been gleaned from the Browns Park is inadequate for exact correlation. Osborn's correlation appears to have been based chiefly on stratigraphic data and upon the classic belief that Browns Park is practically a synonym of Uinta. This belief was strongly questioned by Sears (261: 286-287) in 1924. Sears said:

"The age of the Browns Park has long been in dispute, and guesses have ranged from Eocene to Pliocene. By various authors the formation has been correlated with the Green River, the Bridger, and the Uinta (all of Eocene age); parts of it have been mapped as Wasatch, Green River, Cathedral Bluffs red beds member of the Green River, Laney shale member of the Green River, and Bridger. Until a discovery by Professor Douglass in 1923, no identifiable fossils had ever been obtained from it. ... It can

be stated with certainty, however, even without the evidence of fossils, that the formation is younger than the Bridger. The writer has personally traced the contact of Browns Park and Bridger continuously between Little Snake River and Vermilion Creek, a distance of 20 miles. The lithology of the two formations is quite different; the Browns Park lies on the Bridger with an angular unconformity nowhere less than 10 degrees, and almost all of the way the base of the Browns Park contains its striking red conglomerate.

* * *

"In August, 1923, was published a statement that Prof. Earl Douglass had recently made 'three very important discoveries of fossils in the Browns Park formation south of Sunbeam, Colorado.' These were remains of vertebrates, mostly of carnivorous types. Professor Douglass was quoted as believing the formation to be probably of Miocene age. These fossils were later examined by Mr. O. A. Peterson, who says he believes them to be probably of lower Miocene age, although they may belong to the uppermost Oligocene."

In 1926 Peterson (228: 231) remarked that in 1925 J. L. Kay had discovered the remains of a proboscidean, Tetrabelodon osborni, in strata between 600 and 700 feet above the base of the formation, on the south slope of Douglas Mountain, Moffat County, Colorado. Peterson remarked that he had previously considered the Browns Park formation to be lower and middle Miocene in age, but that, in the light of this additional evidence, he found it necessary to refer it to the upper Miocene and lower Pliocene.

Osborn, in his paper of 1929, did not mention these earlier observations.

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