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OF THE

UNITED STATES

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No. 83

CORRELATION PAPERS—EOCENE.

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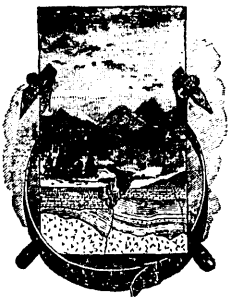
J. W. POWELL, DIRECTOR

CORRELATION PAPERS

EOCENE

BY

WILLIAM BULLOCK CLARK



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U. S. GEOLOGICAL SURVEY,
DIVISION OF GEOLOGIC CORRELATION,
Washington, D. C., June 1, 1891.

SIR: I have the honor to transmit herewith an essay by Dr. William B. Clark on the Eocene of the United States, prepared for publication as a bulletin.

The Division of Geologic Correlation was created for the purpose of summarizing existing knowledge with reference to the geologic formations of North America, and especially of the United States; of discussing the correlation of the formations found in different parts of the country with one another, and with formations in other countries; and of discussing the principles of geologic correlation in the light of American phenomena. The formations of each geologic period were assigned to some student already well acquainted with them, and it was arranged that he should expand his knowledge by study of the literature and by field examination of classic localities, and embody his results in an essay. The general plan of the work has been set forth on page 16 of the Ninth Annual Report of the Survey, and on pages 108 to 113 of the Tenth Annual Report, as well as in a letter of transmittal to Bulletin No. 80 of the Survey.

The present essay is the fourth of a series resulting from this work. The first, prepared by Prof. Henry S. Williams, pertains to the formations of the Carboniferous and Devonian periods, and constitutes Bulletin No. 80; the second, prepared by Mr. C. D. Walcott, pertains to the formations of the Cambrian, and constitutes Bulletin No. 81; the third, prepared by Dr. C. A. White, pertains to the formations of the Cretaceous, and constitutes Bulletin No. 82. The present essay is closely related to the one which follows it in the series, an essay by Dr. William H. Dall on the formations of the Neocene, Bulletin No. 84.

Dr. Clark has devoted himself chiefly to the correlation and systematic presentation of published material and opinions bearing on correlation of the formations of the Eocene. He finds that the marine faunas of the Atlantic and Gulf coasts permit a separation of the

Eocene as a whole from formations belonging to earlier and later periods with a high degree of confidence, but that with present evidence the lines of separation are not sharply drawn among the marine and fresh-water formations of the Pacific Coast and the Interior region. The correlation of the individual formations one with another has not yet been satisfactorily made throughout the Atlantic and Gulf Coast, constituting the district best known, and still less has this been found practicable when comparison is extended to the Interior and Pacific regions.

Very respectfully, your obedient servant,

G. K. GILBERT,
Geologist in Charge.

Hon. J. W. POWELL,
Director.

OUTLINE OF THIS PAPER.

This essay comprises, first, a general discussion of the limitations of the term Eocene as employed in American geology. The two-fold character of the Tertiary (1. Eocene, 2. Neocene) in America is insisted on.

After a somewhat extended review of the literature, in which the various opinions upon disputed points are especially considered, a general study of the stratigraphical, paleontological, and topographical characteristics of the Eocene in the various portions of the country is undertaken.

A division of the Eocene of the United States into three distinct regions is made—

1. Atlantic and Gulf Coast region.
2. Pacific Coast region.
3. Interior region.

Following a study of the stratigraphical relations of the Eocene of the Atlantic and Gulf Coast region, an attempt is made to correlate the very diverse formations of this great area. Four provinces are provisionally established (1. New Jersey province, 2. Maryland-Virginia province, 3. Carolina-Georgia province, 4. Gulf province), though fuller knowledge may break down their bounds. The general similarity of the deposits and their fossils to extra-American Eocene is shown, but detailed correlation is not considered feasible.

The meager knowledge of the Pacific Coast Eocene precludes any general discussion of the stratigraphical and paleontological relations of that horizon. The local peculiarities, shown both in fossils and deposits, are referred to, and the close relationship existing between the Eocene and Cretaceous is dwelt upon. Their separation is a matter of some uncertainty with our present information. Certain points of identity with Eocene deposits elsewhere are mentioned. Two groups of strata are recognized, one marine (Tejon group), the other brackish (Puget group).

The remarkable conditions under which the deposits of the Interior region were accumulated and the interesting fauna and flora that they afford are fully discussed in the final division of the essay. The Lara-

mie problem, although more fully presented by Dr. White in his paper upon the Cretaceous, is here referred to, and facts are given to show that the Laramie is probably in part Eocene. The conflict between the evidence afforded by animals and plants is stated and the consequent hindrance to satisfactory correlation is shown. The general relations of the fauna and flora of the Eocene of the Interior to that of other regions is pointed out, though no attempt is made at a detailed correlation of its various members.

In conclusion, an alphabetical list of the leading articles upon the Eocene of the United States is presented.

PREFACE.

The present report is one of a series of essays in which, as authorized by the Director, "existing data affecting the problems of American geologic nomenclature should be collected and discussed." The division of the work assigned to the writer embraces that portion of the American geological column designated as the "Eocene." As the limits to be assigned to this horizon have been variously determined by different geologists, the discussion of its delimitation forms an important feature of the essay. Furthermore, the divisions into which the Eocene has been separated have each received many different names and boundaries, and have been variously correlated by those who have examined the different areas of their occurrence or who have employed one or the other of the various classes of paleontological data that the deposits afford.

That a wide variance in the opinions of geologists upon Eocene stratigraphy should prevail is not surprising, but oftentimes the extreme meagerness of obtainable information on important points renders a critical comparison of their views impossible. At every point the insufficiency of existing knowledge has been forcibly shown as the investigation has proceeded.

In the preparation of the essay I have been necessarily guided largely by the published opinions of others, which I have endeavored, as far as possible, to arrange logically and correlate with one another.

Although the facts employed have thus been, in the main, acquired from the literature, I have nevertheless had an opportunity of personally examining extensive areas of the Atlantic Coast region from New Jersey to Georgia, together with the more typical localities of the Interior. As the object of the report, however, is to present a summary of existing knowledge rather than to give the results of original research, the investigations made have had largely for their aim the acquirement of a general acquaintance with the leading features of Eocene stratigraphy and the possible reconciliation of conflicting statements.

I wish especially to thank Dr. C. A. White, of the U. S. Geological Survey, for many valuable suggestions that have been kindly given during the preparation of this report. Thanks are likewise due to Dr. Whitman Cross, and Dr. W. H. Dall for much important information. Of special value in the preparation of this essay has been Prof. Heilprin's "Contributions to the Tertiary Geology and Paleontology of the United States," from which frequent quotations have been made.

THE EOCENE OF THE UNITED STATES.

By William B. Clark.

INTRODUCTION.

The Eocene of the United States is widely represented both in the Coastal and the Interior portions of the country. Formed in the several areas under very different conditions, it exhibits clearly defined dissimilarities in structure and in fossils. Marine and brackish-water strata, with their attendant lithological and paleontological characteristics, by which the presence or close proximity of the open sea is attested, prevail generally throughout the Coastal regions. In the Interior, on the other hand, the sediments were deposited in great fresh-water lakes, that admitted of the accumulation of beds that equal or surpass in extent those of the ocean border, and in which are entombed the remains of lacustrine life. A natural division, therefore, of the Eocene deposits into a Coastal Province and an Interior Province may be made. Furthermore, the coast regions of the Atlantic and Pacific borders are so clearly limited geographically, and at the same time present such widely varying stratigraphical relations and fossil remains, that they merit separate consideration.

On stratigraphical and geographical grounds, then, the Eocene of the United States will be treated in the succeeding portions of this paper under the three divisions above outlined:

I. The Atlantic and Gulf Coast region.

II. The Pacific Coast region.

III. The Interior region.

Before proceeding further with their consideration it becomes necessary to outline, in a general way, the limits of the term Eocene as employed in the present essay. As one of the eleven classificatory units established by the U. S. Geological Survey to designate the several time periods in American geological history, it has equal value with the terms Cretaceous and Neocene, the names adopted for the preceding and succeeding divisions, respectively. Together with the Neocene, it constitutes what is frequently denominated the Tertiary, and individually includes those deposits that have been hitherto described in Amer-

ican literature as Eocene and Oligocene. These latter terms, as indicating divisions of the lower Tertiary, have no place in the nomenclature of American geology, however applicable they may be found for European formations. The Tertiary strata of America, on both stratigraphical and paleontological grounds, may be best divided into two groups. The term Eocene, which is retained as equivalent to Lower Tertiary, may or may not coincide with the division so designated by European geologists.

The attempt at a detailed correlation of American formations with European, so often made in the past on insufficient data, is greatly to be deprecated. The Tertiary strata of America, deposited under conditions peculiar to themselves, merit consideration upon those characteristics rather than upon features typical for other and far distant regions. Certainly not until the strata have been much more exhaustively studied will it be possible even to approximate to an accurate correlation of the leading divisions of the American Tertiary with those of other lands.

In the treatment of the subject in the pages of this paper the Eocene, so far as practicable, will be separated into three divisions: (1) Lower. (2) Middle. (3) Upper. Although in many localities too little is known of the deposits, due to the partial representation of the series, to make an accurate determination possible, yet where best developed a triple division is the most natural.

More complete observations will doubtless clear up many points that are now obscure, and enable a correlation to be made of dissimilar deposits in contiguous areas that at present defy comparison. Until such exhaustive investigations have been made many discrepancies in our knowledge of American Tertiary geology must continue to exist.

ATLANTIC AND GULF COAST REGION.

PRELIMINARY REMARKS.

The Atlantic and Gulf Coast region, as regards its geographical extent, its stratigraphical diversity, and its copious literature far exceeds in importance the other Eocene areas. It stretches as an almost continuous belt along our eastern coast from New Jersey to Texas, and has been variously considered in official reports of the several States and in numerous articles scattered through scientific journals. Wide differences of opinion have prevailed among the various writers, as regards the geographical and stratigraphical limits of the Eocene, as will be set forth in the historical sketch.

In the following pages the stratigraphical relations of the Eocene are discussed in considerable detail, and the leading sections for each State given with their typical fossils. The topographical characteristics, although greatly modified by later deposits, are yet sufficiently distinctive in many instances to demand attention.

An extended correlation of the Eocene deposits of the Atlantic and Gulf Coast region is generally unsatisfactory, although a more or less accurate reference of the strata to a relative position in the series may usually be made.

The fauna, in different portions of the area, shows marked variations, but is as yet too imperfectly understood to warrant a division of the Atlantic and Gulf Coast region into established provinces. A provisional separation is, however, attempted. When further correlation is made by comparison with European formations the task is still more difficult and the results of correspondingly less value. To each of these subjects a special chapter will be devoted.

HISTORICAL SKETCH.

The earlier writers upon the geology of the North American continent dwelt exclusively upon the general relations of the strata, and included the entire Upper Mesozoic and Cenozoic series of the coastal plain in the "alluvial formation." Later others, whose personal investigations or study had extended to an examination of the geology of foreign lands, endeavored to correlate upon lithological grounds the various formations of the coastal area with the minuter divisions established in Europe. Recognizing the futility of such detailed correlation before a knowledge of the fossils of the several horizons had been acquired, Conrad, Morton, Say, Lea, and others proceeded with marked industry

to describe the rich fauna that the deposits afforded. Based upon this work, many important papers appeared, dealing either with the relations of local deposits or the general features of the entire coastal region. The State geological surveys, during the same time, made more or less complete examinations of their respective territories, presenting us with data relating to the stratigraphy. In short, during the last half century the activity displayed in every other field of American geology has not been wanting in this, the eastern Tertiary belt, if the numerous publications are a criterion. Unfortunately, the results as a whole have not been as valuable as in many other lines of investigation, although many marked exceptions might be cited.

In the historical sketch that follows the leading articles and reports bearing upon the different epochs in the evolution of our knowledge of the Eocene will be considered, though much of value must of necessity be hurriedly passed over.

The first important contribution appeared in 1809, when William Maclure[1] read before the American Philosophical Society at Philadelphia his "Observations on the Geology of the United States," in which the entire coastal plain is referred to the alluvial formation, the fourth of the grand divisions of the geological column according to the Wernerian classification which Maclure adopted. The general limits of the region are given, and the shell deposits, limestone, and buhrstone are referred to, although it is evident that the author was ignorant of their stratigraphical position or taxonomic importance. Maclure subsequently revised and enlarged the work, which appeared in book form[2] in 1817, and in the Transactions of the American Philosophical Society for the same year.[3]

A few years subsequent to the appearance of Maclure's articles H. H. Hayden published a volume of "Geological Essays" (1820) in which an explanation is given of the great accumulation of "alluvial deposits" in the eastern and southern portions of the United States, and the stratigraphy of the region is described in much greater detail than by his predecessor. Reference is made to the wide distribution of fossil shells, and vertebrate remains, and many localities are cited.

A second work of the same general character, so far as it relates to the geology, was published in 1822, by Parker Cleveland, entitled "An Elementary Treatise on Mineralogy and Geology," in which, on page 785, under "Remarks on the Geology of the United States Explanatory of the Subjoined Geological Map," the author defines the limits of the "alluvial deposits," and in general terms describes their lithological character.

[1] Am. Phil. Soc. Trans., vol. 6, 1809, pp. 411-428. A translation appeared in the Journal de Physique, vol. 69, 1809, pp. 204-213, and vol. 72, 1811, pp. 137-165.

[2] Observations on the Geology of the United States of America, etc. By William Maclure, Philadelphia, 1817, 8vo, 130 pp.

[3] Am. Phil. Soc. Trans., new ser., vol. 1, 1817, pp. 1-92. Also Leonard's Zeitschrift, Band 1, 1826, pp. 124-138.

Before the publication of the latter work, articles descriptive of local points in the stratigraphy had appeared, chiefly as communications to the American Journal of Science and Arts.[1] Of importance among these is a paper by Elias Cornelius in which the limits of the alluvial formation of the Mississippi are outlined and potent reasons given for its extension beyond the boundaries assigned by Maclure.

Samuel Akerly, in an essay published in New York in 1820, discusses the "alluvial deposits" of northern New Jersey. In this paper the marl beds, together with some of their fossils, are described, but no evidence is adduced that the author recognized their taxonomic position.

In volume 3 of the American Journal of Science two articles appeared: The first by John Dickson,[2] on the geology of parts of North and South Carolina; the second by Dr. Troost,[3] on the stratigraphy of the region about the Magothy River, Anne Arundel County, Maryland.

James Pierce, in a "Notice of the Alluvial District of New Jersey,"[4] published in 1823, describes the marl deposits of Monmouth County.

By far the most important contribution to the stratigraphy of the coastal plain that had up to that time appeared was made by Prof. John Finch in a "Geological Essay on the Tertiary Formations in America,"[5] in the American Journal of Science and Arts for 1824. This was the first attempt at a correlation of the deposits of the coastal plain on scientific grounds, and although thus early in the history of the subject, minute comparisons, which are always unsatisfactory, were made, yet the knowledge of American Tertiary formations was materially advanced. The author says:

> In America an immense tract of country, extending from Long Island to the Sea of Mexico, and from 30 to 200 miles in width, is called an alluvial formation. From an examination of fossils brought from that quarter of the United States, from a personal inspection of some of its strata, and the perusal of most of the publications which bear a reference to it, I wish to suggest that what is termed the alluvial formation in the geological maps of Messrs. Maclure and Cleveland is identical and contemporaneous with the newer Secondary and Tertiary formations of France, England, Spain, Germany, Italy, Hungary, Poland, Iceland, Egypt, and Hindostan.

The deposits, which will be discussed in a later portion of this report, as exhibited in New Jersey, Maryland, on the James River, Virginia, on the Santee River and at Orangeburg, South Carolina, at Shell Bluff, on the Savannah River in Georgia, and at numerous localities in Alabama and Mississippi are considered in greater or less detail, and an attempted correlation made with one another and with European strata. In short, the author states that—

> Many more instances might be advanced to establish the identity of what has been called the alluvial district in America with the Tertiary formation of England and

[1] Am. Jour. Sci., vol. 1, 1819, pp. 214–226, 317–331.
[2] Ibid., vol. 3, 1821, pp. 1–5.
[3] Ibid., vol. 3, 1821, pp. 8–15.
[4] Ibid., vol. 6, 1823, pp. 237–242.
[5] Ibid., vol. 7, 1824; pp. 31–43.

the continent of Europe. The fossil shells from the various beds would not, perhaps, be exactly like those of Europe, but a sufficient number would be found so to establish their relation and order of succession.

In the same volume of the American Journal, Prof. Edward Hitchcock[1] describes the presence of the "Plastic Clay formation" on Martha's Vineyard and the Elizabeth Islands, an attempt at detailed correlation that is not supported by facts as we now interpret them.

During 1824 and 1825 Olmsted's "Report on the Geology of North Carolina" appeared, and a review[2] of the same in the American Journal in 1828. The shell marl of the Neuse is herein described, together with its fossils.

During the year 1825 Jer. Van Rensselaer delivered a course of lectures in the New York Athenæum, on geology, that were subsequently published in book form.[3] The author adopted the classification proposed by Finch, although he confined his descriptions to the more northern representatives of the Tertiary series.

On page 34 of "Mills's Statistics of South Carolina" (1826) reference is made to the limestones of the Santee and Savannah Rivers, which contain "many oyster shells of uncommon size, and different from those now found near our shores." An occurrence of a shell deposit at Orangeburg is described in this work in considerable detail, and the general geological characteristics of the region are given.

The American Journal for 1826 contains a communication by James Pierce[4] "On the shell-marl region of the eastern parts of Virginia and Maryland," in which reference is made to the river sections on the James and Potomac, and to the "shell rock" at Upper Marlboro, Maryland.

In volume 13 of the same journal Mr. S. Porter,[5] in a letter to Prof. Silliman, gives some valuable information in regard to the shell deposits of Alabama; and Elisha Mitchell[6] presents still more detailed statements in regard to the stratigraphy of similar strata in South Carolina.

In notes[7] by Lardner Vanuxem, arranged by Dr. S. G. Morton for publication in the Journal of the Academy of Natural Sciences of Philadelphia, the attempt is made to more accurately define the limits of the Tertiary. The author states that much that had been designated by that name properly belongs to other formations.

Up to the year 1830 all investigations upon the stratigraphy of the Tertiary had been carried on in the main independently of a study of its fossils. Generic similarities had been cited as grounds for correlation, and although this aided largely in determining the limits of the Tertiary itself, further subdivisions were impracticable.

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[1] Am. Jour. Sci., vol. 7, 1824, pp. 240–248.
[2] Ibid., vol. 14, 1828, pp. 230–251.
[3] Lectures on Geology, 1825, 8vo., 358 pp.
[4] Ibid., vol. 11, 1826, pp. 54–59.
[5] Am. Jour. Sci., vol. 13, 1828, pp. 77–79.
[6] Ibid., 1828, pp. 336–347.
[7] Geological observations on the Secondary, Tertiary, and Alluvial formations of the Atlantic coast of the United States of America. Philadelphia Acad. Nat. Sci., Jour., vol. 6, 1828, pp. 59–71

With the publication of Conrad's article[1] "On the Geology and Organic Remains of a part of the Peninsula of Maryland," with an appendix containing descriptions of new species of fossil shells, a new era in the investigation of the Atlantic and Gulf Coast strata was inaugurated. It is true that Say[2] had described several Tertiary species, but, as stated in Conrad's paper, he did not "draw any geological inferences from the organic remains examined." Conrad from the first applied the paleontological evidence he possessed to an interpretation of the stratigraphy; and although many of his conclusions were erroneous, still the knowledge of the geology of the coastal plain was very materially advanced. In this first paper such well known early Tertiary forms as *Turritella Mortoni*, *Cucullæa gigantea*, and *Crassatella alæformis* are figured and described, and the presence of *Venericardia planicosta* Lamarck is also noted. Making use of the data afforded by these investigations, the strata at Fort Washington were correlated with the London Clay of England.

In 1832 Conrad published an important work on the "Fossil Shells of the Tertiary Formations of North America,"[3] which was followed in 1833 by a description[4] of a large number of new forms from Claiborne, Alabama. In the latter article the position of the white limestone below the Claiborne sands is affirmed.

The same year Lea published his "Contributions to Geology"[5] in which he treats of the general features of the Atlantic and Gulf Coast Tertiary, but especially considers the Claiborne section, describing 219 new species. The Claiborne beds are correlated with those at Fort Washington, Maryland. In regard to their European equivalence, the author says:

> After a careful examination of a great number of genera and species from the Tertiary of Claiborne, Alabama, I had no hesitation in referring them to the same period as the London Clay of England, and the Calcaire Grossier of Paris. * * * This part of the Tertiary formation * * * is called by Mr. Lyell the Eocene period.

This is the first application of the term Eocene to American deposits.

About the same time Withers gave in the American Journal[6] the general features of the section at St. Stephen's Bluff, Alabama.

A year later, in "Observations on the Tertiary and more recent formations of a portion of the Southern States,"[7] Conrad adopted the term Eocene for the well known sections at Fort Washington, Maryland; Eutaw Springs, South Carolina; Shell Bluff, Savannah River, Georgia; Claiborne, Alabama, and many intermediate points. In an

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[1] Philadelphia Acad. Sci., Jour., vol. 6, 1830, pp. 205–217.

[2] Am. Jour. Sci., vol. 1, 1819, pp. 381–387; vol. 2, 1820, pp. 34–45. Philadelphia Acad. Nat. Sci., Jour., vol. 4, 1824, pp. 124–155 (*Ostrea compressirostra*).

[3] 8°, 56 pp. 16 pls., Philadelphia, 1832.

[4] Am. Jour. Sci., vol. 23, 1833, pp. 339–346, 405.

[5] Contributions to Geology, by I. Lea. 8vo. 1833. 227 pp., 6 pls.

[6] Am. Jour. Sci., vol. 24, 1833, pp. 187–189.

[7] Philadelphia Acad. Nat. Sci., Jour. vol. 7, 1834, pp. 116–157.

appendix to this paper many new fossils are described. A diagram representing the bluff at Claiborne is added, in which the white limestone is again placed below the fossiliferous sands. Conrad quotes Lyell on European formations as stating that no secondary fossils are found in the Eocene, yet his own observations at Claiborne warranted him in claiming the admixture of a few species. He further considers the Eocene of Claiborne older than the Eocene of Fort Washington, Maryland, and of Europe.

Prof. Chas. U. Shepard published in the American Journal of Science the same year "Geological Observations upon Alabama, Georgia, and Florida,"[1] in which several of the Eocene localities of those States are described.

Three other articles appeared at this time by Harlan,[2] McGuire,[3] and W. B. Rogers,[4] that added somewhat to the knowledge of local deposits. The paper by Rogers is especially interesting, as the first of a series of articles and reports on the geology of Virginia that give us a clearer insight into the Tertiary geology of that State than of any other on the Atlantic seaboard.

About the same time Dr. Morton published a "Synopsis of the organic remains in the ferruginous sand formations of the United States," in which several species from the "white limestone" of South Carolina are included through a misconception of the proper stratigraphical position of that formation.

In 1835 Conrad added two more papers[5] on the Atlantic Tertiary region. In the transactions of the Geological Society of Pennsylvania he says:

> Having traced the burr stone of Georgia, the fossiliferous sands of Claiborne, Alabama, and a calcareous clay near Orangeburg, South Carolina, to common or synchronous origin, I immediately perceived that the deposit at Upper Marlboro was a link in the chain of older Tertiary beds.

Reference is made in both articles to the commingling of the Cretaceous and Eocene forms, a point subsequently more fully considered. It was held, at the same time, worthy of mention that no fossils had been found common to the Eocene and Miocene.

H. B. Croom[6] published an account of early Tertiary fossils found in Craven County, North Carolina, in the American Journal of Science of the same year.

William B. Rogers published in the Farmers' Register for 1835, "Further observations on the greensand and calcareous marl of Virginia"[7] The marked lithological similarity of the beds to the greensand of New

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[1] Am. Jour. Sci., vol. 25, 1834, pp. 162–173.
[2] Am. Phil. Soc. Trans., new ser., vol. 4, 1834, pp. 397–403.
[3] Am. Jour. Sci., vol. 26, 1834, pp. 93–98.
[4] Farmers' Register, 1834. Reprinted in Geology of the Virginias, 1884, pp. 3–9.
[5] Pennsylvania, Geol. Soc. Trans., 1835, pp. 335–341; Am. Jour. Sci., vol. 28, 1835, pp. 104–111.
[6] Am. Jour. Sci., vol. 27, 1835, pp. 168–171.
[7] Reprinted in Geology of the Virginias, 1884, pp. 11–20.

Jersey is mentioned in this article, but the character of the fossils is shown to place those of Virginia in the Eocene.

For the next few years Professor Rogers devoted himself to a most careful study of the Tertiary geology of Virginia, and as State geologist published annual reports[1] giving detailed accounts of the progress of the survey. Numerous sections of early Tertiary marl and greensand are herein described, and lists of characteristic fossils are given. As these publications afford the most important literature upon the geology of Virginia, a consideration of the details will be reserved for a later portion of this report.

In conjunction with his brother, H. D. Rogers, the same writer published in the Transactions of the American Philosophical Society of Philadelphia a series of articles entitled, "Contributions to the geology of the Tertiary Formations of Virginia,"[2] that, beyond the description of several new species of early Tertiary shells, cover much the same ground as the annual reports.

During this same period, Mr. T. A. Conrad contributed several papers[3] of importance, first among them being a special treatise on Tertiary shells,[4] that appeared in 1838.

A point much discussed in southern Tertiary stratigraphy was considered by Conrad in the American Journal of Science for 1840, under the title "On the geognostic position of the Zeuglodon or Basilosaurus of Harlan."[5] The statement is made that the Zeuglodon occurs "in the limestone of Alabama immediately under the lower Tertiary fossiliferous strata," and further that "this formation seems to fill the chasm which in Europe has been often noticed to occur between the Secondary and Tertiary series."

While Prof. William B. Rogers and T. A. Conrad were conducting their important investigations, others were not idle. H. D. Rogers, as State geologist for New Jersey, published reports in 1836 and 1840, in which the marls of Monmouth County at Shark River and Squankum are described and referred to the "upper Secondary."

In Delaware the State geological survey, under J. C. Booth, published two annual reports of work done during 1837–'38, which were subsequently (1841) issued in enlarged form as a "Memoir."

In Maryland a series of annual reports, extending from 1833 to 1840, were made by the State geologist, J. T. Ducatel, to the legislature. The sections exhibited at numerous points in the Tertiary area are given in these reports, together with lists of fossils.

In 1836, J. R. Cotting published a "Report of a Geological and Agri-

[1] Reports were published for the years 1835–1841, inclusive. Reprinted in Geology of the Virginias, 1884, pp. 21–546.

[2] Am. Phil. Soc., Trans., new ser., vol. 5, 1835, pp. 319–342; vol. 6, 1837–1839, pp. 347–370, 371–377. Abstract in Amer. Phil. Soc. Proc., vol. 1, 1840, pp. 88–90.

[3] Am. Jour. Sci., vol. 35, 1839, pp. 237–251; vol. 38, 1840, pp. 86–93. Philadelphia Acad. Nat. Sci., Jour., vol. 8, 1841, p. 190. Philadelphia Acad. Nat. Sci., Proc., vol 1, 1841, p. 33.

[4] Fossils of the Tertiary Formations of the United States, 8vo., 1838, 89 pp., 49 pls.

[5] Am. Jour. Sci., vol. 38, 1840, pp. 381–382.

cultural Survey of Burke and Richmond counties, Georgia," in which the character of the Tertiary deposits is reviewed in considerable detail, though the author had little conception of their stratigraphical relations.

The occurrence of early Tertiary strata in Arkansas is recorded in Featherstonhaugh's "Geological Report of an Examination made in 1834 of the Elevated Country between the Missouri and Red rivers."

Nine biennial geological reports were presented by G. Troost, the State geologist, to the legislature of Tennessee, between the years 1831–'47. The geology of the eastern portion of the State is in the main considered, though now and then references are made to the later formations of the west. The information conveyed is, however, of slight importance, so far as the older Tertiary is concerned. Very much the same remarks apply to W. W. Mather's "Report on the Geological Reconnaissance of Kentucky, made in 1838."

The activity manifested by the geological surveys of the States just mentioned in the study of the Tertiary deposits, was accompanied by much private investigation, the result of which appeared in numerous articles in the American Journal of Science and Proceedings of the Academy of Natural Sciences of Philadelphia.

Some of the more striking features of the topography and geology of Florida are pointed out by Maj. Henry Whiting, in a paper entitled "Cursory Remarks upon East Florida in 1838,"[1] that was published in 1839.

In 1841 Edmund Ravenal[2] and Henry C. Lea[3] published descriptions of new Eocene fossils from South Carolina and Alabama, respectively.

An article by James T. Hodge, on "Observations on the Secondary and Tertiary Formations of the Southern Atlantic States,"[4] followed in the succeeding volume of the American Journal of Science. So far as the Eocene is concerned, his observations chiefly related to points in North and South Carolina, and to Shell Bluff and Jacksonboro, in Georgia. In this article the limestone and conglomerate on the Northeast Cape Fear River and at Wilmington are held to be an "upper Secondary" deposit, interposed between the Cretaceous and Eocene.

Some interesting points in the Eocene stratigraphy of Virginia were reported by Prof. Tuomey, in 1842,[5] from a shaft sunk at Evergreen, on the James River.

In the Proceedings of the National Institution for the Promotion of Science, Conrad contributed further "Observations on a portion of the Atlantic Tertiary Region, with a description of new species of Organic Remains."[6] Especial importance was at that time attached to the fact

[1] Am. Jour. Sci., vol. 35, 1839, pp. 47–64.
[2] Philadelphia Acad. Nat. Sci., Jour., vol. 8, 1841, pp. 333–336.
[3] Am. Jour. Sci., vol. 40, 1841, pp. 92–103.
[4] Ibid., vol. 41, 1841, pp. 332–348.
[5] Ibid., vol. 43, 1842, p. 187.
[6] Second Bulletin, 1842, pp. 191–194. (See Rogers, Am. Jour. Sci., vol. 47, 1844, p. 254.)

that the author found what he considered proof of the commingling of Secondary and Tertiary types. He presented a list of forms that were supposed to show the connection of the "white limestone" of Alabama to the "greensand formation" of New Jersey.

The first of Lyell's contributions to the literature of the Eastern Tertiary belt appeared in the Proceedings of the Geological Society of London, for 1842. His conclusions were derived from personal observations, and were of special value from his wide knowledge of the Tertiary in other portions of the globe. He succeeded in explaining many hitherto imperfectly understood points in American Tertiary stratigraphy.[1] The narrative of this first report contains the following statement:

> Having examined the most important Cretaceous deposits in New Jersey, Mr. Lyell proceeded, in the autumn of 1841 to investigate the Tertiary strata of Virginia, the Carolinas and Georgia, with a view to satisfy himself, first, how far the leading divisions of the Tertiary strata along the Atlantic border of the United States agree in aspect and organic contents with those of Europe; and secondly, to ascertain whether any rocks containing fossils of a character intermediate between those of the Cretaceous and the Eocene beds really exist. The conclusions at which he arrived from his extensive survey are given briefly as follows:
>
> (1) The only Tertiary formations which the author saw agree well in their geological types with the Eocene and Miocene beds of England and France; (2) he found no Secondary fossils in those rocks which have been called upper Secondary, and supposed to constitute a link between the Cretaceous and Tertiary formations.

Each of the above mentioned States was at this time separately considered and a careful description given of every locality visited.

During the next few years six important contributions by the same writer to the Tertiary geology of the eastern United States, appeared in the Proceedings and Quarterly Journal of the Geological Society of London. In most cases special points in the stratigraphy, that had been the subject of discussion by American geologists, were taken up, and much light thrown upon the questions at issue.

In regard to the occurrence of early Tertiary strata on Marthas Vineyard, as claimed by Prof. Hitchcock[2] in 1824, when the deposits at Gay Head were correlated with the "Plastic and London clay of Alum Bay," Mr. Lyell[3] thought that the evidence was altogether in favor of considering them Miocene.

In an article on the "Cretaceous of New Jersey and other parts of the United States bordering on the Atlantic"[4] the lithological similarity of the Eocene and the Miocene farther south to the Cretaceous of New Jersey, and the necessity of fossils for the identification of the various green sand horizons, are clearly set forth, thus substantiating the earlier claims of Rogers.

A later communication "On the Miocene Tertiary strata of Mary-

[1] Geol. Soc., London, Proc., vol. 3, 1842, pp. 735–742.
[2] Am. Jour. Sci., vol. 7, 1824, pp. 240–248.
[3] Geol. Soc. London, Proc., vol. 4, 1843, pp. 31–33.
[4] Ibid, Proc., vol. 4, 1844, pp. 301–306.

land, Virginia, and North and South Carolina."[1] contains numerous sections in which the Eocene occurs.

Immediately following the last paper in both the "Proceedings" and the "Journal," are the "Observations" of Mr. Lyell "on the White Limestone and other Eocene or Older Tertiary formations of Virginia, South Carolina, and Georgia."[2] After stating that the Eocene of Virginia "consists in great part of green sand and marl, containing green earth * * * like that which characterizes the Cretaceous strata of New Jersey," he adds:

> Farther south, in North and South Carolina and in Georgia, the Eocene formation acquires a larger development and a new mineral type, consisting of highly calcareous white marl and white limestone, and passing upward, especially in Georgia, into red and white clays, ferruginous sands, with associated layers of burrstone and siliceous rock.

Speaking of the already well known Claiborne section, he states in an article "On the newer deposits of the Southern States of North America"[3] that the relationship of the deposits is different from that previously held, inasmuch as the "Nummulite limestone" occurs above the Claiborne fossiliferous sands and not below, and that the remains of the Zeuglodon are always found "in the Eocene white limestone below the level of the Nummulitic rock and above the beds which contain the greater number of perfectly preserved Eocene shells," among them *Cardita planicosta*, and *Ostrea sellæformis*. Writing[4] on the same subject a year later, he reaffirmed the position he had previously taken in this matter, showing at the same time from numerous sections the much wider application of this relationship of the strata.

During this time Lyell made four contributions[5] to the American Journal of Science, which contain in the main the same conclusions as the previously cited articles.

Murchison,[6] in his presidential address delivered to the Geological Society of London in 1843, reviewed the results of Lyell's investigations upon the "Older Tertiary" strata of America, and added his own interpretation of a few points.

During these years, due in part to Lyell's inspiring presence and valuable publications, many articles appeared from the pens of American geologists. Dr. Morton[7] found it necessary in 1842 to correct certain statements he had made in his synopsis in 1834 in regard to the occurrence of Cretaceous fossils, since the observations of Lyell had shown the deposits to be Eocene.

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[1] Proc. Geol. Soc. London, vol. 4, 1845, pp. 547–563; and Quart. Jour. Geol. Soc. London, vol. 1, 1845, pp., 413–429.

[2] Proc. Geol. Soc. London, vol. 4, 1845, pp. 563–576; and Quart. Jour. Geol. Soc. London, vol. 1, 1845, pp. 429–442.

[3] Quart. Jour. Geol. Soc. London, vol. 2, 1846, pp. 405–410.

[4] Ibid., vol. 4, 1847, pp. 10–17.

[5] Am. Jour. Sci., vol. 47, 1844, pp. 213, 214; 2d ser., vol. 1, 1846, pp. 313–315; 2d ser., vol. 3, pp. 34–39; 2d ser., vol. 4, 1847, pp. 186–191.

[6] Proc. Geol. Soc. London, vol. 4, 1843, pp. 127–133.

[7] Philadelphia Acad. Nat. Sci., Jour., vol. 8, 1842, pp. 216–227.

The following year Edmund Ruffin, director of the agricultural survey of South Carolina, presented to the legislature a report[1] in which the early Tertiary marls are given the name of the "Great Carolina bed." He states that "this great deposit has been by different geologists considered as belonging to different formations. Vanuxem first, and also Conrad and Morton afterward, supposed it the 'Upper Cretaceous.' Lyell, from recent inspection, includes it in the Eocene." He then adds: "The 'Great Carolina bed' of marl will serve every present purpose of designation and distinction as well as if it were definitely settled and the bed named either Upper Cretaceous or Eocene." Over thirty finely printed pages are devoted to a detailed description of the area occupied by these calcareous deposits and the siliceous beds along their northern margin. The stratigraphical position of the latter is not properly interpreted in this work. In short, the siliceous beds are described as overlying the calcareous deposits.

Several papers treating especially of Eocene fossils appeared during this and the succeeding year by Bulkley,[2] Conrad,[3] and Ravenel.[4]

In the "Supplemental Report of the Agricultural Survey of South Carolina for 1843," Prof. M. Tuomey discusses the character and geological age of the "marl in adjacent parts of North Carolina." The occurrence of the "Great Carolina bed" with its characteristic fossils is asserted from the region to the north and northeast of Wilmington. In the American Journal of Science for 1844, the same writer[5] expresses the opinion that the South Carolina formations will prove older than the Eocene of Maryland and Virginia, although he accepts Lyell's position that they are not "Upper Secondary."

In an address delivered at the meeting of the Association of American Geologists and Naturalists, held in Washington in May, 1844, Prof. H. D. Rogers presented an outline of opinions regarding American Tertiary formations,[6] in connection with a general statement of progress in American geology.

From the importance of the Zeuglodon as a charcteristic fossil of the Jackson group of the Upper Eocene, and the extended discussion which its character and geological position have hitherto occasioned, it becomes necessary to refer briefly to the extensive literature upon that subject.

Although originally described as a saurian by Dr. Harlan,[7] in 1834, under the name of Basilosaurus, its mammalian character was subse-

[1] Report of the Commencement and Progress of the Agricultural Survey of South Carolina for 1843. Columbia, 1843.

[2] Am. Jour. Sci., vol. 44, 1843, pp. 409-412.

[3] Philadelphia Acad. Nat. Sci., Proc., vol. 1, 1843, p. 310; vol. 2, 1844, pp. 173, 174.

[4] Ibid., vol. 2, 1844, pp. 96-98.

[5] Am. Jour. Sci., vol. 47, 1844, p. 117.

[6] Ibid., vol. 47, 1844, pp. 254-259.

[7] Am. Phil. Soc., Trans., new ser., vol. 4, 1834, pp. 397-403; Pennsylvania Geol. Soc., Trans., vol. 1, 1853, pp. 348-357.

quently established by Richard Owen[1] and the name Zeuglodon substituted.

Later, papers appeared by Wyman,[2] Rogers,[3] Bulkley,[4] Lister,[5] Gibbes,[6] Tuomey,[7] and others, in which the views of Owen were substantiated, and more definite information given in regard to the localities and geological horizon of the many specimens up to that time discovered.

Important contributions to the geology of the Southern States were made during the years 1846–'49. Conrad alone published eight[8] articles in which many new species of fossil shells are described, and considerable additions made to the knowledge of the stratigraphy of the Eocene in Florida and Mississippi.

In the American Journal of Science for 1846, Dr. Conrad[9] made the first attempt at correlating the "limestone" of Florida. From a study of the fossils he proposed to place it in the Upper Eocene together with "the limestone of the Savannah River in Georgia, between Savannah and Shell Bluff."

In 1848 Conrad[10] published a description of *Aturia ziczac* from the upper portion of the upper marl bed of New Jersey, and referred the marl, principally on account of the presence of this shell, to the Eocene era.

During this time Morton,[11] Bouvé,[12] Lea,[13] and Gibbes[14] described many new fossils, while Allen,[15] Couper,[16] Agassiz,[17] Tuomey,[18] Hale,[19] and Holmes[20] contributed important data relative to the stratigraphy of local areas.

Tuomey, in a "Report on the Geology of South Carolina," published in 1848, enters into a detailed description of the geology of that State, and proposes three divisions for the Eocene formation, viz: 1, Buhrstone; 2, Santee marls, and 3, Ashley and Cooper marls.

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[1] Geol. Soc. London, Proc. vol. 3, 1839, pp. 24–28; Geol. Soc., London, Trans. 1842, pp. 69–79; Ann. Sci. Nat., vol. 12 (Zool.), 1839, pp. 222–229; Mag. Nat., vol. 3, 1839, pp. 209–213.

[2] Boston Soc. Nat. Hist., Proc., vol. 2, 1845, pp. 65–68.

[3] Ibid., p. 79.

[4] Am. Jour. Sci., 2d ser., vol. 2, 1846, pp. 125–131.

[5] Boston Soc. Nat. Hist., Proc., vol. 2, 1846, pp. 95–96.

[6] Philadelphia Acad. Nat. Sci., Jour., 2d ser., vol. 1, 1847, pp. 5–15.

[7] Ibid., pp. 16–17.

[8] Am. Jour. Sci., 2d ser., vol. 1, 1846, pp. 209–221, 395–405; vol. 2, 1846, pp. 36–48, 124–125, 210–215, 399–400. Philadelphia Acad. Nat. Sci., Proc., vol. 3, 1846, pp. 19–27; vol. 3, 1847, pp. 280–299. Philadelphia Acad. Nat. Sci., Jour., 2d ser., vol. 1, 1848, pp. 111–134.

[9] Am. Jour. Sci., 2d ser., vol. 2, 1846, p. 47.

[10] Philadelphia Acad. Nat. Sci., Jour., 2d ser., vol. 1, 1848, p. 129.

[11] Ibid., Proc., vol. 3, 1846, p. 51.

[12] Boston Soc. Nat. Hist., Proc., vol. 2, 1846, p. 192.

[13] Philadelphia Acad. Nat. Sci., Proc., vol. 4, 1848, pp. 95–107.

[14] Ibid., Jour., 2d ser., vol. 1, 1848, pp. 139–147; 1849, pp. 191–206.

[15] Am. Jour. Sci., 2d ser., vol. 1, 1846, pp. 38–42.

[16] Boston Soc. Nat. Hist., Proc., vol. 2, 1846, pp. 123, 124.

[17] Ibid., p. 193.

[18] Am. Assoc. Adv. Sci., Proc., vol. 1, 1848, pp. 32–33; Report on the Geology of South Carolina, 1848, pp. 136, 139–170, 211.

[19] Am. Jour. Sci., 2d ser., vol. 6, 1848, pp. 354–363.

[20] Ibid., vol. 7, 1849, pp. 187–201.

Roemer, in 1849, published at Berne a general treatise upon Texas, in which he gives the first account of the occurrence of the Eocene in that State. Fossils were found sufficiently similar to those of Claiborne, Alabama, to justify him in considering the deposits of like age. Although discovered at only one locality, he expressed the opinion at that time that it was hardly probable that the Eocene was thus limited to one point, but doubtless existed as a continuous deposit across the State. He considered that the surface exposures were only prevented from being seen by overlying formations.

During 1850 papers appeared on the geology and paleontology of the Atlantic Coast Eocene by Ravenel,[1] Ruffin,[2] Gibbes,[3] Wyman,[4] Conrad,[5] and Holmes.[6]

A year later, Tuomey, in a "Notice of the Geology of the Florida Keys, and of the Southern Coast of Florida,"[7] confirmed the observations of Conrad concerning the age of the Tampa Bay limestone, and showed its wider extension.

In the same volume of the American Journal of Science, Prof. J. W. Bailey published a notice of "Silicified Polythalamia in Florida," in which he speaks of large masses possessing all the mineralogical characters of flint, occurring in the white "orbitolite limestone," which, he says, is common throughout the portion of Florida between Tampa and Palatka.[8]

In 1850 Desor discussed the equivalence of the American Tertiary at a meeting of the Boston Society of Natural History. He agreed with Prof. Rogers as to the want of a complete correspondence of American and Europaan Tertiary, and also with regard to the absence of a close correlation between the American Tertiary of different epochs.[9]

During the next few years contributions were made to the paleontology of the Eocene by Bouvé,[10] Tuomey,[11] Holmes,[12] and Conrad.[13]

Conrad,[14] in "Remarks on the Tertiary Strata of San Domingo and Vicksburg (Miss.)," states that a comparison of fossils from the two localities had resulted in the recognition of several identical forms, and from that circumstance he drew the conclusion that the strata were probably of the same age.

In a later publication entitled "Observations on the Eocene deposit

[1]Am. Assoc. Adv. Sci., Proc., vol. 3, 1850, pp. 159-161.
[2]Am. Jour. Sci., 2d ser., vol. 9, 1850, pp. 127-129.
[3]Philadelphia Acad. Nat. Sci., Jour., 2d ser., vol. 1, 1850, pp. 299, 300.
[4]Am. Jour. Sci., 2d ser., vol. 10, 1850, pp. 228-235.
[5]Philadelphia Acad. Nat. Sci., Jour., 2d ser., vol. 2, 1850, pp. 39-41.
[6]Am. Assoc. Adv. Sci., Proc., vol. 3, 1850, pp. 201-204.
[7]Am. Jour. Sci., 2d ser., vol. 11, 1851, pp. 390-394.
[8]Ibid., p. 86.
[9]Boston Soc. Nat. Hist., Proc., vol. 3, 1850, p. 247.
[10]Ibid., vol. 4, 1851, pp. 2-4.
[11]Philadelphia Acad. Nat. Sci., Proc., vol. 6, 1852, pp. 192-194.
[12]Elliott Soc. Nat. Hist., Proc., vol. 1, 1853, p. 21.
[13]Philadelphia Acad. Nat. Sci., Proc., vol. 6, 1853, pp. 316-319, 320, 321, 448, 449; vol. 7, 1854, pp. 29-31, vol. 7, 1855, pp. 257-263, 265-268, 269; vol. 9, 1857, p. 166.
[14]Ibid., vol. 6, 1852, pp. 198, 199.

of Jackson, Mississippi, etc."[1] the same author presents a table to "show the order of succession of Eocene groups." The Jackson group is placed between the Claiborne and the Vicksburg, and the "orbitolite limestone" of St. Stephen's Bluff is placed in the lower part of the Vicksburg series. From the fossils sent him Conrad came to the conclusion that the Jackson deposits contained no species in common with those of Vicksburg, and very few with those of Claiborne.

During this time Winchell,[2] Le Conte,[3] Emmons,[4] Rogers,[5] Safford,[6] and McCrady[7] contributed the results of observations that relate wholly or in part to the stratigraphy of the eastern Eocene.

During the decade 1850–'60, while so much valuable information relative to the Eocene was accumulated by private industry, the State governments were not inattentive to the importance of geological investigations of their territories.

The State Geological Survey of New Jersey, under William Kitchell, published three annual reports for 1854, 1855, and 1856, in which the descriptions of the marls in the eastern and southern parts of the State were prepared by the assistant geologist, Geo. H. Cook. As a result of his investigations, he states in the first report that "there are three distinct beds of marl," and that "the third bed includes the marls of Deal, Poplar, Shark River, and Squankum," localities that will receive later consideration. The second and third reports added nothing as to the taxonomic position of the upper marls, though the local stratigraphy had been worked out in greater detail. Although accepting the conclusions of Vanuxem and Morton that the marls of the State were Cretaceous, he wisely says that "it is felt to be a matter of much importance to know as many as possible of the fossils found here."

In Maryland the State agricultural chemist published six reports between 1850–'58, but they are of slight importance from a geological standpoint.

Prof. Emmons, in a report on the Geological Survey of North Carolina, published in 1852, considers the Eocene at some length. The outliers in the central part of the State are referred to in connection with the more extensive deposits that occupy the eastern portions. In a subsequent report, published in 1858, the special features of the Eocene are treated in much greater detail, and many sections and new species of fossils are described.

During 1856–'60 the State geologist of South Carolina, Oscar M. Lieber, presented four annual reports to the general assembly, but nothing of importance was added to the earlier contributions of Ruffin and Tuomey upon Eocene stratigraphy.

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[1] Philadelphia Acad. Nat. Sci., Proc., vol. 7, 1855, pp. 257–263.
[2] Am. Assoc. Adv. Sci., Proc., vol. 10, pt. 2, 1856, pp. 94–103.
[3] Am. Jour. Sci., 2d ser., vol. 23, 1857, pp. 46–60.
[4] Am. Assoc. Adv., Sci., Proc., vol. 11, part 2, 1857, pp. 76–80.
[5] Boston Soc. Nat. Hist., Proc., vol. 7, 1859, pp. 60–64.
[6] Am. Jour. Sci., 2d ser. vol. 27, 1859, pp. 363, 364.
[7] Elliott Soc. Nat. Hist., Proc., vol. 1, 1859, pp. 282, 283.

Prof. Tuomey, in the "First Biennial Report on the Geology of Alabama" (1850), considers the extent, structure, and stratigraphy of the earlier Tertiary of that State, and gives numerous typical sections and a list of fossils. A second report, finished in 1855, but on account of the death of the author not published until 1858, contains considerable new information and extended lists of fossils from well known localities.

Wailes's "Report on the Agriculture and Geology of Mississippi" appeared in 1854. The work deals largely with the economic features of the deposits, but lists and figures of characteristic fossils are given, together with the local character of the beds in which they occur.

Three years later a "Preliminary Report on the Geology and Agriculture of the State of Mississippi, by L. Harper," was published, but very little of importance was added to the stratigraphy of the Eocene.

A greatly expanded account of his geological observations in Texas is given by Prof. Roemer in "Die Kreidebildungen von Texas," published in Bonn in 1852.

The "First Report of the Geological and Agricultural Survey of Texas" was prepared by Dr. Shumard in 1859, but little attention is given in this work to the Tertiary, although reference is made to the lignite brown coal of the eastern and middle portions of the State. Nothing of importance was added to the earlier statements of Roemer.

Two reports upon the geology of Arkansas were published in 1858 and 1860 by D. D. Owen, in which several occurrences of the Eocene, with characteristic fossils, are cited. But slight attempt, however, was made at a delimitation of the Tertiary area.

Safford's first and second biennial reports on the geology of Tennessee, presented to the general assemblies of 1855 and 1857, contain a few references to "The Lignite group" which crosses the western portion of the State.

The four large quarto volumes of the Kentucky Geological Survey that was prosecuted between the years 1854 to 1859 are devoted almost exclusively to a description of the economic products of the State. The Tertiary strata are barely referred to.

Important contributions were made to the paleontology of the Eocene by Conrad,[1] Gabb,[2] Whitfield,[3] and Marsh[4] during the next decade (1860–'70).

An important paper by J. M. Safford, on the lignitic beds of the southern Tertiary, entitled "On the Cretaceous and Superior Formations of west Tennessee,"[5] appeared in the American Journal of Science

[1] Philadelphia Acad. Nat. Sci., Jour., new ser., vol. 4, 1860, pp. 275-298. Philadelphia Acad. Nat. Sci., Proc., vol. 14, 1862, pp. 284-291; ibid., vol. 16, 1864, pp. 211-214. Amer. Jour. Conch., vol. 1, 1865, pp. 1-35, 137-141, 142-149, 210-212, 213-215; vol. 2, 1866, pp. 75-78, 101-103, 104-106; vol. 3, 1867, pp. 188-190. Philadelphia Acad. Nat. Sci., Proc. vol. 17, 1865, pp. 73-75, 75, 184.

[2] Philadelphia Acad. Nat. Sci., Proc., vol. 13, 1861, pp. 367-372, Jour., new ser., vol. 5, 1862, pp. 111-179.

[3] Am. Jour. Conch., vol. 1, 1865, pp. 259-268.

[4] Am. Jour. Sci., 2d ser. vol. 48, 1869, pp. 397-400. Am. Assoc. Adv. Sci., Proc,, vol. 18, 1869, pp. 227-230.

[5] Ibid., vol. 37, 1864, pp. 360-372.

for 1864. In this article the lignite beds of the Eocene are divided into the Porters Creek group (lower) and the Orange Sand or La Grange group (upper). Overlying these is placed a third group, called the Bluff Lignite, that at that time was provisionally considered Tertiary by Safford.

In an article by Conrad "On the Eocene Lignite Formation of the United States,"[1] the upper marl of the Upper Marl Bed of New Jersey is correlated with the Brandon (Vermont) and southern lignites. The presence of such a horizon between Cretaceous and Eocene is claimed in this paper on the authority of Vanuxem and Tuomey to occur in South Carolina and Alabama, and upon that of Durand[2] and Harper in Maryland and Mississippi.

Conrad[3] proposed, in 1866, the name "Shell Bluff group" for certain strata of the Eocene he considered characterized by *Ostrea georgiana*, an oyster found at Shell Bluff, on the Savannah River, as well as "at Vicksburg * * *, in the lower part of the bluff below the Orbitolite limestone of the Jackson group."

In a communication in the succeeding volume of the American Journal of Science, Hilgard[4] takes exception to Conrad's statements and conclusions upon this point.

In this article he says that the "Orbitolite limestone of the Jackson group" is erroneous, as he knows of no case where *Orbitoides* are found below the Vicksburg strata. He further casts doubt upon the occurrence of *Ostrea georgiana* at Vicksburg. In conclusion, he says that the "Shell Bluff group" is above the Jackson and probably identical with his own "Red Bluff group."

In an article "On the Tertiary Formations of Mississippi and Alabama,"[5] the same writer says:

> I can not, therefore, with the lights before me, agree to the propriety of distinguishing as separate divisions the *Orbitoides* limestone and the Vicksburg group of fossils. * * Even the occurrence of a different species of *Orbitoides* (*O. nupera*, Con.) at Vicksburg can not alter the case, for the undoubted *O. Mantelli* occurs there also in the solid rock, and there are few of the characteristic fossils of the Vicksburg profile which I have not on some occasions found side by side with the *O. Mantelli* and its companions, the *Pecten Poulsoni* and *Ostrea vicksburgensis*.

He states further that Lyell and Hale were the only two observers who had hitherto comprehended the proper position of the "Zeuglodon bed" in relation to the "*Orbitoides* rock."

In "Notes on American Fossiliferous strata,"[6] published in 1869, Conrad presents some facts relative to the section at Shark River, New Jersey, and gives an account of the more interesting fossil remains found there.

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[1] Philadelphia Acad. Nat. Sci., Proc., vol. 17, 1865, pp. 70–73. Am. Jour. Sci., 2d ser., vol. 40, 1865, pp. 265–268.

[2] Philadelphia College of Pharmacy, Jour., vol. 5, 1834, p. 12.

[3] Am. Jour. Sci., 2d ser., vol. 41, 1866, p. 96.

[4] Ibid., vol. 42, 1866, pp. 68–70.

[5] Ibid., vol. 43, 1867, pp. 29–41.

[6] Ibid., vol. 47, 1869, pp. 358–364.

During the period 1860 to 1870 the State governments interested themselves but little in geological surveys. The war broke up those that did exist, excepting in New Jersey, and the inauguration of new ones had hardly begun at the close of the decade.

In New Jersey George H. Cook, now appointed State geologist, prosecuted the survey of that State vigorously, and presented a report of progress for 1863, which was followed by yearly reports thereafter. In the report for 1863 he states that "a section has been surveyed across the State from the mouth of Shark River Inlet, on the Atlantic shore, to the Delaware Water Gap." The areal distribution of the Eocene, together with certain of its characteristics, is described, though its taxonomic position was but partially appreciated. In the report for 1864 an analysis of the Eocene marl is given, together with the most important localities at which it is exposed. Nothing further of importance upon Eocene geology appeared until the publication of the "Geology of New Jersey," in 1868, in which the boundaries, structure, and fossil remains of the Upper Marl Bed receive careful and detailed treatment.

In Maryland a geological survey was started under Philip T. Tyson, who published reports in 1860 and 1862. The sudden termination of the survey, after the appearance of the second report, prevented the publication of a large amount of important data that would have thrown much light upon the stratigraphy of the Maryland Eocene.

Maury's "Physical Survey of Virginia," which appeared in 1869, contains several references to the stratigraphy of the Eocene.

The later reports of Emmons at the opening of this decade, and the earlier reports of Kerr, at its close, present practically nothing new on the Eocene geology of North Carolina.

In the "First Report to the Cotton Planters' Convention of Georgia on the Agricultural Resources of Georgia" (1860), the author, Joseph Jones, gives an account of "the Tertiary lime formations" of the State. Many localities are cited where fossils had been found, and the general character of the strata in Burke and Washington Counties is dwelt upon.

Of the geological work performed under State authority during this period, the investigations of Hilgard in Mississippi and Louisiana deserve special mention. In the former his "Report on the Geology and Agriculture of the State of Mississippi (1860)" has been by far the most important contribution to its geology. In this report the early Tertiary is divided into (1) Great Northern Lignite; (2) Claiborne; (*a*) siliceous, (*b*) calcareous; (3) Jackson; (4) Vicksburg. The most detailed observations are there recorded, and from a comparative study of the fossils collected a correlation of the leading horizons of the Eocene is successfully accomplished.

Two short reports on the geology of Louisiana by the same author appeared at the close of the decade. The second or final report was not published, however, until 1873. The stratigraphy of the Eocene is

not dwelt upon very fully in these reports, but the author's conclusions are valuable from his intimate knowledge of the same formations in Mississippi.

Safford's "Geology of Tennessee" (1869), contains much of importance upon the Teritary of that State. The lignite deposits are divided into (1) Porters Creek group (provisional); (2) Orange Sand or La Grange group; (3) Bluff Lignite group.

Numerous sections and lists of plant remains are given, and the general limits of the Eocene are designated.

The second of Owen's reports on the geology of Arkansas (1860), although it appeared at the beginning of this decade, has been earlier referred to.

A valuable classificatory list of Eocene fossils was published by Conrad in 1866, in the Smithsonian Miscellaneous Collections.[1]

Some most valuable contributions to the history of the life of the Eocene period, which includes the descriptions of many new species, were presented by Conrad[2], Marsh[3], Cope[4], Lesquereux[5], and Heilprin[6], during the decade 1870–'80.

In an article on the "Geological History of the Gulf of Mexico,"[7] read before the American Association for the Advancement of Science, Hilgard presents some important conclusions as to the age of the lignite deposits of the Gulf States. He says:

> So far, indeed, from considering the predominently lignitiferous area as representing a period distinct from the older marine Tertiary, I have little doubt that the larger portion, if not all, of the beds I have heretofore designated as the northern lignitic (and Flatwood clay) group (La Grange and Porter's Creek groups of Safford) are the strict equivalents in time of the oldest marine beds observed in South Carolina and Alabama, and designated by Tuomey as the Buhrstone group ("Siliceous Claiborne" of my Mississippi Report).

He adds, further, that the lignitic facies is but slightly developed in Alabama as compared with the upper portion of the Mississippi Embayment. "In Arkansas, nevertheless, small marine beds are more liberally interspersed among the lignitic clays than is the case east of the Mississippi."

Articles by Shaler[8], Hitchcock[9], Leidy[10], Vogdes[11], Heinrich[12], and Fontaine[13], contain references to early Tertiary stratigraphy that are of

[1] Smithsonian Misc. Coll., vol. 7, 1866, art. 6, pp. 1–41.

[2] Am. Jour. Sci., 3d ser., vol. 1, 1871, pp. 468, 469; Philadelphia Acad. Nat. Sci., Proc., vol. 24, 1872, pp. 50–55, 216, 217.

[3] Am. Assoc. Adv. Sci., Proc., vol. 26, 1877, pp. 211–258.

[4] Am. Phil. Soc., Proc., vol. 11, 1870, pp. 285–294; vol. 17, 1877, pp. 82–84.

[5] Ibid., Trans., new ser., vol 13, 1870, pp. 411–433.

[6] Philadelphia Acad. Nat. Sci., Proc., vol. 31, 1879, pp. 211–216, 217–225.

[7] Am. Assoc. Adv. Sci., Proc., vol. 20, 1871, pp 222–236; Am. Jour. Sci., 31 ser., vol. 2, 1871, pp. 391–404.

[8] Boston Soc. Nat. History, Proc., vol. 13, 1870, pp. 222–236.

[9] Am. Assoc. Adv. Sci., Proc., vol. 22, pt. 2, 1873, pp. 131, 132.

[10] Philadelphia Acad. Nat. Sci., Jour., new ser., vol. 8, pp. 209–262.

[11] Am. Jour. Sci., 3d ser., vol. 16, 1878, pp. 69, 70.

[12] Am. Inst. Min. Eng., Trans., vol. 6, 1878, pp. 227–274.

[13] Am. Jour. Sci., 3d ser., vol. 17, 1879, pp. 25–39, 151–157, 229–239.

value in conjunction with the more extended accounts of the same localities elsewhere published and referred to.

A work that contains much scattered information in regard to the Eocene is Macfarlane's "American Geological Railroad Guide," that first appeared in 1879. A second edition was published in 1890.

During the decade (1870–'80) a marked increase in activity in geological work was manifested on the part of the States.

In New Jersey annual reports were published by Prof. Cook, though little of importance was added to the knowledge of the Eocene.

"Virginia, a geographical and political summary," by Jed. Hotchkiss, is the title of a book that appeared in 1876. It contains a brief summary of the Tertiary geology of that State and several type sections of the Eocene. Most of the author's conclusions are identical with those in the earlier reports of Rogers.

The State geologist of North Carolina, W. C. Kerr, published several reports during this period, the most important of which is a "Report of the Geological Survey of North Carolina, vol. 1, 1875," in which the Eocene is stated as limited by the Neuse and Cape Fear Rivers on the north and south respectively, a few isolated outcrops alone excepted. An appendix to this report contains an article by Conrad on the Tertiary, with descriptions of new species of fossils.

Several works of a geological character appeared at this time bearing upon the Eocene of Georgia. Three short reports by the State geologist, George Little, were published in 1875, 1876, and 1878. The "Geology and Mineralogy of Georgia" (1871), by M. F. Stevenson, contains an outline of the main features of the Eocene, which were later restated by T. P. Janes in his "Handbook of the State of Georgia" (1876.)

The earlier publications of the present geological survey of Alabama, beginning in 1875, contain nothing upon the Eocene. In an "Outline of the Geology of Alabama," by E. A. Smith, State Geologist, in "Berney's Handbook of Alabama" (1878), the Eocene is divided into:

5. Grand Gulf 4. Vicksburg	Upper Eocene.
3. Jackson 2. Claiborne	Middle Eocene.
1. Lignitic and Buhrstone	Lower Eocene.

The characteristic features of each group are given, and in a general way its boundaries.

Three annual reports on the geology of Louisiana were published in the early part of this decade by F. V. Hopkins. Much attention is given to the Eocene, particularly to the Jackson and Vicksburg groups, and lists of fossils are appended.

Two reports of the geological and agricultural survey of Texas were presented by S. B. Buckley in 1874 and 1876. They added little of value to previously existing knowledge of the Eocene.

Prof. N. S. Shaler published four reports upon the geology of Ken-

tucky that contain meager reference to the Eocene strata of the western portion of the State.

It is hardly necessary to consider in detail the literature of the last decade (1880–'90), as the results of the investigations of that period will be incorporated in the subseqent portions of this report. In passing, however, it is necessary to refer to a discussion, precipitated by Dr. Otto Meyer, in regard to the stratigraphical position of the various members of the early Tertiary of the Gulf States. Chiefly from a study of the fossils, but likewise from investigations in the field, Meyer came to the conclusion that the order of succession of the various Tertiary formations is just the reverse of that generally accepted, viz: That the Vicksburg beds occupy the position accorded to the Claiborne, and that the order, beginning with the lowest, is (1) Vicksburg, (2) Jackson, (3) Claiborne, instead of (1) Claiborne, (2) Jackson, (3) Vicksburg, as first made out by Lyell and accepted by all subsequent investigators. Meyer's position was attacked by Hilgard, Smith, Heilprin, and others, whose long experience in the study of the southern Tertiary showed the fallacy of such conclusions. It is not necessary here to enter into the details of the discussion, or present more at length the grounds upon which Meyer based his argument. Most of the articles appeared in the American Journal of Science[1] and Science[2] in 1885–'86.

Among the contributors upon Eocene geology during this decade are Heilprin,[3] Smith,[4] Hilgard,[5] Aldrich,[6] Johnson,[7] Meyer,[8] Kerr,[9] Gardner,[10] Dall,[11] Mell,[12] White,[13] Winchell,[14] Hill,[15] Miller,[16] Uhler,[17] Campbell,[18] Langdon,[19] McGee,[20] Darton,[21] and the writer of this paper.[22]

[1] Am. Jour. Sci., 3d ser., vol. 29, 1885, pp. 457-468; vol. 30, 1885, pp. 60-72, 266-269, 270-275, 300-308, 421-435; vol. 32, 1886, pp. 20-25.

[2] Science, vol. 5, 1885, pp. 475, 476; vol. 6, 1885, pp. 44, 83, 143, 144; vol. 7, 1886, p. 11.

[3] Philadelphia Acad. Nat. Sci., Proc., vol. 32, 1880, pp. 20-33, 364-375; vol. 33, 1881, pp. 151-159, 416-422, 423-428, 444-447, 448-453; vol. 34, 1882, pp. 150-186, 189-193; vol. 36, 1884, pp. 321-322; vol. 39, 1887, pp. 314-322; Science, vol. 5, 1885, pp. 475, 476; Wagner Free Inst. Sci., Trans., vol. 1, 1887, pp 1-134; U. S. Geological Survey, Fourth Ann. Report, 1882-'83, Appendix I, pp. 309-316.

[4] Am. Jour. Sci., 3d ser., vol. 21, 1881, pp. 292-309; Science, vol. 5, 1885, pp. 376, 395-396; Am. Geol., vol. 2, 1888, pp. 269-284; U. S. Geol. Surv., Bull. No. 43, 1887.

[5] Am. Jour. Sci., 3d ser., vol. 22, 1881, pp. 58-65.

[6] Cincinnati Soc. Nat. Hist. Jour., vol. 8, 1885, pp. 145-153, 256, 257; vol. 9, 1886, pp. 104-114.

[7] Science, vol. 2, 1883, p. 777; Am. Jour. Sci., 3d ser., vol. 36, 1888, pp. 230-236.

[8] Philadelphia Acad. Nat. Sci., Proc., vol. 36, 1884, pp, 104-112; vol. 39, 1887, p. 51; Bericht über d. Senck. Naturf. Gesells. in Frankfurt, a. M., 1887, pp. 1-20.

[9] Am. Nat., vol. 19, 1885, p. 69; Elisha Mitchell Sci. Soc., Proc., vol. 2, 1884-'85, pp. 79-84, 86-90.

[10] Brit. Assoc., Rept. 54th meet., 1884, pp. 739-741; Geol. Mag., new ser., decade 3, vol. 1, 1884, pp. 492-506.

[11] Am. Jour. Sci., 3d ser., vol. 34, 1887, pp. 161-170.

[12] Am. Inst. Min. Eng., Trans., vol 8, 1880, pp. 304-313.

[13] Washington Biol. Soc., Proc., vol 3, 1885, pp. 1-20; Am. Jour. Sci., 3d ser., vol. 35, 1888, pp. 432-438.

[14] Science, vol. 3, 1884. p. 32.

[15] U. S. Geol. Surv., Bull. 45, 1887.

[16] North American Mesozoic and Cenozoic Geology and Paleontology, 1881.

[17] Maryland Acad. Sci., Trans. vol. 1, 1888-'90, pp. 10-32, 45-72, 97-104.

[18] Am. Jour. Sci., 3d ser., vol. 31, 1886, pp. 193-202.

[19] Ibid., vol. 31, 1886, pp. 202-209; Geol. Soc. America, Bull., vol. 2, 1891, pp. 587-605.

[20] Ibid., vol. 35, 1888, pp. 120-143, 328-330, 367-388, 448-466; Geol. Soc. America, Bull., vol. 2, 1891, pp. 2-6.

[21] Geol. Soc. America, Bull., vol. 2, 1891, pp. 431-450

[22] Ibid,, vol. 1, 1890, pp. 537-540; Johns Hopkins University, Circulars, vol. 7, 1887, pp. 65-57; vol. 9, 1890, pp. 69-71; vol. 10, 1891, pp. 105-108.

In 1884 Heilprin published the most important treatise[1] that has appeared upon the general features of Eocence stratigraphy. In the main the work embodies the points presented in numerous articles in the Proceedings of the Academy of Natural Sciences of Philadelphia, and referred to above. It has thus far been the only attempt at a succinct treatment of the subject of Tertiary geology, and the conclusions at which Prof. Heilprin has arrived are most valuable, and will often find place in the pages of this report.

Surveys were prosecuted in many of the States during this decade. In New Jersey Prof. Cook, the State geologist, published annual reports. Under the same auspices a memoir by Prof. Whitfield on the Brachiopoda and Lamellibranchiata, appeared, in which the Eocene species from Monmouth County are figured and described.

In the Carolinas two works of a general character that include chapters upon geology appeared in 1883; the first, entitled a "Handbook of the State of North Carolina," was published under the direction of the board of agriculture; the second, "South Carolina Resources and Population, Institutions and Industries," prepared by H. Hammond.

The municipal report of the city of Charleston for 1884 contains an article on artesian wells, in which a detailed section is given of the geological strata beneath the city, to a depth of nearly 2,000 feet.

"The Commonwealth of Georgia" (1885), by J. T. Henderson, gives the boundaries and general character of the Eocene belt.

The Florida State geological survey, under J. Kost, has published but little on the older Tertiary limestones.

In Alabama the State Geological Survey has been ably prosecuted under Prof. E. A. Smith, and the reports of the survey, together with Bulletin 43 of the U. S. Geological Survey, afford a detailed account of the most important sections of the Eocene of that State.

In Arkansas the State geological survey published in 1889 a report on the Neozoic formations by Prof. Robert T. Hill, in which the Eocene is fully considered.

The present Texas geological survey has presented in its first annual report for 1889 a preliminary statement by R. A. F. Penrose, jr., concerning the Gulf Tertiary area in which the stratigraphical relations of the Eocene are discussed.

A critical examination of the literature, a brief summary of which has been given, will convince one that although much has already been done, far more exhaustive and systematic investigations must be made before our knowledge of the Eocene formation of the Atlantic and Gulf coast region approaches in any degree to completeness.

[1] Contributions to the Tertiary Geology and Paleontology of the United States, Philadelphia, the author, 1884, 4to, 117 pp. and map.

GENERAL BOUNDARIES.

The Eocene of the Atlantic coast extends as a narrow band intermittingly appearing and disappearing across the States of New Jersey, Delaware, Maryland, and Virginia, and thence with an increase in width of surface exposure across the Carolinas and Georgia into Florida. Within the Gulf States it outcrops over a still greater area, extending from Florida across central Alabama and Mississippi, while in the latter a northward extension covers much of the northern portion of that State together with parts of eastern Tennessee and Kentucky and southern Illinois. Upon the western bank of the Mississippi the Eocene is found in southeastern Missouri, and much more widely represented over eastern and southern Arkansas and western Louisiana, while a band of considerable width extends across Texas in a southwesterly direction to the Mexican border.

Throughout the Atlantic and Gulf States the exposures of Eocene are separated from the coast line by a region of greater or less width, in which later Tertiary and post-Tertiary deposits constitute the land surface. On the other hand, the Eocene seldom comes in contact with the older rocks of the Piedmont Plateau, but is in nearly all cases separated from them by an area of Mesozoic formations. Occupying as it does a more or less central position in the coastal plain, the Eocene, after its first appearance in eastern New Jersey near the coast, maintains a distance of from 50 to 75 miles from the same through Maryland and Virginia. Beginning with a width of exposure in eastern New Jersey of less than 5 miles, it broadens in Maryland and Virginia to 20 or 25. This is very greatly increased in North Carolina, where many isolated outcrops are found scattered from Wilmington and New Berne to near Raleigh, the first scarcely 10 miles from the coast, the last considerably over 100 miles. In South Carolina the different divisions of the Eocene are found over quite as wide an area, and in the vicinity of Charleston approach within a few miles of the sea. Less is known of its boundaries in Georgia and Florida, but that it is widely extended and in the former State reaches over 150 miles from the coast is recognized. The careful study made of the Eocene in Alabama and Mississippi make it possible to speak with some accuracy as to its limits. Extending in a northwesterly direction across the southern and central portions of these States, its distance at the boundary between them is not far from 100 miles from the Gulf, while its northward extension in the latter State, to form the Mississippi embayment, reaches across Tennessee and Kentucky into Illinois, with a width of exposure north of the Gulf and east of the Mississippi River of from 50 to over 100 miles. The region of the Eocene extending from Missouri southwestward through Arkansas, Louisiana, and Texas, although a continuation of the eastern belt is yet separated from it and the Gulf by a wide area of more recent deposits that have been formed by the Missis-

sippi and other streams reaching the coast. The width of the outcrop in Louisiana and Arkansas is quite 150 miles, which again becomes contracted as eastern central Texas is reached.

In the next chapter a more detailed discussion of the geographical distribution of the deposits in the several States will be found.

STRATIGRAPHICAL AND PALEONTOLOGICAL CHARACTERISTICS.

GENERAL REMARKS.

The Eocene constitutes a well defined stratigraphical and paleontological unit in the series of late Mesozoic and Cenozoic deposits of the coastal plain. A brief sketch of the succession of events during the formation of that area will aid in acquiring a clear idea of the relationship of the Eocene to the other members of that series.

At about the opening of the Cretaceous period, or perhaps somewhat earlier, a great depression of the continent took place along the Atlantic and Gulf borders, by which the coast line was moved far inland against the buttress of Archean and Paleozoic strata. The gravels, sands, and clays of this basal formation have received different names in the different regions in which they are represented—upon the Atlantic coast the Potomac, on the eastern Gulf coast the Tuscaloosa, and on the western Gulf the Trinity formation. In the western Gulf region the Trinity formation is succeeded by the Comanche series, characterized by limestones and a fauna that denotes a deep infralittoral origin.

A marked continental elevation occurred previous to the great subsidence that opened the Upper Cretaceous epoch throughout the Atlantic and Gulf coast region. The deposits of this age, largely greensand marls on the Atlantic coast and marls and limestone on the Gulf border, are the basement beds upon which the Eocene strata have been chiefly laid, though these are also found unconformably overlying the earlier horizons in local areas.

The materials of which the Eocene deposits are formed were mainly derived from the softer beds of the Cretaceous series, although the continental area to the north and west supplied a considerable admixture of sand and clay. The deeper water deposits of late Eocene time were, however, largely the accumulations of organic remains in a sea only periodically exposed to the inroads of land-derived materials. Throughout the Gulf area and at times locally represented on the Atlantic coast are shore deposits of lignitic character and in part at least of brackish water origin, that attain great thickness in the Mississippi embayment, and in the southwest appear at different horizons to the top of the Eocene.

Unconformably overlying the Eocene with its varied development in brackish and marine deposits, is the Neocene which likewise occurs under very different facies in different portions of the coastal area. Composed largely of sands, clays, and marls that have been in part

derived from the Eocene itself, it occupies a band of varying breadth upon the shoreward side of the deposits of that horizon.

Spread widely over nearly the entire area of the coastal plain are post-Tertiary deposits of varied origin, the details of which it is unnecessary to discuss here, that bury, almost completely, the Cretaceo-Tertiary series.

Due to the slight elevation of the region above sea level and the comparatively slight inroads that have been made into the surface covering by denudation since their deposition, the outcrops of the pre-Quaternary series are confined chiefly to the channels of the rivers and their larger tributaries. The strata that have just been described as entering into the formation of the coastal plain are approximately horizontal, with a dip of a few feet to the mile toward the east on the Atlantic coast and toward the south on the Gulf border. Few disturbances of the strata have occurred throughout the territory, and only locally have the beds shown any change from the original condition of their deposition.

When search is made in the literature for data upon which to construct a typical section of Eocene strata for the Atlantic and Gulf coast region the contradictory nature of the material at hand renders the consummation of the task difficult and the results doubtful.

The Eocene is so varied in its facies in different portions of the area that it becomes often perplexing to determine to which division of the series a particular deposit belongs.

As the work has been prosecuted largely under State supervision, and as the State geologists have employed chiefly local terms in the designation of the different horizons, it is thought advisable to consider the stratigraphy of each State by itself, and subsequently to endeavor to correlate, so far as may be, the different divisions. Such treatment is but seldom warranted on stratigraphical grounds, yet the character of the literature makes it in this case the only feasible method. A consideration of the subject by provinces is much more to be desired, but this would be hazardous with our present meager knowledge of the area. A provisional establishment of provinces is, however, attempted in a later chapter.

NEW JERSEY.

The green-sand marls of New Jersey early attracted the attention of geologists, and the similarity of the fossils to those of the Cretaceous of Europe was soon recognized. That horizons other than the Cretaceous were represented in the marl series was not at first entertained, and even after the upper beds were shown to contain Eocene fossils their conformity to the Cretaceous marls was for a still longer period considered probable. Conrad,[1] in 1848, first referred the marls of the upper portion of the Upper Marl Bed near Long Branch to the Eocene,

[1] Philadelphia Acad. Nat. Sci. Jour., 2d ser., vol. 1, 1848, p. 129.

and Cook,[1] in 1883, first proved by detailed field work the unconformity of that formation to the Cretaceous. The paleontological investigations of Whitfield have further substantiated the results of Conrad and Cook.

From the standpoint of stratigraphy the Eocene of New Jersey does not form a prominent feature in the coastal deposits. The conditions for its formation were not markedly different from those in other portions of the marl series, so that structurally the dissimilarities are not conspicuous. Furthermore, the inconsiderable thickness of the deposits renders the geographical distribution limited. Although the dip has been estimated to be only 25 feet[2] to the mile, it soon carries the strata below sea level in a country so slightly elevated above tide as this portion of the coastal plain.

It is probable that the Eocene extends as an unbroken band from northeast to southwest across the State, although its surface continuity is frequently interrupted by the covering of more recent deposits. These toward the south acquire considerable thickness.

The most northern exposure is on Deal Beach, where numerous pits have been sunk into the marl near tide water. Several other localities are found in Monmouth County, particularly that of Shark River, the best known of all, and isolated exposures near Farmingdale, Squankum, and neighboring places. To the southeast of these localities an almost continuous band of the Upper Marl Beds is found extending from near New Egypt, Ocean County, across Burlington County to near Clementon in Camden County. A continuation of this belt, beginning at Deal and extending to Clementon, would reach the Delaware River not far from Salem, but to the southwest of Clementon it is buried from sight by later deposits.

The stratigraphical sequence of deposits in the Upper Marl Bed, as established by the late Prof. Cook, State geologist, is as follows:

Upper Marl Bed	Blue Marl	Eocene.
	Ash Marl..	
	Green Marl	Cretaceous.

He thus describes the Blue Marl:

The Blue Marl.—This layer lies directly upon the Ash Marl, without any well marked line of division, and it is terminated above by surface sand and loam, or by what is called rotten stone; it is 11 feet thick; it is a mixture of green sand and light-colored earth; the upper 2 or 3 feet are quite hard and stony. It lies unconformably on the layers beneath; its fossils are quite distinct and are pronounced by paleontologists to be of the Eocene division of the Tertiary age.[3]

The stratigraphical and paleontological individuality of the New Jersey Eocene thus clearly stated by Cook has been recognized by many other geologists who have investigated the strata.

The fossils, although varying in a marked degree from those of the preceding deposits of the marl series, still lack the more characteristic

[1] Geol. Surv. New Jersey, Ann. Rept., 1883, pp. 13–19.
[2] Ibid., p. 19.
[3] Geology of New Jersey, 1868, p. 275; reprinted in Geol. Surv. New Jersey, Ann. Rept., 1886, p. 182.

forms found in the Eocene to the south. Such typical species as *Ostrea compressirostra*, *Ostrea sellæformis*, *Cucullæa gigantea*, *Cardita planicosta*, and *Turritella Mortoni* are wanting. The important contributions (published and in press) to the paleontology of the New Jersey Cretaceous and Eocene by Prof. R. P. Whitfield, give the following Eocene species from the Blue Marl of the Upper Marl Bed:

Lamellibranchiata.

Ostrea glauconoides Whitfield.
linguafelis Whitfield.
Pecten Kneiskerni Conrad.
Rigbyi Whitfield.
Avicula annosa Conrad.
Nucula circe Whitfield.
Nuculana albaria Conrad (Yoldia protexta Conrad).
Nucularia secunda Whitfield.
Axinea Conradi Whitfield.
Astarte castanella Whitfield (Crassina veta Conrad).
planimarginata Whitfield.
Cardita perantiqua Conrad (Cardita subquadrata Gabb).
Brittoni Whitfield.
Crassatella alta Conrad.
obliquata Whitfield.
Protocardium curtum Conrad.
Caryatis ovalis Whitfield (Caryatis delawarensis Conrad).
Veleda equilatera Whitfield.
Corbula (Neæra) nasutoides Whitfield.
Neæra æquivalvis Whitfield.
Parapholas Kneiskerni Whitfield.
Teredo emacerata Whitfield.

Glossophora.

Leptomaria gigantea Whitfield.
pergranosa Whitfield.
perlata Conrad sp.
Architectonica annosa Conrad.
Natica globulella Whitfield.
Xenophora lapiferens Whitfield.
Scalaria tenuilirata Whitfield.
Mesalia elongata Whitfield.
Calyptophorus vetusta Conrad.
Rhinocantha [?] Conradi Whitfield.
Cypræa sabuloroides Whitfield.
Cassidaria carinata Lamarck.
Ficus penitus Conrad.
Triton eocense Whitfield.
Pseudoliva vetusta Conrad.
Fusus angularis Whitfield.
eocenicus Whitfield.
paucicostatus Whitfield.
perobesus Whitfield.
pluricostatus Whitfield.
(Neptunea) hector Whitfield.
var. multilineatus Whitfield.
staminea Conrad.
(Urosalpinx) multicostatus Whitfield.
Trematofusus venustus Whitfield.
Clavella raphanoides Conrad.
Fasciolaria hercules Whitfield.
propinqua Whitfield.
Samsoni Whitfield.
Voluta Newcombiana Whitfield.
parvula Whitfield.
perelevata Whitfield.
scaphoides Whitfield.
vesta Whitfield.
lelia Whitfield.
Caricella ponderosa Whitfield.
pyruloides Conrad.
Volutilithes cancellata Whitfield.
Sayana Conrad.
Murex (Pleuronotus?) levivaricosa Whitfield.
Cancellaria rudis Whitfield.
Pleurotoma surculiformis Whitfield.
regularicostata Whitfield.
(Surcula) altispira Whitfield.
perobesa Whitfield.
Surculites arenosa Conrad.
cadaverosa Whitfield.
curta Whitfield.
Conus subsauridens Whitfield.
Actæon prisca Conrad.
(Tornatina) lata Conrad.
Wetherelli Lea.

Cephalopoda.

Nautilus Cookana Whitfield.
Aturia Vanuxemi Conrad.

In addition to the invertebrate fossils described by Conrad and Whitfield, Marsh[1] and Cope[2] have added a few vertebrate forms.

Mammalia	Sus. sp	Monmouth Co.
Reptilia	Dinophis littoralis Cope	Shark River.
	halidanus Cope	Squankum.
	grandis Marsh	Shark River.
Pisces	Myliobatis glottoides Cope	Farmingdale.
	rectidens Cope	Harrisonville.
	biculus Marsh	Monmouth Co.
	Cœlorhynchus acus Cope	Farmingdale.
	Histiophorus parvulus Marsh	Squankum.
	Embalorynchus Kinnei Marsh	Squankum.
	Phyllodus elegans Marsh	Farmingdale.

DELAWARE.

Until the recent investigations of Darton[3] no positive evidence had been adduced of the occurrence of Eocene within the limits of the State of Delaware, although Heilprin in his "Contributions to the Tertiary Geology and Paleontology of the United States" says:

> No reasonable doubt can be entertained as to its existence there (although possibly entirely obscured by the newer Miocene deposits) as a direct continuation of, or connection between, the belts developed in Maryland and New Jersey.

Booth[4] mentions the occurrence as far north as Old Duck Creek of Tertiary fossils which, from their description, must be Neocene, while Chester's[5] investigations show that the Cretaceous is found somewhat to the south of Appoquinimink Creek.

The intervening country, at most 6 miles in breadth, has been hitherto doubtfully referred to the Eocene. Darton, by the recent discovery of several characteristic Eocene fossils, among them *Cardita planicosta*, has proved beyond doubt that surface exposures of Eocene strata occur within this area. The characteristic greenish gray and red sandstone that is typical for the more northern exposures of the Maryland Eocene has been recognized at numerous localities.

The lithological and paleontological features of the Delaware Eocene ally it so closely with the Maryland representatives of this horizon, of which it is, in fact, only the northward prolongation, that a consideration of its relations will be deferred until the Maryland strata are discussed.

MARYLAND.

The Eocene of Maryland is much more extensively developed than in New Jersey and Delaware and becomes for the first time a marked structural feature in the stratigraphy of the coastal plain. This fact, together with the great number and excellent state of preservation of

[1] Am. Jour. Sci., 2d ser., vol. 48, 1869, pp. 397-400; Am. Assoc. Adv., Sci., Proc., vol. 18, 1869, pp. 227-230.
[2] Philadelphia Acad. Nat. Sci., Proc., vol. 20, 1868, pp. 234-235; Am. Phil. Soc., Proc., vol. 11, 1870, pp. 285-294.
[3] Geol. Soc. America Bull., vol. 2, 1891, pp. 441, 442.
[4] Memoir of the Geological Survey of the State of Delaware, 1841, pp. 18, 81, 84.
[5] Proc. Acad. Nat. Sci., Philadelphia, vol. 36, 1884, pp. 249-258.

the fossils, early attracted the attention of geologists. Although the valuable contributions of Finch[1] and Say[2] in 1824 included references to the Maryland Tertiary, the first really important geological inferences, drawn from a study of the organic remains, were made by Conrad[3] in the Journal of the Academy of Natural Sciences of Philadelphia for 1830. Many articles by the same author upon the Maryland Tertiary followed in subsequent years, and to-day the contributions of Conrad remain the most exhaustive that we have upon the Eocene of the State. The more recent articles of Tyson, Uhler, Darton,[4] Heilprin and the writer of this bulletin have added many new facts, but there is much to be done before all the problems presented by the Eocene of Maryland will be fully solved.

The Eocene deposits extend as a nearly unbroken belt from the Delaware line to the Potomac River, and are found in Cecil, Kent, Queen Anne, Anne Arundel, Prince George, and Charles counties. The strike is approximately northeast and southwest; the dip 20 to 30 feet in the mile toward the southeast. The breadth of outcrop upon the eastern shore of the Chesapeake is scarcely 5 miles at the head of the Sassafras River, but gradually expands toward the southwest until upon the western shore it is in places more than 25 miles wide.

The lithological character of the rocks is remarkably persistent. The typical deposit is a green-sand marl, which may, however, by chemical changes, lose its characteristic green color, and by the deposition of a greater or less amount of hydrous iron oxide be found as an incoherent red sand or firm red or brown sandstone. To this is added at times a siliceous cement that produces a firm siliceous sandstone, from which generally most of the carbonate of lime has been removed in solution, so that the organic forms are found only in the shape of casts. The green-sand type is chiefly confined to the southwestern portion of the area in Charles and Prince George counties, where the deposits overlying the Eocene attain their greatest thickness. In Anne Arundel County and on the eastern shore of the Chesapeake the Eocene is less deeply buried and the strata are more thoroughly weathered, affording greenish gray or red sands and at times bands of firm sandstone.

No widespread division of the series into different horizons is indicated upon lithological grounds, as the variations in composition are apparently due to subsequent chemical changes rather than to original deposition. It is likewise impossible with our present imperfect knowledge of the Eocene fauna to attempt to establish definite horizons upon such a basis, as even the geological range of the best known forms has not been as yet fully determined.

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[1] Am. Jour. Sci., vol. 7, 1824, pp. 31-43.

[2] Philadelphia Acad. Nat. Sci., Jour., vol. 4, 1824, pp. 124-155.

[3] Ibid., vol. 6, 1830, pp. 205-217.

[4] Geol. Soc. America, Bull., vol. 2, 1891, pp. 440-442, 450.

Among the more common species found in the Maryland Eocene are—

Ostrea compressirostra Say.
Cucullæa gigantea Conrad.
transversa Rogers.
Pectunculus staminеus Conrad.
Crassatella alæformis Conrad.
palmula Conrad.
capricranium Rogers.
Cardita regia Conrad.
planicosta Lamarck.
Dosiniopsis Meekii Conrad.
Cytherea ovata Rogers.
Pholadomya marylandica Conrad.
Glycimeris elongata Conrad.
Pholas petrosa Conrad.
Monodonta glandula Conrad.
Turritella humerosa Conrad.
Mortoni Conrad.

Among these *Cucullæa gigantea* is chiefly confined to the basal strata, although in individual cases, as reported by Uhler and Darton, it has been found in the upper portions of the series. *Turritella Mortoni*, on the other hand, is infrequent in the lowest beds, and in the sections on the Potomac and its tributaries is found above those layers in which the *Cucullæa gigantea* is most numerous.

Hitherto few Eocene fossils have been obtained from the deposits of the eastern shore of the Chesapeake. At the head of the creeks tributary to the Chester River and on the hills to the north of the latter several characteristic forms are reported by Uhler.[1] Among them *Turritella Mortoni*, *Cardita planicosta*, *Cucullæa transversa*, *Pectunculus staminеus*, and *Ostrea compressirostra* have been identified.

On the western shore of the Chesapeake there are numerous localities where typical Eocene fossils are found in great numbers. At South River, in Anne Arundel County, and Upper Marlboro, Fort Washington, and Piscataway Creek, in Prince George County, the sections with their fossils have been studied with some care.

The section[2] afforded by the Fort Washington bluff, so frequently referred to in geological literature, is presented below.

Section at Fort Washington.

Pleistocene	Coarse gravel	8 feet.
Eocene	Red sand with casts of *Turritella Mortoni, Dosiniopsis Meekii, Cytherea ovata, Crassatella* sp., *Ostrea* sp	12 feet.
Cretaceous	Light, variegated sands, slightly glauconitic.....10 feet. Dark, micaceous sand, with *Cyprimeria densata, Crassatella vadosa, Cucullæa vulgaris*, etc .....10 feet.	20 feet.
Potomac	Variegated clay, slightly lignitic on upper surface, with layers of ironstone	55 feet.

The Eocene deposits of Maryland must be considered to represent a single horizon until a more detailed examination of the range of the different fossil forms afford us evidence for a division upon that basis.

[1] Maryland Acad. Sci. Trans., vol. 1, 1868, p. 29.
[2] Johns Hopkins University Circulars, vol. 9, 1890, p. 70.

VIRGINIA.

There is no State upon the Atlantic seaboard in which the Eocene has received such careful examination as in Virginia, and certainly none where the literature exists in such a compact and accessible form. For this geology is in the main indebted to Prof. William B. Rogers, who from 1835 to 1841 held the position of State geologist of Virginia and who published during that time annual reports, in each of which defined areas were taken up for detailed investigation.

The first mention by Prof. Rogers of the occurrence of Eocene deposits in Virginia was made in the Transactions of the American Philosophical Society for 1835[1] where, to use the author's words, "the existence of an extensive Eocene formation in eastern Virginia is now for the first time announced."

In my study of the Eocene of Virginia I have had occasion to refer constantly to Prof. Rogers's writings, and from personal examination of the localities described have been impressed with the accuracy of that investigator's observations.

More recently Mr. N. H. Darton,[2] of the U. S. Geological Survey, has examined the Tertiary area of Virginia, and has more accurately delimited the extent of the Eocene in the various river basins.

The deposits of the early Tertiary of Virginia form an intimate continuation southward of the Maryland belt, and extend from the Potomac River, where the width of outcrop is about 25 miles, to the James and its southern tributary the Appomattox, where the limits have been much narrowed. Throughout much of this region the thick covering of post-Eocene sediments renders an exact delimitation of the boundaries of the Eocene formation altogether impossible. Presumably this belt continues on to the southern border of the State, but so far as we have any evidence it is buried, throughout most if not all of that distance, by more recent deposits. McGee[3] reports a single occurrence on the Nottoway River below Bollings Bridge where the Potomac formation "is unconformably overlain by 3 or 4 feet of stratified greenish-blue clay containing Eocene fossils."

The strike of the strata is approximately north and south; the dip at a very low angle toward the east. If we take the data furnished by the well-boring at Fortress Monroe, not 50 miles to the east of the supposed seaward boundary of the Eocene, we find the sands that have been referred to that formation at a depth of something less than 600 feet. This at the outside would admit of a dip of 10 to 15 feet to the mile.

On account of the surface covering of post-Tertiary deposits, the sections are chiefly found along the water courses or on the steeper

[1] Am. Phil. Soc., Trans., new ser., vol. 5, 1835, pp. 319–341.
[2] Geol. Soc. America, Bull., vol 2, 1891, pp. 439–443.
[3] Am. Jour. Sci., 3d ser., vol. 35, 1888, p. 126.

slopes of the higher ridges. The slight elevation of the coastal plain above tide level, together with the incoherent nature of the materials, renders the occurrence of high cliffs even along the larger rivers exceptional and consequently the superposition of any considerable thickness of strata in a single section out of the question. It thus becomes a matter of some difficulty to measure accurately the entire thickness of the Eocene deposits, but it is doubtful if they are found to exceed 150 feet. In fact no single section thus far described shows a thickness of even 100 feet.

The deposits are in the main identical with those hitherto described as typical for Maryland. The green-sand marl predominates, though beds of a micaceous or aluminous character are not infrequent in the southern portion of the area.

Along the northern portion of the belt, the Eocene marl rests unconformably upon the Fredericksburg sandstone, the local representative of the Potomac formation. Farther south, however, the Eocene overlaps the Archean and so continues until it is itself buried by more recent deposits. To the east it is followed in direct succession by the Neocene, while over the whole, when not completely eroded, an uneven covering of post-Tertiary deposits is found.

The most northern and one of the most typical of the river sections of the Virginia Eocene is found upon the south bank of the Potomac River, extending from the mouth of Acquia Creek to the vicinity of Mathias Point.

At Acquia Creek the following section of the Eocene overlain by Pleistocene has been observed by the writer.[1]

Section at Acquia Creek.

Pleistocene	Red sandy loam		20 feet.
Eocene	Light-colored sand, slightly glauconitic	20 feet.	65 feet.
	Light green-sand, with *Cardita planicosta, Turritella Mortoni, Cucullæa onochela, Crasatella capricranium, Cytherea ovata*, etc	9 feet.	
	Soft, yellowish green-sand, with *Ostrea compressirostra*	15 feet.	
	Ledge of dark green-sand, with *Turritella Mortoni, Cardita planicosta, Panopæa elongata, Fusus sp.* etc	3 feet.	
	Dark green-sand, with *Cytherea ovata, Crassatella capricranium*, etc	18 feet.	

In the basin of the Rappahannock the Eocene is reported by Darton as extending from the vicinity of Fredericksburg to a point below Port Royal. He says that it consists at the higher elevations landward of buff-colored weathered green-sand that to the east becomes a typical green-sand with abundant and characteristic fossils. Rogers and Darton both refer to the exposures of Eocene in the valleys of the Matapony and Pamunky that afford a marked admixture of argillaceous materials

[1] John Hopkins University Circulars, vol. 9, 1890, p. 70.

and at times show bands of limestone. The Eocene is not reported from the basin of the Chickahominy. On the James River, however, the bluffs, particularly in the vicinity of City Point, afford excellent exposures of Eocene green-sand with numerous characteristic fossils.

In its paleontological characteristics the Eocene of Virginia is closely allied to that of Maryland. The common forms *Turritella Mortoni* and *Cardita planicosta* are widely distributed, while the prevalent oyster of Maryland, the *Ostrea compressirostra*, has given place for the most part to *Ostrea sellæformis*, so important as a typical Eocene fossil in the States farther south.

Among the species recognized from the Virginia strata are the following:

Ostrea sellæformis Conrad.
sinuosa Rogers.
Anomia Ruffini Conrad.
Cucullæa transversa Rogers.
onochela Rogers.
Nucula cultelliformis Rogers.
parva Rogers.
Nuculana improcera Conrad.
Cardita planicosta Lamarck.
ascia Rogers.
Crassatella capricranium Rogers.
Protocardia virginiana Conrad.
Cytherea ovata Rogers.
lenticularis Rogers.
eversa Conrad.
lenis Conrad.
liciata Conrad.
perbrevis Conrad.
Dosiniopsis alta Conrad.
Turritella Mortoni Conrad.

Even less is known of the range of these forms in Virginia than in Maryland, and they afford no basis for a division of the strata into separate horizons. The Eocene of Virginia must be considered, for the present at least, as a single lithological and paleontological unit.

NORTH CAROLINA.

The Eocene of North Carolina is very different from that in Maryland and Virginia. Neither in the stratigraphical nor paleontological characteristics of its members does it afford many points for comparison with the Eocene of the more northern areas. Furthermore, the isolated manner of its occurrence makes a determination of its boundaries extremely difficult, and thus, hitherto, where fossils have not been found its separation from other horizons has been rendered uncertain. From the State reports of Emmons and Kerr and the paleontological writings of Conrad our knowledge of the structure and fossils of the Eocene is mainly derived.

Geographically considered, the Eocene is confined in its northern and southern extension between the Neuse and Cape Fear Rivers, and is found scattered between those limits from near the mouths of the larger streams to over a hundred miles inland. As in Virginia the sections are chiefly exhibited along the river channels, which alone cut through the surface covering of more recent deposits. Thus the cliffs along the banks of the Neuse, New, and Cape Fear Rivers and their larger tributaries afford the best exposures. The Neuse, between New Berne and

Goldsboro and its large southern tributary, the Trent, for the last 30 or 40 miles of their courses, frequently cut through Eocene strata. The headwaters of the New, in Onslow County, and its southwest branch penetrate similar deposits. The lower course of the Cape Fear in Bladen and New Hanover Counties and the Northeast Cape Fear, in the latter county, afford extensive sections. Some distance to the west of the Coastal region several isolated areas of the Eocene occur, that in each case reach an altitude of over 300 feet above sea level. The most northern of these areas is situated a short distance east of Raleigh, while two others occur to the northwest of Fayetteville in Harnett and Moore Counties. If, as seems probable, these isolated outcrops are but the remnants of a once continuous belt of Eocene strata, then the inland extension of the Eocene must have been more than 100 miles from the present coast line.

The relations of the Eocene to the Cretaceous on the one hand and the Neocene on the other are especially well exhibited in the basin of the Cape Fear River, where the Eocene has been shown by the writer[1] to occupy hollows within the Cretaceous, which afforded an unevenly eroded surface upon which the sediments of the Eocene period were accumulated. The erosion that followed the elevation of the Eocene deposits approximately base-leveled the region before the submergence in Neocene time.

Kerr became convinced latterly of a much wider extension of the Eocene than had been previously admitted by him or other writers upon the geology of the State. In an article in the American Naturalist for 1885 upon "The Eocene of North Carolina,"[2] he states:

> I have recently ascertained by the discovery of the unmistakable superposition of the small outliers of Eocene fossiliferous rocks (noted in the text and geological map of the State in the report of 1875) and of other similarly situated patches of the same beds, with Upper Eocene shells capping the highest hills of the so-called Drift or Quaternary, that nearly all of these beds of sand and gravels heretofore referred to the latter horizons are of Eocene age. The area of Tertiaries in this State must now be extended over a wide stretch of country from the tops of the Laurentian hills near Raleigh and the higher elevations of the Huronian slates to from 50 to 75 miles southeast along the course of the Deep River and so onward to the South Carolina border, reaching at one point an elevation of 600 feet above tide. This leaves the Quaternary, like the Miocene, to be represented by a thin and broken covering of superficial deposits of only a few feet to a few yards in thickness and reaching from the coast only about 100 miles inland, and an elevation of but little above 100 feet.

Although from the data at hand it seems probable that the views of Professor Kerr, as to the wide distribution of the Eocene, are too extreme, yet the supposition that the post-Eocene depressions were not sufficient to bring the higher and more inland portions of the Eocene deposits below sea level, is fully substantiated by the facts. Our knowledge of the stratigraphy is far too meager to admit of the incorporation in the Eocene of many of the unfossiliferous beds that such a

[1] Geol. Soc. America, Bull., vol. 1, 1890, p. 538.
[2] Am. Naturalist, vol. 19, 1885, p. 69.

conclusion would require. Much that Kerr has included in the Eocene is referred by McGee and Holmes to the Appomattox formation.

In the character of its deposits the Eocene is in a marked degree calcareous, occurring as a finely comminuted, light-colored marl, shell conglomerate, calcareous sandstone or hard, gray limestone. The isolated outcrops situated far inland are more siliceous than the deposits in the extreme eastern portions of the State, which afford still further evidence of their closer proximity to the shore of the Eocene sea. The calcareous nature of the eastern deposits indicates a comparatively clear and open sea and a sufficient distance from the Eocene shore to prohibit the intermingling of large quantities of land-derived sediments with the calcareous accumulations of marine organisms out of which the strata are largely formed.

The paleontological characteristics of the North Carolina Eocene are very imperfectly comprehended. No collections of importance are now in existence, and the lists of fossils hitherto reported can not at the present time be substantiated. Moreover, there is particular danger in the use of such data so far as the North Carolina deposits are concerned from the fact that a commingling of Cretaceous and Eocene fossils is known to occur. Futhermore, that intermixture has been shown to be due to mechanical agencies rather than contemporaneous existence. The best evidence of this may be seen in the limestone beds in the vicinity of Wilmington, where this remarkable occurrence has been observed and recorded by several investigators.[1]

A few typical Eocene fossils have been recognized by myself from the North Carolina Eocene deposits, including *Ostrea sellæformis* and *Cardita planicosta*. From the fact that the fossils are chiefly preserved in the form of casts, their determination is frequently in doubt, and extensive collections will have to be made before a comparative study of the forms will afford satisfactory results.

SOUTH CAROLINA.

In many of its structural peculiarities the Eocene of South Carolina shows a close relationship to the early Tertiary deposits of North Carolina that have just been described. In its geographical distribution it covers a much more extensive area than in the States hitherto referred to, and becomes one of the most important features in the geology of the Coastal plain.

The reports of Ruffin, Tuomey, and Lieber present us with detailed descriptions of the stratigraphy of the Eocene, while Ravenel, Conrad, Bouvé, and others have figured and described the organic remains from the same horizon. Although a review of the conclusions arrived at by these different authors affords but few points for comparisons with

[1] Tuomey, Am. Assoc. Adv. Sci., Proc., vol. 1, 1848, p. 33; Tuomey, Philadelphia Acad. Nat. Sci., Proc., vol. 6, 1852, 193; Conrad, Philadelphia Acad. Nat. Sci., Proc., vol. 17, 1865, p. 72; Clark, Geol. Soc. America, Bull., vol. 1, 1890, pp. 537-540.

other areas, careful descriptions of local deposits render the literature of South Carolina geology among the best of official publications. Numerous sections within the Tertiary belt are discussed in minute detail, but the attempt at a geological establishment of boundaries has given vague and unsatisfactory results.

The inland border of the Eocene forms a more or less continuous line "from the mouth of Stevens Creek, on the Savannah, north of Hamburg, crossing the Saluda and Broad Rivers near their junction; the Wateree at the canal; Lynch Creek at Evans Ferry, and Thompson Creek at the point where it enters the State in Chesterfield district."[1] Its seaward extension is buried under more recent deposits, of different character, or the disturbed upper layers of the Eocene itself, a condition of outcrop that occasions an extremely sinuous boundary, and one at the same time very difficult of determination. In the vicinity of Charleston the strata approach nearly to the coast line, though complicated in the aforesaid manner. As the river sections afford almost the only indications of the pre-Quaternary geology the field of observation is much narrowed, and the tracing out of intermediate deposits, binding what may be only different facies of contemporaneous development, is greatly hindered.

Tuomey, in the "Report on the Geology of South Carolina," published in 1848, divides the Eocene of the State into three horizons, which in ascending order are: 1, Buhrstone; 2, Santee Beds; 3, Ashley and Cooper Beds. Ruffin had previously (1843) designated the last two of Tuomey's[2] divisions as the "Great Carolinian Bed," and had likewise described the Buhrstone and its fossils, although he did not consider the latter apparently of much taxonomic importance, and, moreover, entirely mistook its stratigraphical position. Following in great measure the authority of Lyell, Ruffin accepted tentatively the Eocene age of the "Great Carolinian Bed," thus going counter to the opinions of Vanuxem, Conrad, and Morton, who had pronounced it "Upper Secondary." In a later statement he says, "the 'Great Carolinian Bed' of marl will serve every present purpose of designation and distinction as if it were definitely settled and the bed named either 'Upper Cretaceous' or Eocene."[3] The important contributions made by Ruffin to the geology of the State were greatly augmented by the more extensive observations of Tuomey. For our present purpose the three divisions established by the latter will be accepted, although some suggestions as to their taxonomic value will be stated in subsequent pages.

The Buhrstone.—The Buhrstone, the basal member of the Eocene series, as recognized by Tuomey, occupies the inner border of the Tertiary belt.

[1] Tuomey: Report on the Geology of South Carolina, 1848, p. 140.

[2] The Santee Beds and Ashley and Cooper Beds are also referred to by Tuomey at the "Calcareous Strata of the Charleston Basin."

[3] Ruffin: Report of the Commencement and Progress of the Agricultural Survey of South Carolina, 1843.

It is chiefly developed in the area lying between the Congaree and Savannah Rivers. Its eastern boundary begins at or near Lower Three Runs, on the Savannah River, passes in a sinuous line near Barnwell and Orangeburg, and thence to the Santee River, beyond which its limits are unknown.

The Buhrstone receives its name from the layer of silicified shells that forms but an insignificant portion of the strata. Sands, clays, and marls are the chief deposits. They are generally incoherent, though at times consolidated. In the area to the east of the Savannah River beds of kaolin (reaching at Aiken 60 feet in thickness) form an important element in the series.

Tuomey[1] gives a section of the beds in the vicinity of Aiken that is held to be typical for the Buhrstone elsewhere. The strata rest upon granite, and are in descending order, as follows:

6. Beds of sand and iron ore.
5. Silicified shells.
4. Siliceous clay bed.
3. Beds of sand, gravel, colored clay, etc.
2. Bed of sandstone and grit.
1. Granite on Horse Creek.

Tuomey mentions the occurrence of individual members of the series at many other places throughout the area above outlined, although the different beds exhibit more or less important variations in thickness and lithological characters. The stratum of silicified shells is found often at the top of the Buhrstone and in close proximity to the marl of the "calcareous strata." The lower deposits of the Buhrstone are composed largely of coarse sands that may upon further study afford evidence for a stratigraphical separation from the overlying beds. A statement as to their probable equivalence is given in the chapter on correlation.

The northward extension of the Buhrstone toward the North Carolina State line has received but little attention. Tuomey cites localities on the Pee Dee River and Lynch Creek where beds of silicified shells are found, and mentions the occurrence of *Cardita planicosta* and other fossils. The thickness of the Buhrstone has been estimated at 200 feet in its typical localities. Tuomey gives a list of over ninety species of fossils from the Buhrstone in the Report on the Geology of South Carolina, which, with a few exceptions, belong to marine mollusca. Among other well known forms the writer has recognized *Turritella humerosa*, *T. Mortoni*, *Cardita planicosta*, and *Pectunculus stamineus*.

The Santee Beds, which overlie the Buhrstone, form, according to Tuomey, the lowest member of the "Calcareous Strata of the Charleston Basin." They occupy the region between the boundaries given above as the seaward limits of the Buhrstone and an undetermined line farther eastward. The deposits are most typically developed on the

[1] Report on Geology of South Carolina, 1848, p. 143.

Santee River, where they reach as far down the stream as Mazyck's Ferry. The base of the Santee beds is at times a green sand, though this is not constant. Tuomey mentions a locality on the headwaters of the Cooper River where a bed of "white marl abounding in corals, which may be designated the coralline bed of the Charleston basin" underlies the green sand. That the green sand is allied with the Santee Beds rather than with the Buhrstone is shown by the occurrence of the bones of the Zeuglodon that have not been found in the latter formation. The typical deposits of the Santee Beds are white marls, more often incoherent, though frequently consolidated to form a marlstone. At Vance's Ferry, on the Santee, a superb section of the Santee Beds 6 miles in extent is exposed that in places reaches 30 feet in height.

Tuomey gives a list of 60 to 70 species of fossils, chiefly lamellibranchs, gasteropods, echinoderms, and corals. The bones of Zeuglodon likewise occur. *Ostrea sellæformis*, *Crassatella alta*, *Lucina panda*, and *Lutraria petrosa* are common types.

The Ashley and Cooper Beds, which are held by Toumey to occupy a position above the Santee Beds and to constitute a separate formation, have many species of fossils in common with the Santee, including the Zeuglodon, which ranges throughout the Santee and Ashley and Cooper Beds. More than that, the deposits are similar lithologically, and no break has been recognized in the series of beds, which shows that the conditions under which they were formed were probably the same and continuous. In this connection Heilprin says: "There appears to me no good reason for separating the above deposits from each other as indications of special horizons, although they may occupy different stratigraphical positions in the geological scale, and therefore I have retained them as one group, the correspondent of the 'Jacksonian.'"[1]

The geographical range of the Ashley and Cooper Beds is limited to the basins of the Ashley and Cooper Rivers, and even there the surface outcrops are much complicated by the post-Pliocene rearrangements to which the upper layers have been subjected. As the fossils of the earlier beds have been transported and occur commingled with those of later date, accurate discrimination between the original and derived deposits is rendered difficult. In general the Ashley and Cooper Beds are darker than the Santee Beds. They are sometimes dark gray, and at other times approach an olive color.

Tuomey mentions 25 invertebrate fossil forms from this horizon. The Zeuglodon is likewise found and is the most characteristic of the Eocene types. Among the molluscan forms *Panopæa elongata*, *Lucina panda*, and *Modiola cretacea* are common species.

Upon the Carolina bank of the Savannah River are deposits of white marl containing fossils whose stratigraphical position in reference to the deposits just described has not as yet been satisfactorily determined.

[1] Contributions to the Tertiary Geology and Paleontology of the United States, 1884, p. 20.

By many they have been considered to be later than the uppermost strata of the Charleston Basin, though the data for such conclusions seem to the writer inadequate. As these beds are much better developed on the Georgia bank of the Savannah River, a discussion of them will be deferred until the geology of that State is considered.

GEORGIA.

The Eocene deposits of Georgia are less fully comprehended than those of any other State on the Atlantic Coast. No works of great importance have been published, due largely to the fact that Georgia has not hitherto maintained a geological survey of the pretensions of the States immediately to the north. The publications of Cotting, Hodgson, Jones, Stephenson, Little, and Henderson, all of a more or less official character, present a meager outline of the Eocene geology of local areas or the entire State, though generally the information given is rather of agricultural than stratigraphical importance.

Stephenson[1] and Little[2] give the inland boundary of the Eocene as a sinuous line extending from near Augusta, on the Savannah River, past Macon and Milledgeville to Pataula Creek, just above Fort Gaines, on the Chattahoochee River. Too little is known of its seaward extension to warrant a statement of its boundaries, although should any portion of the deposits in Screven County, hitherto referred to the Eocene, be proved such, the width of the belt would reach fully 50 miles. On the Ocmulgee River its most eastern outcrop has been found by Burns near the boundary of Dodge and Telfair Counties.

A separation of the Eocene into definite horizons has not been attempted in Georgia as in South Carolina and Alabama, although it is probable that the leading divisions there represented extend across the State, as beds of sand and clay here form the base of the series and are followed by calcareous strata. Situated as the Eocene deposits of Georgia are, intermediate between the Atlantic and Gulf areas, an accurate knowledge of their relations would render it possible to determine many points in the stratigraphy of each that are at present very imperfectly understood.

The locality of Shell Bluff, on the Savannah River, about 20 miles below Augusta, has been so often referred to in geological literature as to merit more special attention than the other Eocene areas of the State. Conrad[3] was led to the conclusion that on both structural and paleontological grounds the deposits at Shell Bluff possessed sufficient individuality to warrant the establishment of a new and distinct "group" which he called the Shell Bluff group. The common oyster, *Ostrea georgiana*, was considered by him to be the characteristic fossil for the

[1] Geology and Mineralogy of Georgia, 1871, p. 28.
[2] Catalogue of Ores, Rocks, etc., for the Paris Exposition, 1878, p. 14.
[3] Am. Jour. Sci., 2d ser., vol. 41, 1866, p. 96.

horizon. The deposits are similar to those represented on the Carolina bank of the Savannah River, and previously referred to. The position of the strata in the Eocene series can not be determined until more is known of the fossils and the stratigraphical relations of the beds. A section made by myself at the locality is given below:

	Feet.
Red loam	40
White sandy marl	4
Coarse white marl with shell fragments	2
Fine white marl with *Ostrea* sp	2
Shell marl with numerous casts	4
Coarse yellowish white shell marl	5
Compact fine white marl	2
White sandy marl with *Ostrea georgiana*	10
Ledge of hard white marl	1
Fine yellowish white, sandy marl	8
Compact marl filled with casts of shells, *Ostrea* sp	5
Yellow shell marl alternating with beds of clay	6
Indurated yellow and white variegated shell marl	6
Yellowish white, coarse shell marl with numerous fragments of shells	14

The detailed sections of other observers[1] differ considerably from that just given, both as to the divisions of the beds and the fossil-bearing horizons.

The deposits at Jacksonboro in Screven County, hitherto referred to the Eocene, although presenting similar characteristics lithologically, afford, so far as the collections made by myself are concerned, no forms in common with other Eocene localities. Lyell gives a long list of such similar types, but I have failed to obtain them. The specimens collected seem to point to a decidedly younger fauna, probably Neocene in age.

Dr. Jones, in a report on the agricultural resources of the State, refers to the shell marl of Washington and Jefferson Counties, although presenting few data of stratigraphical importance. Of the more western counties even less information is at hand.

The section of Eocene strata afforded by the Chattahoochee River has been quite recently investigated by Langdon,[2] who, however, has studied the deposits in their relations to the Alabama series and mainly on the Alabama bank of the river, so that a detailed consideration of them will be deferred until the strata of that State are discussed. Representatives of the Lignitic, Buhrstone, Claiborne, and White limestone have been established and the thickness of the series placed at 1,200 feet.

FLORIDA.

The presence of Eocene strata in Florida was early recognized by Conrad[3] and Tuomey[4], though later doubt was cast upon their conclu-

[1] Loughbridge—Report on the Cotton Production of the State of Georgia, Tenth Census of the U. S. vol. 5, 1884, pp. 14–16.

Singleton—see Heilprin, Contrib. Tert. Geol. and Pal. U. S., 1884, p. 22, foot-note.

[2] Geol. Soc. America, Bull., vol. 2, 1891, pp. 594-605.

[3] Am. Jour. Sci., 2d ser., vol. 2, 1846, pp. 36–48, pp. 399, 400.

[4] Ibid., vol. 11, 1851, pp. 390–394.

sions by Agassiz[1] and Le Conte,[2] who endeavored to prove that the peninsula was of coral formation and more recent in origin. The later investigations of Smith, Dall, Heilprin, and Johnson have shown the truth of the earlier observations, and have more fully identified the various horizons represented.

That Eocene covers a wide area in Florida is now generally conceded, though the various writers differ as to the limits that are to be assigned to it. Direct reference to the publications will best explain these differences. Smith says:

From specimens collected by me at points widely distant from each other, from the observations of others as quoted above, and from evidence derived from other sources, I am brought to the conclusion that almost the whole of Florida, from the Perdido River on the west, eastward and southward, including the middle and western parts of the peninsula, certainly as far south as the latitude of Tampa Bay, and probably as far as the latitude of Charlotte Harbor, has for its underlying formation the white or Orbitoides limestone of Vicksburg age, the exceptions as yet known being the post-Pliocene or recent limestones forming the Keys and the immediate coasts along the western, southern, and eastern shores, and isolated patches, if not a continuous belt, of Miocene limestone between the St. Johns River and the elevated tablelands westward.

Heilprin,[3] in his "Contributions to the Tertiary Geology and Paleontology of the United States," remarks upon the geographical boundaries:

From what has preceded, taken in connection with the observations that have been made in western as well as in northern Florida, it may safely be conceded that the underlying rock of the greater portion, if not of nearly the entire State, is of Oligocene age, and therefore no countenance is given to the theory which assumes a recent formation. How far south the Orbitoitic limestone extends has not yet been determined, but there appear to be no reasons for assigning it to a limit far removed from the border line of the Everglades. For aught we know to the contrary, it may extend quite or nearly to the peninsula's extremity.

Dall,[4] discussing the same point, says:

The older rocks of course come out to the northward and along the central part of the peninsula, and the succession of the newer ones is toward the southern extreme end, and the Atlantic and Gulf shores. The hypothetical southward extension of the Oligocene (sometimes taken as Eocene) on most recent geological maps, now seems erroneous. It is without doubt represented as considerably too great.

Johnson[5] states in regard to its limits that—

The most southern actually seen are at Pemberton, Pasco County, and on the headwaters of Hillsboro River, in Polk County, Secs. 27 and 28, T. 26, R. 23—which, till further advised, may be set as the southern boundary of Eocene exposure.

From the above statement of views it will be perceived that the Eocene covers a wide area in the State, even though somewhat restricted in

[1] Report U. S. Coast Survey, 1851, pp. 145 et seq.
[2] Am. Jour. Sci., 2d ser., vol. 23, 1857, pp. 48-60.
[3] Pages 23, 24.
[4] Am. Jour. Sci., 3d ser., vol. 34, 1887, p. 165.
[5] Ibid., vol. 36, 1888, p. 233.

range, as suggested by Dall and Johnson. The deposits are in the main calcareous, and possess many points in common with the "calcareous strata of the Charleston basin," though paleontologically more closely allied to the limestone of Alabama and Mississippi, described later on.

The Eocene strata in the northern portions of the State apparently afford two horizons, the significance of which has not been as yet fully determined. The lower horizon, composed chiefly of limestones and marls, and the one most generally represented, contains great numbers of *Orbitoides Mantelli* and *Pecten perplanus*. Overlying this is a thin layer, generally silicified, that contains *Orbitoides ephippium*, *O. dispansa*, and *Operculina complanata*.

Johnson states that "it is a mistake, however, to suppose that this Nummulitic formation everywhere hides the Vicksburg rocks of the *Orbitoides Mantelli*, or ever did overlie the whole of it. Numerous are the exposures to prove the contrary." A typical locality in which to see the superposition of the beds is at Levyville, Levy County, where the upper horizon is "really a stratum overlying the Vicksburg rocks," and "is a beautiful, soft, porous building stone about 20 feet in thickness." "Often struck in artesian borings and easily identified by the peculiar nummulites, it has a greater thickness under the Neocene formations to the east. In these western regions it has probably suffered general removal by erosion. Apparently conformable in deposition with the Vicksburg stage, the Levyville formation is evidently not identical with it, and demands a further investigation." Later observations tend to show that Johnson has confounded the Eocene and Miocene siliceous rocks at many points, so that his conclusions are somewhat vitiated.

ALABAMA.

No other portion of the coastal area has received such careful and detailed investigation as that contiguous to the Tombigbee and Alabama Rivers. The publications of Hale, Conrad, Tuomey, Lyell, Hilgard, Winchell, Smith, Johnson, Langdon, Heilprin, Aldrich, and others afford an extensive literature that gives us the results of investigations extending over a long term of years. The State geological survey, under the directorship of Prof. E. A. Smith, has been the chief factor in this work, and its members have compiled the only complete section of the early Tertiary strata that has thus far been made.

The deposits of Eocene age extend across the State from the Chattahoochee River to the Mississippi border in a slightly sinuous southeast and northwest direction, and with an average width of about 60 miles. The thickness of the entire series has been estimated by Smith to be not far from 1,700 feet and the dip seaward approximately 30 feet to the mile, although marked variations occur at several points. The

divisions established by Smith and Johnson[1] are adopted here, and are in descending scale as follows:

			Feet.
Eocene.	White limestone	Coral limestone (Vicksburg?)	150
		Vicksburg (orbitoidal)	140
		Jackson	60
	Claiborne		140–145
	Buhrstone		300
	Lignitic	Hatchetigbee	175
		Woods Bluff	80–85
		Bells Landing	140
		Nanafalia	200
		Matthews Landing and Naheola	130–150
		Black Bluff	100
		Midway	25

Lignitic.—The lowest member of the Eocene series has been designated the Lignitic by Hilgard. It has a thickness of about 900 feet, and according to Smith and Johnson—

Is made up of laminated clays and laminated and cross-bedded sands of a prevailing gray color, except immediately below the Buhrstone, where for 200 feet or more they are of dark brown, often purplish colors. With the above-mentioned laminated clays and sand are interstratified several beds of lignite and several beds holding marine fossils, and usually characterized by the presence of glauconite or greensand. * * * The Lignitic formation comprises three well marked divisions defined by color, which is here an index of constitution. The upper one-fourth consists of irregularly bedded, dark, siliceous, and lignitiferous clays and heterogeneous sands, approaching the basal portion of the Buhrstone formation in composition and structure, interstratified with discontinuous beds of lignite and continuous layers of clay and sand containing marine fossils. The medial three-fifths of the formation is made up of rather more regularly stratified clays and sands of light color, frequently cross bedded, containing occasional beds of lignite and of marine sands yielding littoral fossils, one of which (the *Gryphœa thirsœ* bed) is 50 to 60 feet in thickness. The basal deposits are irregularly bedded, dark, or even black, calcareous, shaly or slaty clays, with few fossils or definite beds of lignite, though considerable quantities of carbonaceous matter are disseminated throughout its mass.

At the base of the Lignitic there is a rapid change in the character of both rocks and fossils, the lowermost 15 to 20 feet of the formation being limestone, at first argillaceous, then quite pure, and even crystalline. This crystalline limestone rests with apparent conformity upon the yellow sands which make the summit of the Cretaceous group.[2]

The Lignitic group as a distinct horizon is, according to Smith, separated from the overlying formation (Buhrstone) upon lithological grounds alone. He says:

In the strata which we have called Lignitic the material, as compared with that of the Buhrstone, is more sandy and calcareous and at the same time more fossiliferous. The shells in many cases are decayed and the calcareous matter of the same often appears to have been leached out and diffused through the surrounding sands, occasionally cementing them together and forming calcareous sandstone. These sandstone beds always show a tendency to weather into rounded, bowlder-like masses, which project from the faces of the bluffs or, broken off, roll down, forming a talus. When broken open these bowlders usually show a nucleus of thoroughly decayed shells or of ferruginous, lignitic matter. * * * A ledge of calcareous sandstone of this kind is found about 20 or 30 feet below the lowermost of the alu-

[1] U. S. Geol. Surv., Bull. 43, 1887, p. 18. [2] Ibid., pp. 39, 135.

minous rocks, which we consider as characteristic of the Buhrstone, and similar calcareous sandstones weathering into bowlders occur at intervals throughout the underlying Lignitic strata. * * * None of the beds of the underlying Lignitic have even a remote resemblance to the Buhrstone rocks, except certain indurated clays which overlie the *Gryphæa thirsæ* beds in the Grampian Hills of Wilcox County and their prolongation into Butler County. Even in this case the distinction between the two can readily be discovered, as the indurated clays of the Lignitic are, in some of the beds, quite full of shell casts, principally Turritellas and Cythereas, and the material itself, upon close examination, does not so strongly resemble the Buhrstone as upon first sight appears.[1]

The Lignitic occupies the inland border of the Eocene area, increasing in thickness from the east toward the west. The interstratified marine beds, each of which has its "peculiar association of fossils," together with certain "lithologic and structural character," have been divided by Smith and Johnson into the following 7 horizons, which are given in descending order:

7. The Hatchetigbee marls.
6. The Woods Bluff or Bashi marl.
5. The Bells Landing series.
4. The Nanafalia or *Gryphæa thirsæ* marl.
3. The Matthews Landing and Naheola marls.
2. The Black Bluff beds.
1. The Midway or Pine Barren beds.

The sections exhibited on the Alabama and Tombigbee Rivers are characterized as follows:[2]

The Midway or Pine Barren section.—Thickness, 25 feet. The strata are: a white, argillaceous limestone holding a large nautilus, which is characteristic of the horizon, 10 feet; calcareous sands and a yellowish crystalline limestone, with Turritellas, Carditas, and corals, the sands 6 feet, the limestone 8 or 9 feet. This section is best seen in eastern Wilcox County, on Pine Barren Creek, but the upper or Nautilus rock occurs at Midway, on the Alabama River, and westward across Marengo County.

The Black Bluff section.—We have difficulty in determining the exact thickness, since on the Tombigbee the strata of this section are spread over an extent of surface which would, with uniform dip, correspond to a thickness of over 200 feet, while on the Alabama, and more particularly inland in the eastern part of Wilcox County, the thickness is not greater than 35 or 40 feet. Since 80 feet of these beds are seen in superposition at one locality (Black Bluff), we think that the maximum thickness can not be less than 100 feet. The characteristic strata which compose nearly the whole of this section are black or very dark brown clays, which are in part fossiliferous.

The Naheola and Matthews Landing section.—It is difficult to give the precise thickness of this section, since it varies on the two rivers. We have placed it at 130 to 150; the strata are gray, sandy clays in the main, alternating with cross-bedded sand. The beds of dark, sandy, and glauconitic clay, containing marine fossils, lie at the base of the section. At Naheola, on the Tombigbee, the upper and more glauconitic part of the bed is most prominent, while at Matthews Landing, on the Alabama, the lower part of the bed dark gray sandy clay forms the bluff.

The Nanafalia or Coal Bluff section.—The strata of this section are 200 feet in thickness, and consist of about 50 feet of gray sandy clays at top, which shows a tendency to indurate into tolerably firm rocks resembling very closely some of the strata of the

[1] U. S. Geol. Surv., Bull. 43, 1887, pp. 35, 36.

[2] Ibid., pp. 69, 70.

Buhrstone. Below this, about 80 feet of sandy beds, often strongly glauconitic, characterized throughout by shells of a small oyster (*Gryphæa thirsæ*). Near the base of this sandy division there is a bed about 20 feet thick, literally packed with these shells. Below the *Gryphæa thirsæ* beds follow some 70 feet of cross-bedded sands, glauconitic and apparently devoid of fossils, including, about 10 feet from the base of the section, a bed of lignite which varies in thickness from 4 to 7 feet.

The Bells Landing section.—This is 140 feet in thickness, and includes two important marine beds, and a third quite small and apparently unimportant. These fossiliferous beds are interstratified with yellowish sands in the upper and rather heavy bedded sandy clays in the lower part of the section. The upper marine bed, called the Bell's Landing marl, is about 10 feet in thickness and has 40 feet of sandy strata above it. The middle bed is called the Greggs Landing marl, and it is 20 to 25 feet below the preceding; it is about 5 feet in thickness. The lowermost of the fossiliferous beds of this section is only about one foot in thickness and lies about 50 feet below the Greggs Landing bed. It is highly glauconitic, but does not contain any great variety of fossils. The Bells Landing marl is distinguished from all others in Alabama by the great size of the shells which it contains.

Voluta Newcombiana, *Rostellaria trinodifera*, *Turritella Mortoni*, *Cardita planicosta*, and *Ostrea compressirostra* are common forms.

The Wood's Bluff or Bashi section.—This is 80 to 85 feet in thickness. The uppermost 30 feet of the section consist of dark brown clays passing into a green sand, which holds a great variety of finely preserved marine shells. Below this greensand marl are gray sandy clays, with 4 or 5 thin beds of lignite within the first 25 feet, succeeded by about 30 feet of cross-bedded sands, with a 2-foot seam of lignite at the base.

The Hatchetigbee section.—This section is 175 feet in thickness, made up of sandy clays of prevailing brown or purplish color, containing 3 or 4 beds of marine fossils in the uppermost 75 feet, and of somewhat similar purplish brown sandy clays nearly devoid of marine fossils in the lower 100 feet. All these brown sandy clays become much lighter colored upon drying and exposure to the weather.

Due to several folds in the strata, the Lignitic beds appear at the surface at several points to the south of its continuous outcrop, and have been very fully investigated in the western portion of Clarke County.

Langdon[1] has recently published an article in which the continuation of the Lignitic into the Chattahoochee drainage is shown. Several of the horizons established by Smith in the central and western portions of the State are traced to the banks of the Chattahoochee River, although they frequently exhibit marked changes in both deposits and fossils. In general the strata present a more marine phase, and the lignitic character of the beds farther west is gradually lost. The Midway or Pine Barren beds reach the thickness of about 220 feet on the Chattahoochee and become the most important member of the Lignitic series. The Black Bluff beds and the Matthews Landing and Naheola marls are wanting. The Nanafalia marl rests unconformably upon the Midway beds and attains a thickness of 175 feet. This marl was considered Claiborne by Loughridge.[2] The Bell's Landing series is 173 feet thick on the Chattahoochee, and is with difficulty separated from the overly-

[1] Geol. Soc. America, Bull., vol. 2, 1891, pp. 587-605.

[2] Rep. on the Cotton Production of Ga., 10th Census, vol. 15, p. 14.

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ing formation, the Wood's Bluff or Bashi marl, which here attains a thickness of 44 feet. The uppermost member of the Lignitic, the Hatchetigbee marls, present quite similar lithological characteristics on the Chattahoochee River as at the place of its typical development, though the beds have been reduced to 10 feet in thickness.

Buhrstone.—Overlying the Lignitic is a series of alluminous sands and sandstones that are at times glauconitic, even appearing locally as well-defined layers of greensand.

In most cases they are merely alterations of indurated clays, with alluminous sandstones of varying degrees of hardness. While in the extremes of pure clay and almost pure quartz the materials of this formation differ widely, the formation as a whole leaves upon the mind of the observer a lively impression of the uniformity in the lithological structure and general appearance of its constituent strata. * * * In general the uppermost beds (15 to 20 feet) are composed of joint clays, which, when indurated, form tolerably firm rocks. Near the base of the formation similar clays or claystones are usually seen. In many places there is a bed several feet in thickness of a hard, siliceous, or flinty sandstone, almost a quartzite, just at the base of the Buhrstone.[1]

Smith and Johnson separate this horizon from the Lignitic upon lithological grounds alone. Following Tuomey, they employ the term Buhrstone to designate it. They say, "The aluminous rocks we assign to the Buhrstone, while the sandy rocks, with the intercalated beds of calcareous matter we place with the Lignitic." Although this discrimination seems possible in Alabama, too little is known of the relationship of the beds beyond the State to say whether this difference is widespread.

The Buhrstone is found as a sinuous band to the south of the Lignitic, and extending from southeast to northwest across the State.

On the Alabama River the uppermost of the Buhrstone beds are well exposed at Lisbon Landing, and the lowermost a short distance above Hamilton's, whence they extend across Clarke County westward or northwestward to White Bluff and McCarthy's Ferry, and thence in a northwesterly direction across Choctaw County, just south of Butler. On the eastern side of the Alabama River they appear in the hills south of Bells Landing, and across Monroe County north of Kempsville and south of Turnbull, turning a little to the northward in the eastern part of the county. To the eastward they may be seen again near Ozark, in Dale County, and near Abbeville, in Henry County.[2]

There is considerable doubt as to the thickness of the Buhrstone series, but the least estimate places it at 300 feet. The fossils do not afford a means of discrimination either from the Claiborne above or the Lignitic below. They are not numerous and are for the most part poorly preserved.

Langdon[3] has more recently noted the occurrence of the Buhrstone on the Chattahoochee, where "the percentage of clay decreases, while the rocks become more calcareous and the fossils more abundant. In lieu of the silicified casts characterizing the Buhrstone of the Tombig-

[1] U. S. Geol. Surv., Bull, 43, 1887, pp. 35, 36.
[2] Ibid., p. 36.
[3] Geol. Soc. America, Bull., vol. 2, 1891, p. 597.

bee and Alabama Rivers, extensive beds of *Ostrea sellæformis* (var. *divaricata*) and an *Anomia* occur." The thickness of the beds here is stated to be about 190 feet.

Claiborne.—The Claiborne formation, so typically represented at the Claiborne Bluffs, on the Alabama River, consists of incoherent sands and clays, that are frequently ferruginous or calcareous and often glauconitic. The thickness of the deposits is about 150 feet. The beds of this horizon are renowned for their many fossils, which, however, are chiefly confined to the ferruginous sands near the top of the formation. Beneath this upper bed, known as the "Claiborne Fossiliferous sand," and which is about 15 feet in thickness, are "some 60 feet of calcareous clays and calcareous sands."

The whole of this 60 feet of strata, except perhaps some 10 feet of blue clay near the top, is distinguished from all the other beds of the Claiborne formation by the great numbers of shells of *Ostrea sellæformis* which it holds. These shells are found more abundantly in the hard sandy ledges which occur at intervals of a few feet through the whole thickness of these beds. * * * Below these *Ostrea sellæformis* beds we find at Claiborne and at Lisbon some 50 feet or more of sandy and clayey beds in many cases strongly glauconitic and holding a great number as well as a great variety of well preserved fossils.[1]

A generalized section of the Claiborne Bluff, according to Prof. E. H. Smith, is given below:[2]

7. A bed of very variable thickness, consisting of sand, pebbles, and red loam, which forms the surface over a great part of the State. The average thickness of this bed along the bluff may be put at ..... 35 to 40 ft.
6. A band of white limestone, containing glauconite grains, forming vertical faces usually striped by thin projecting ledges ..... about 45 ft.
5. A band showing two very distinct parts, viz, an upper part, a bed holding great numbers of *Scutella Lyelli*, 3 feet thick, and a lower part, 6 feet thick, of coarse, ferruginous sands, which are indurated at the base and form a very marked projecting ledge ..... 9 ft.
4. A band of very uniform appearance of reddish yellow or buff color, consisting of a mass of shells embedded in red sand. This is the celebrated Claiborne sand. It weathers very smoothly and is less projecting than the ledges above and below it ..... 15 to 17 ft.
3. A band of light gray calcareous clay with a few sandy stripes and indurated ledges ..... 25 to 28 ft.

   All these beds make up the nearly vertical part of the bluff near and between the two landings. Below these to the river level the slope is almost entirely covered by the loose fragments rolled down from above, so that the underlying stratified rocks are discovered only where these loose materials have been removed. Between the upper landing and the ferry these lower strata of the bluff are more clearly exposed to view.
2. A band of light yellowish, gray, calcareous sand striped with a number of hard ledges of similar sandy material. This band is a very prominent part of the bluff, but is in many places, as above stated, much obscured by the fragments of the other beds which have rolled down from above ..... about 35 ft.

[1] U. S. Geol. Surv., Bull. 43, 1887, pp. 26, 27. [2] Ibid., p. 28.

1. A band of dark bluish green color, consisting of clayey sands and clays passing downward into a green sand bed 6 to 8 feet thick, which appears, however, above water only above the upper landing..... about 12 ft.

No. 4, probably represents the top of the Claiborne division. The base of the series is not reached at this point, but the following more detailed section presents in Nos. 6–15 the portion of the Claiborne Bluff just given in Nos. 1–4, while Nos. 1 [1]–6 [6] in the detailed section are represented at Lisbon Landing, a few miles above, thus affording a complete series of the Claiborne in the vicinity of its type locality. Smith says:

There is no doubt as to the geologic horizon of the Lisbon section, since the two lowermost beds of the Claiborne section appear at the top of the Lisbon Bluff, the peculiar association of the shells making the identification easy and certain.[1]

Detailed section of Claiborne group of Claiborne Bluff and Lisbon Landing, Alabama River, after Smith and Johnson.[2]

15. Ferruginous sand, holding vast numbers of comminuted as well as well preserved shells. Near the center of this there are in places thin bands of lignite, and along the ferry road the upper part of it is composed of laminated gray clays filled with leaf impressions. This is the source of the celebrated Claiborne fossils, and we shall call it the Claiborne Fossiliferous sand. In many parts of Monroe and Clarke Counties, where this bed is more protected, the material in which the shells are embedded is seen to be a green sand, while at the Claiborne Bluff and vicinity, and at a bluff above St. Stephens, it is completely oxidized into a red ferruginous sand. Thickness about Claiborne ..... 15 to 17 ft.
14. Bluish green glauconitic, sandy marl, with *Ostrea sellæformis* usually somewhat indurated above, and forming a hard projecting ledge.....3 to 4 ft.
13. Calcareous clay or clayey marl, of gray color when dry, but blue when wet. It contains a few badly preserved chalky fossils, Bulla and small Turritellas. This bed becomes sandier below, as well as glauconitic and highly fossiliferous, the principal shells being *Ostrea sellæformis* and a few Pectens. The clayey sandy parts, together about.....18 ft.
12. Light gray calcareous clay similar to the upper part of the preceding bed, with hard, sandy ledges at the top and bottom .....7 ft.
11. Light yellowish gray calcareous sands, with *Ostrea sellæformis* and Pectens; the lower half indurated and full of the molds or casts of univalve shells.....5 ft.
10. Light yellowish gray calcareous sands, like those which make the upper half of bed No. 11. This bed has several hard projecting ledges of the same sandy material and contains a number of fossils: *Ostrea sellæformis*, fragments of *Scutella Lyelli*, *Scalpellum eocense*, *Pecten Deshayesii*, etc. The sandy parts of this bed are loose, crumbling easily between the fingers. There are thin beds of more clayey texture, one of which, about the center of the stratum, holds a number of irregularly shaped concretionary masses of clay. Near the base are one or two indurated ledges of glauconitic sand and shells of *Ostrea sellæformis* .....27 ft.
9. Layer of comminuted shells of *Ostrea sellæformis*, together with perfect shells of some other species embedded in glauconitic or green sand.....3 ft.
8. Dark bluish black sandy clay.....2 ft.
7. Bluish green clayey sands with few fossils in the upper part, but becoming more clayey below and highly fossiliferous: *Venericardia planicosta*, *V. rotunda*, *Nucula magnifica*, *Arca rhomboidella*, *Ostrea sellæformis*, *Voluta Sayana*, *Turritella lineata*, *T. bellifera* Aldrich, besides species of *Natica*, *Corbula*, *Cytherea*, *Lucina*, etc. This bed averages 10 feet or more in thickness.

[1] U. S. Geol. Surv., Bull. 43, 1887, p. 30. [2] Ibid., pp. 29, 30.

6. Dark green sandy marl, glauconitic; grayish above, bluish below. This bed is sometimes badly weathered and of more brownish color. It holds a number of fossils, among which the most noticeable are a peculiar small form of *Venericardia planicosta* Lam. and large *Turritella Mortoni* Con. This bed, which is the lowest at Claiborne, may be seen between the upper landing and the ferry, and its exposure is from 6 to 8 feet, according to the stage of the water.
6. [6] Dark brown sandy clays, badly weathered, highly fossiliferous, containing the same shells as beds Nos. 7 and 6 at Claiborne, viz, the peculiar small variety of *Venericardia planiscosta* Lam., large *Turritella Mortoni* Con., *Arca rhomboidella* Lea, *Lucina compressa* Lea, *Nucula magnifica* Con., *Turritella bellifera* (Aldrich), etc. This bed becomes more sandy below ..... 8 to 12 ft.
5. [5] Hard projecting sandy ledge ..... 8 in.
4. [4] Calcareous, clayey sands, light yellow when wet, nearly white when dry, glauconitic, forming smooth vertical bluff ..... 6 to 8 ft.
3. [3] Coarse grained sandy glauconitic bed with comminuted shells and many finely preserved shells of uncommon occurrence ..... 3 ft.
2. [2] Light yellow glauconitic sands capped with hard ledge ..... 15 ft.
1. [1] Blue glauconitic sands, probably the same as No. 2 above, but less completely oxidized, lowest of Claiborne strata ..... 5 ft.

Important sections are found at Gosport Landing and Rattlesnake Bluff, on the Alabama River, and at Coffeeville Landing, on the Tombigbee River, as well as at other points in Choctaw, Washington, Clarke, and Monroe Counties.

On the Chattahoochee River Langdon[1] states that the Claiborne is represented by the *Ostrea sallæformis* zone alone, which persists across Alabama with a thickness of about 75 feet, occurring as a bed of gray calcareous sand.

White limestone.—Under this division are included deposits that have hitherto been generally designated as the Jackson and Vicksburg groups, terms derived from Mississippi localities, where strata of similar age are more extensively represented. That there is little distinctive difference in the fauna of these two horizons has been shown by the fossils which have recently been collected in Alabama by Mr. T. H. Aldrich, as well as "the finding by him of *Cardita planicosta* in the uppermost beds of the White limestone near Claiborne." Smith and Johnson[2] state that although certain paleontological and lithological differences may be observed in the two portions of the series, these differences do not justify the division of a formation which in Alabama so clearly presents itself as a unit. Moreover, overlying the Jackson and Vicksburg groups a third horizon has been recognized by them and designated the Coral limestone.

The term White limestone, which includes these three subdivisions, was early employed by Tuomey[3] with much the present significance, although later used by Heilprin[4] for the lower or Jackson group only.

The literature of the White limestone is rather confusing, owing to the fact that the stratigraphical position of the Zeuglodon beds was

[1] Geol. Soc. America, Bull., vol. 2, 1891, pp. 597, 598.
[2] U. S. Geol. Surv., Bull., 43, 1887, p. 19.
[3] Geol. Surv., Alabama, 1st Rien. Rept., 1850, p. 154.
[4] Contrib. Tert. Geol. and Pal. U. S., 1884, p. 33.

not early recognized. Conrad held that the Zeuglodon and Orbitoides were referable to deposits of the same age. Lyell[1] was the first to properly distinguish the two horizons and to assign to the Zeuglodon beds (Jackson) their real position below the Orbitoides limestone (Vicksburg). The same fact was also recognized by Hale[2] and strongly insisted on by Hilgard[3] and most subsequent writers.

The general features of the White limestone are described in the following terms by Smith and Johnson:[4]

It consists chiefly of regularly bedded, impure limestone, with intercalated layers of marl, calcareous clay and sand, and some ledges of pure limestone. Its upper portion is perceptibly more calcareous than the lower, and contains a notably greater proportion of deep sea fossils; but neither the lithologic nor the paleontologic features are sufficiently distinct to warrant division of the formation. Its position and its structure alike indicate that it was laid down in a deep and probably deepening sea.

The different subdivisions of the White limestone are further described in detail.[5]

The lower division of the White limestone, about 60 feet in thickness, is in general terms a light colored argillaceous limestone, resembling the Rotten limestone of the Cretaceous formation both in the character of the rock and in that of the soils to which it gives rise on disintegration. It is traversed by thin bands of tolerably pure white limestone, and by beds of slightly calcareous clay, the latter often impregnated with gypsum. In places it is strongly glauconitic. This division contains a greater variety of fossils than either of the other two, though probably a smaller number. The fossils appear in general to be much more abundant in the upper half of the rock, where the more commonly occurring species are *Pecten perplanus* Mort., *Spondylus dumosus* Mort., *Ostrea cretacea* Mort., sharks' teeth, bones of *Zeuglodon cetoides*, and *Terebratula lachryma* Mort. This upper and most highly fossiliferous part holds calcareous clays which are strongly phosphatic and occasionally well filled with phosphatic or coprolitic nodules. The lower half of this division, while less fossiliferous than the preceding, has, in nearly every locality examined, a bed near its base at least 3 feet in thickness holding vast numbers of *Scutella Lyelli* Con. This, which we have called the Scutella bed, has often served us as a guide in the study of this formation in the field, since it overlies by a few feet only the Claiborne fossiliferous sands.

The middle division of the White limestone has a thickness of at least 140 feet. Lithologically it varies considerably, being in part a hard, crystalline limestone weathering into rough, irregularly shaped pieces, which have suggested the name "horse bone" rock, popularly used to designate it. Another variety is a soft, sometimes pulverulent mass of nearly pure carbonate of lime, which is everywhere quarried for building purposes. When fresh, this rock may easily be cut with an ax or a saw, but it hardens on exposure to the air and lasts for many years in chimneys and pillars to houses. This part of the White limestone contains as a characteristic fossil *Orbitoides Mantelli*, often in such numbers that the rock is little more than a mass of the disks of Orbitoides packed in soft, white carbonate of lime. The Orbitoides are most abundant in the upper two-thirds of this division, becoming less and less abundant below this.

The uppermost division, 150 feet in thickness, has as yet been observed in one locality only, viz, at Salt Mountain at the Middle Salt Works in Clarke County.

[1] Am. Jour. Sci., 2d ser., vol. 4, 1847, pp. 186–191.
[2] Ibid., vol. 6, 1848, pp. 354–363.
[3] Ibid., vol. 43, 1867, p. 29-32.
[4] U. S. Geol. Surv., Bull. 43, 1887, p. 134.
[5] Ibid., pp. 20, 21.

The rock here is a hard, white limestone, composed in great measure of masses of corals partly silicified. Near the base of this rock there occur great numbers of the spines and plates of echinoderms.

The White limestone is widely represented in Choctaw, Washington, Clarke, Monroe, Conecuh, Covington, and Geneva Counties. The White limestone of the Chattahootchee section, according to Langdon, is represented by both the Jackson and Vicksburg, though "it loses its distinctiveness as Jackson and Vicksburg, and may well be included under one head."[1] It is estimated to attain a thickness of 275 feet.

MISSISSIPPI.

The Eocene of Mississippi covers a wide area in the central and northern portions of the State. The publications of Prof. E. W. Hilgard, whose exhaustive investigations have extended over fully 40 years, afford the chief source of information upon the geology of this area.

The boundary of the Eocene upon the north and east passes in a curve northwest to north, through Kemper, Noxubee, Oktibbeha, Clay, Chickasaw, Pontotoc, Union, and Tippah Counties, near Macon, Starkville, Houston, and Ripley. Upon the south the boundary passes in a somewhat sinuous line through Wayne, Jones, Jasper, Smith, Rankin, Hinds, and Warren Counties, and somewhat to the south of Waynesboro, Jackson, and Vicksburg.

The Eocene overlies the Cretaceous upon the north and east, which it succeeds in its various horizons regularly from northeast to southwest. The relations of the deposits are described by Hilgard, in his Report on the Geology and Agriculture of the State of Mississippi. He says:

The position of the Tertiary strata appears to be more or less in conformity with that of the Cretaceous beds. It certainly is so in the southern portion of the State, where their dip is distinctly southward. Whether or not the same is true in reference to the strata occupying the northern portion of the State I have thus far been unable to determine, in consequence both of the rare accessibility of the strata and their character. If, however, any westerly dip exists in the Tertiary strata of northern Mississippi (as is the case in the Cretaceous strata) it is certainly much less than that of the latter.

In a later publication[2] the same writer estimates the dip in the north as 4 to 5 feet in the mile toward the west; in the south 10 to 12 feet in the mile toward the south.

In the official report first referred to, the lithological character of the Eocene is thus described:

It exhibits, essentially, three different facies, viz, that of lignitiferous clays and sands, varying in color from black to brown, blue, green, yellow, gray, and almost white, with remains of vegetables; that of siliceous sandstones and claystones with marine fossils; and that of limestone and calcareous marls, with marine fossils.

Although these three divisions correspond in the main with the leading stratigraphical divisions of the Eocene, yet many modifications

[1] Geol. Soc. America, Bull., vol. 2, 1891, p. 600.
[2] Am. Jour. Sci., 2d ser., vol. 43, 1867, p. 36.

occur in the series. The lignitic phase has often bands of sandstone intercalated which contain marine fossils, while "the several marine stages are separated by intervening strata of dark colored, often lignitic clays." This peculiarity is not confined alone to the sands and sandstones, but is likewise found in the calcareous beds. The following generalized section, changed but slightly from that given by Hilgard in the report above mentioned, is presented in descending scale:

VICKSBURG. Crystalline limestones and marls with, *Ostrea, vicksburgensis, Ostrea gigantea, Pecten Poulsoni, Arca mississippiensis, Navicula mississippiensis, Navicula lima, Crassatella mississippiensis, Cardium diversum, Panopæa oblongata, Dentalium mississippiensis, Fulgoria mississippiensis, Cyprœa lintea, Madrepora mississippiensis, Orbitoides Mantelli*..... 80 feet.

Ferruginous rock of Red Bluff, with *Plagiostoma dumosa*, etc..... 12 feet.

Lignitic clay and lignite, at Vicksburg and north of Brandon..... 20 feet.

JACKSON. White (often indurate) and blue marls with *Zeuglodon macrospondylus*, etc.

Lignitic clay and lignite, at Jackson, Garlandsville, Coounpy Creek..... 80 feet.

CLAIBORNE (Calcareous Claiborne). White (sometimes indurate) and blue marls with *Ostrea cellæformis*, etc.

Lignitic clays and sands of northern Clarke County.

BUHRSTONE (Siliceous Claiborne). Sandstones and claystones with *Cardita planicosta*, etc. Found in Neshoba, Newton, Lauderdale, and Clarke Counties.

LIGNITIC. Lignitiferous strata with interstratified beds of brown, yellow, and gray sands and clays containing marine fossils and plant remains. *Quercus* sp., etc. *Cardita planicosta*, etc.

Lignitic.—The term lignitic, first employed by Hilgard to designate the deposits now under consideration, had, under the name "the Northern Lignitic," much the same stratigraphical significance that it has received in the present report.

Heilprin has suggested the use of Eolignitic, but the earlier term is here retained. Although there seems to be but little doubt as to the stratigraphical position of the greater part of the deposits here referred to the Lignitic, the evidence is somewhat conflicting as to other portions. Much more exhaustive examinations must be made before all the lignitic strata can be assigned to their proper horizons. The deposits of undoubted Lignitic age have been observed to dip below the Buhrstone, and further afford specimens of *Cardita planicosta*, *Aturia ziczac*, and other early Eocene forms. The Lignitic occupies a much wider area than any other member of the Eocene series. It covers the whole or portions of Lauderdale, Kemper, Neshoba, Leake, Madison, Yazoo, Holmes, Attala, Winston, Noxubee, Oktibbeha, Clay, Webster, Choctaw, Montgomery, Carroll, Grenada, Tallahatchee, Yallabusha, Calhoun, Chickasaw, Pontotoc, Union, Lafayette, Panola, Tate, De Soto, Marshall, Benton, and Tippah Counties.

The northeastern portion of the area bordering the Cretaceous has been designated by Hilgard the "Flatwoods." The deposits are gray or whitish, often laminated clays. The Lignitic strata to the west of this area are thus described by Hilgard:

Westward of the Flatwoods proper, however, the clays are commonly laminated, less uniform in their character, and interstratified more or less with the sand. Such usually are the clays associated with the lignite beds and containing impressions of leaves; nevertheless, the genuine "Flatwoods clay" character frequently reappears over the whole region. * * * Through these clay stones any sign of lithological transitions, from the pure almost white clay to the fossiliferous sandstone of Tippah County, may be traced, and careful examination will sometimes detect in them unequivocal remnants of marine fossils. * * * In short, the greatest diversity of material generally obtains in connection with the lignite beds.

Buhrstone.—The Buhrstone called Siliceous Claiborne by Hilgard is characterized by aluminous sandstones and claystones. It is found chiefly in the eastern portion of the State and extends from the Alabama State line across Clarke, Lauderdale, Newton, and Neshoba Counties into Scott and Leake Counties, occurring also as an outlier in Attala, Holmes, Choctaw, Montgomery, and Carroll Counties. Its stratigraphical position below the Claiborne and above the Lignitic has been fully established, and among its more important fossils are *Ostrea divaricata*, *Cardita planicosta*, *Cardita rotunda*, *Cardium Nicolleti* and *Voluta petrosa*. Hilgard corroborates the statements of Tuomey and Conrad of the division of the Buhrstone into two horizons, but the investigations have hardly been exhaustive enough as yet to admit of their final acceptance.

Claiborne.—The Claiborne, or as it is designated by Hilgard, the Calcareous Claiborne, is poorly represented in Mississippi. So far as its presence has been reported it is found mainly in Clarke County, although Hilgard, in an article in the American Journal of Science in 1867, states that he has "received evidence that it extends somewhat farther westward, between the territory of the Jackson and Siliceous Claiborne groups, than it appears on the map" in his State report. As a group the strata are not very sharply defined "inasmuch as the transition from siliceous to calcareous materials is a gradual one" and on this account the Claiborne deposits occupy a somewhat intermediate position lithologically between the Buhrstone and the Jackson.

The beds are chiefly blue and white marls, the latter generally arenaceous and often indurated. The fossils of this horizon are so poorly preserved that but few have been recognized. Among those reported by Hilgard are *Ostrea divaricata*, *Ostrea sellæformis*, *Pecten Lyelli*, *Corbula gibbosa*, and *Voluta petrosa*.

Jackson.—This division of the Eocene was first recognized in Mississippi by Conrad,[1] who described an extensive collection of fossils from the neighborhood of Jackson and first employed that name to designate the horizon since so called. He assigned to the strata their proper stratigraphical position above the Claiborne and below the Vicksburg, although from the nature of the material he had for examination he failed to recognize the true faunal relationship of the several horizons. His investigations led him to the conclusion that there were

[1] Philadelphia Acad. Nat. Sci., Proc., vol. 7, 1855, pp. 257–263.

no forms in common with the Vicksburg series and but four or five with the Claiborne. Subsequent observations, however, have shown in Mississippi, as well as in Alabama, that there are many forms common to the three horizons. Such common species as *Cardita planicosta* and *Cardita rotunda* of the Claiborne, with many less usual types, are found, while the list of species reported as likewise occurring in the Vicksburg is very large. The most distinctive fossil of the Jackson beds is the Zeuglodon, which, as already stated under Alabama, had been reported by Conrad and others to occur at the same horizon with Orbitoides, though this was denied by Hilgard. If such intermingling has been locally found it is explained probably on the ground of subsequent rearrangement of the deposits.

The Jackson beds are composed "at times of a soft yellowish limestone or indurate marl containing a good deal of clay; at others of, in reality, nothing more than soft gray or yellowish calcareous clay." Hilgard recognizes two horizons, an *upper* of about 70 feet of marl or clay in which the bones of the Zeuglodon are prominent, and a *lower* of 10-20 feet of bluish sandy strata, containing green-sand grains. It is the lower horizon that is developed at Jackson and contains the important series of fossils described by Conrad. In this lower division beds of lignite are conspicuously developed at several points.

The Jackson deposits extend as a band of varying width from Wayne across Clarke, Jasper, Smith, Scott, Rankin, and Madison Counties, into Yazoo, where they disappear below the alluvium of the Mississippi.

Vicksburg.—The Vicksburg strata extend as a narrow band across the State south of the region occupied by the Jackson group, and pass through Wayne, Jasper, Smith, Rankin, Hinds, and Warren Counties, reaching the Mississippi River at Vicksburg Bluff.

As stated in a previous paragraph, the Vicksburg group is both lithologically and paleontologically closely associated with the Jackson. This is shown most clearly when the section exposed at Red Bluff in Wayne County is considered. The intermediate deposits there exhibited, which Hilgard thought sufficiently important to establish as a subgroup of the Vicksburg series, contain a most interesting association of typical Jackson and Vicksburg forms (the latter predominating), together with a large number of species peculiar to the horizon. Conrad, who had examined beds on the Savannah River at Shell Bluff, held that this division (Red Bluff group of Hilgard), in which the same species of oyster (*Ostrea georgiana*) was reported to occur, was of the same age and, moreover, that its position was between the Claiborne and Jackson. He called the formation the Shell Bluff group.[1] In the American Journal of Science for 1866, Hilgard[2] opposed the opinions of Conrad and showed the proper position of the deposits in Mississippi to be at the base of the Vicksburg. The strata of this horizon are

[1] Am. Jour. Sci., 2d ser,, vol. 41, 1866, p. 96.
[2] Ibid., vol. 42, 1866, pp. 68-70.

never of great thickness, and at Red Bluff Station, Wayne County, where typically developed, are only about 4 feet thick. At this point, the beds consist of "irregular masses of fine grained, ferruginous rock, imbedded in a brownish or greenish clayey mass."

The deposits of the Vicksburg group proper consist chiefly of limestones, marls, and clays, which are frequently arenaceous and at times glauconitic. The change is often very marked, for, as Hilgard states, "not only do the materials of the different groups often bear a most extraordinary resemblance to each other, but their character varies incessantly in one and the same stratum within short distances."

The typical fossil is the Orbitoides. Conrad, although at first recognizing in its fossils the close relationship of the Orbitoides limestone with the beds exposed at Vicksburg bluff, was later[1] of the opinion that the faunas should be separated and the former associated with the Jackson group. Subsequent investigation has shown the error of this position, for the Orbitoides has been found in sufficient numbers mingled with the other characteristic Vicksburg forms, to prove the identity of the deposits.

The following section of the Vicksburg Bluff is given in its main details as found in the State report of Hilgard:

	7. Bluff formation	10–20 ft.
	6. Orange Sand	5–20 ft.
Vicksburg group..	5. Alternating strata, 1 to 6 feet thick of limestone and marl, containing the Vicksburg fossils, and some bands of non-effervescent, gray sand and clay	60–65 ft.
	4. Black lignitic clay, and gray sand, with *Ostrea gigantea, Corbula alta, Natica mississippiensis, Cytherea sobrina, Madrepora mississippiensis*	5 ft.
	3. Gray or black lignitic clays and sand, with iron pyrites; exuding salts and sulphureted hydrogen	25 ft.
	2. Solid lustrous lignite, with whitish cleavage planes	3 ft.
	1. White limestone of the Jackson group?	3 ft.

TENNESSEE.

The Eocene of Mississippi, which reaches the northern boundary of that State, continues in a southwest-northeast direction across the western part of Tennessee. It has been reported to cover much of the area lying between the Tennessee River on the east and the Mississippi River on the west, and has been found to outcrop at several localities on the bluffs of the latter stream. It has been estimated to attain a width of quite 50 miles, but with the fragmentary data at hand the exact delimitation of the formation is in much doubt.

The several official reports of Troost upon the Geology of Tennessee barely touch upon the Eocene. Considerable attention, however, is given to this portion of the State by Safford, though the recent investigations of McGee tend to show that much that has been hitherto held to belong to the Eocene series must be referred to later horizons.

Safford,[2] whose authority has been followed up to this time, divides

[1] Am. Jour. Sci., 2d ser., vol. 41, 1886, p. 96.

[2] Am. Jour. Sci., 2d ser., vol. 37, 1864, pp. 360–372. Geology of Tennessee, 1869, pp. 422–428.

the series into two groups which he terms I. The Porter's Creek group, II. The La Grange group. The Upper or La Grange group McGee has recently correlated with the Appomattox formation of the Atlantic slope, so that a large part of the deposits hitherto referred to the Eocene has been given by him a much more recent origin. The Bluff Lignite group, which Safford doubtfully referred to the Tertiary and placed above the La Grange group, is held by Loughridge[1] to be a phase of the Porter's Creek group. McGee, on the other hand, considers it Pleistocene. It will thus be seen that the various authorities upon the geology of western Tennessee vary widely in their opinions.

The problems here presented for solution have to be determined almost wholly on stratigraphical data due to the absence of distinctive fossils. In short, with the exception of a somewhat limited flora, which has not as yet received much study, and a few poorly preserved molluscan remains, there is nothing of a paleontological character to aid in the determination of the geological horizons represented. The Lignitic (Porter's Creek group) is probably, however, the single member of the Eocene series found in Tennessee. In its lithological characters it has much in common with the same formation found in Mississippi. The Flatwoods phase, with its laminated and aluminous structure, is widely represented. Arenaceous and lignitic strata likewise occur. We have much yet to learn of the Eocene of Tennessee, however, before its distinctive features can be at all accurately defined.

KENTUCKY.

The Eocene of Kentucky is the northward extension of the Tennessee formation and presents much the same characters as its more southern representative. It occupies that portion of the State lying between the Tennessee and Mississippi Rivers and the same divisions in the series have been found to occur as in Tennessee. It has been hitherto stated, however, that McGee correlates the La Grange group with the Appomattox and refers the Bluff Lignite to the Pleistocene, although the latter is by Loughridge considered to be a phase of the Porter's Creek group.

The Eocene series as subdivided by Loughridge[2] in his Report upon the Jackson Purchase Region is as follows in descending order:

3. La Grange group (of Safford's Tennessee).
2. Lignitic (Safford's Porter's Creek and Bluff Lignite).
1. Hickman (provisional).

The *Hickman group*, the lowest member of the Eocene, which Loughridge has provisionally established, is found chiefly in the vicinity of Hickman, where exposures occur "in the bluff bordering the Mississippi bottom from Hickman south into Tennessee." In evidence that

[1] Geol. Surv. Kentucky, Rept. Jackson Purchase Region, 1888, p. 41.
[2] Ibid, p. 37.

the deposits at Hickman are older than the Lignitic the author says: "These exposures are embraced in a belt of country 5 miles west of a line running south from the lignitic outcrops at Columbus, and both of the formations have an apparent slight easterly and northwesterly dip, which would carry the Hickman beds much below those of Columbus." The deposits consist of clay, sand, and gravel, but have not been exposed to their base.

The *Lignitic group*, which, according to Loughridge, is the equivalent of Safford's Porter's Creek group—

enters from Tennessee with a width of about 10 miles, passes northward through the middle of Calloway County, soon bends to the northwest through the southwest corner of Marshall, and passes diagonally through the center of McCracken and the northern part of Ballard County into Illinois; southward along the Mississippi River bluffs, its first outcrops occur 2 miles north of Wickliffe, Ballard County, and in the bluffs between Wickliffe and Fort Jefferson reaching eastward 7 miles to Blandville and southward to Laketon; at Columbus and a mile above, and also at Chalk Bluff, 2 miles south, the greatest exposures of the lignitic beds occur.

Loughridge characterizes the group lithologically as follows:

First.—A lower heavy bed of massive joint clay, black when wet, but drying to a lead-gray color, and on exposure to air crumbling to a fine shaly mass. This is the Porter's Creek group of the Tennessee series. It is popularly called soapstone. Along the Mississippi River bluffs the clays, while dark and somewhat jointy, are more sandy than those on the eastern side of the region.

Second.—An upper bed of dark sandy clay, holding two layers of lignite, each varying from 2 to 4 feet in thickness, the topmost being about 5 feet from the surface of the formations. This upper or lignitic portion of the group, while perhaps at one time continuous from the Mississippi River eastward nearly to the Cretaceous, has now almost disappeared on the east, outcropping only on Panther Creek, 6 miles east of Mayfield, in Graves County On the west, however, in the neighborhood of Wickliffe, the lignite beds reach for 3 miles to north and south, and for 7 miles eastward to Blandville.

Loughridge gives the following section which shows the character of the several members comprising the group:

Section of the Lignitic group.

	Feet.
Dark sandy clays	3
Lignite bed	4
Dark sandy clays	5
Lignite bed	3
Dark sandy clays	3
Clay stone with fossil-leaf impressions	2
Dark sandy clay, the upper holding leaf impressions	2
Micaceous sandstone with fossil casts	3
Black joint clay, changing to dark sandy clay	100

The paleontological evidence, with the exception of a few poorly preserved molluscan remains from the micaceous sandstone near Paducah, depends entirely upon fossil leaves, of which a considerable number have been described by Lesquereux from the beds near Columbus[1] and Wickliffe.[2] The molluscan forms, five in number, *Mysia ungulina* (?),

[1] Am. Jour. Sci., 2d ser., vol. 27, 1859.

[2] U. S. National Museum Proc., vol. 11, 1888, pp. 11–13.

Leda protexta (?), *Leda sp.*, *Nucula ovula* (?), and *Turritella Mortoni* are described by Heilprin[1] in the Proceedings of the Academy of Natural Science, of Philadelphia, as occurring "mainly in the form of casts in a highly ferruginous and fairly micaceous yellow-white sandstone."

The non-occurrence of Lignitic strata in the area between the eastern and western outcrops above described is accounted for by the removal of the deposits and "the filling up of the gap by the La Grange beds."[2] This is considered probable from the fact that the La Grange is found at depths below the level of the Lignitic deposits.

The wide surface covering of more recent deposits limits the examination of the Eocene to the exposures afforded by streams and well borings.

ILLINOIS.

In Geology, vol. 1 of the Reports of the Geological Survey of Illinois, certain deposits in the southern portions of the State, in Massac, Pulaski, and Alexander Counties, are referred to the Tertiary. They consist of gravels, sands, and clays that are at times cemented into a ferruginous conglomerate. In Pulaski County, a bed of greensand marl occurs, with casts of marine shells that are referred by Worthen to the genera Cucullæa and Turritella. The bluff at Caledonia, on the Ohio River, affords a fine section of Tertiary strata 100 feet in thickness. Worthen states that a thin bed of lignite is found at the water's edge. Loughridge, who visited the locality at high water, states that the basal member is "greensand (glauconite) with hyoline sand; also, some black sand and clay, 2 to 4 feet." Overlying this he mentions the occurrence of "75 feet of the dark joint clay weathering to a gray shale and similar in every regard to the clay beds of the lignitic." The presence of 20 feet of "dark, sandy clay, indurated" above the joint clay is further stated. This is supposed by Loughridge to represent the micaceous sandstone of the Paducah series.

Worthen is of the opinion that the Tertiary strata may have extended along the basin of the Mississippi as far north, at least, as Hancock County, since the occurrence there of shark's teeth in the alluvial deposits can be explained only on the ground of subsequent rearrangement of earlier marine deposits. It seems probable that the various deposits here referred to are the northward extension of the Lignitic represented in Tennessee and Kentucky and described in the previous pages.

MISSOURI.

Little more than the bare statement of the occurrence of Eocene in the southeastern portion of the State is found in the literature. That the strata partake of the character of the deposits in Kentucky and

[1] Philadelphia Acad. Nat. Sci. Proc., vol. 38, 1886, pp. 57, 58.

[2] Geol. Surv. Kentucky, Rept. Jackson Purchase Region, 1888, p. 51.

Illinois, which collectively outline in a general way the head of the Mississippi embayment in early Tertiary times, is recognized. The outcrops are found chiefly in Mississippi and New Madrid Counties. So far as known, the strata are entirely confined to the Lignitic. No fossils have been reported from the beds, and even the stratigraphical relations of the deposits themselves are very imperfectly understood.

ARKANSAS.

Our knowledge of the Eocene of Arkansas is confined chiefly to a small area in the southwestern portion of the State that has lately been investigated by Prof. Robert T. Hill.[1]

The earlier reports of David Dale Owen, State Geologist of Arkansas, contain many casual references to Tertiary deposits, in the eastern and southern counties, a portion of which can be shown to be Eocene, while the remainder are to be referred in part to older, in part to younger formations. The Tertiary area examined by Hill includes portions of Hot Springs, Dallas, Clark, Howard, Hempstead, Nevada, Ouachita, Columbia, La Fayette, and Miller Counties, and the sections are found for the most part along the Ouachita and Red Rivers and their tributaries. The inland border of the formation is found to extend in an irregular line from southwest to northeast, a short distance to the west of the Iron Mountain Railway and passes near Texarkana, Washington, Arkadelphia, and Malvern. From the scattered data accessible for the remainder of the State it seems probable that this line extends in approximately the same direction toward the northeast, past Little Rock to the Missouri border.

The lignitic formation of this area has been designated by Hill the "Camden series." He describes it as "an extensive, shallow-water, marine formation of stratified, micaceous, non-indurated, alternating laminæ of sands and clay shales, sandy shales occasionally accompanied by bituminous shales, lignitic shales, thin sandstones (quartzites), etc.[2]" The series takes its name from the town of Camden on the Ouachita River, near which the most typical exposure is found. The following section is from Hill's report:

8. Surface soil (residuum of substructure) ferruginous sandy ..... 5 ft.
7. Laminated sand, with green-sand specks, originally white, but ferruginating and cementing into red iron sandstone, with a tendency to shaly disintegration on exposure ..... 32 ft.
6. Little Missouri lignites, or ligneous shales, with white sand between layers of the same character as those seen at the mouth of the Little Missouri ..... 20 ft.
5. Buff-colored, micaceous sand and clay shales, changing on exposure to pink and light yellow ..... 10 ft.
4. Bituminous shales, with bituminous masses and asphalt-like concretions. This stratum is full of concretions of iron pyrites, which oxidize on exposure, coloring the neighboring strata red ..... 15 ft.

[1] Geol. Surv. Arkansas, Ann. Rept. for 1888, vol. 2, pp. 48-65.
[2] Ibid., p. 49.

3. Light drab, fine, micaceous sands or sandy clays, finely laminated..... 25 ft.
2. Concealed..... 25 ft.
1. Repetition of No. 3 to the water line..... 10 ft.

In the vicinity of Arkadelphia are deposits "consisting of alternate bands of blue clay and white or orange-colored sands" that occupy a position below the Camden series as exhibited at Camden. They rest unconformably upon the Cretaceous, and have received the name of "Arkadelphia shales" from Hill.

Hill states that there are many other outcrops within the area that afford deposits similar to the Camden section, but that, judging from the dip, it is not probable that the strata are identical. On the contrary, they represent alternating conditions in the deposition of an extensive series of beds. The thickness of the Camden series can not be accurately given, but it is estimated to be quite 700 feet between Curtis and Camden. At the latter point, 300 feet more are exposed from low water to the top of the highest hills.

Owen mentions the occurrence in the central and northeastern portions of the State in Jefferson, St. Francis, Green, and other counties of lignitic strata that are doubtless the northern continuation of the belt represented by the Camden series of the southwest.

The "Cleveland county red lands" described by Hill, though lithologically similar to the typical Camden series, are "accompanied by extensive deposits of marine shells and greensand which bring into these strata an ingredient of lime, an ingredient which is conspicuously lacking in the underlying beds." *Cardita planicosta*, *Rostellaria velata*, and other forms found also at Claiborne show the probable position that these beds hold in the Eocene series. At White Bluffs, on the Arkansas River, in Jefferson County, Owen mentions a section of Eocene shell marl 50 to 60 feet in thickness containing many Claiborne types.

From the evidence thus afforded the presence of the Lignitic and Claiborne are established, while it is probable that the Buhrstone also occurs. The White limestone is undoubtedly lacking.

LOUISIANA.

The reports of Hopkins and Hilgard, that of the former to the general assembly as State geologist, that of the latter to the New Orleans Academy of Sciences, afford the chief sources of information upon the Eocene geology of Louisiana. As the investigations were hurriedly conducted, admitting in neither case of an extended examination of the deposits, there is much yet to be desired before approximate limits may be given to the several formations, or even the horizons themselves definitely determined.

The Eocene strata are found to the north of a line extending from the Sabine River near the mouth of Bayou Toneau, through Sabine and Natchitoches Counties, crossing the Red River near Cloutierville,

thence through Grant and Catahoula Counties to near Stafford Point on the west bank of the Ouachita River. To the east of the Ouachita River the Eocene is covered by the alluvial deposits of the Mississippi. North of this southern boundary line the strata extends to the Arkansas border.

All the main divisions of the Eocene are probably represented, although we have definite knowledge of but two, the Vicksburg and Jackson. Hilgard describes, under the name of "*The Mansfield group*," a series of beds consisting of lignites, sands, and clays that he states in his first report in part at least overlie deposits with characteristic Jackson fossils. In the final report these deposits are shown to be largely Jackson. Hopkins, about the same time, suggests the identity of a part of the Mansfield group with the "Northern Lignite." Hill, in his Arkansas report, states that similar deposits in Arkansas which he assigns to the Lignitic, and calls the Camden series, represent certainly in part the Mansfield group of Hilgard. If, upon further examination, such proves to be the case, we have in the lignitic strata of northwestern Louisiana the Lignitic represented. That lignitic strata occur at different horizons, as in Mississippi, is beyond doubt, and it may be that the Mansfield group contains representatives of all the divisions from the Lignitic to the Jackson. Too little is known to make positive statements upon this point.

Jackson.—The northern limits of the Jackson group, as finally established, will depend upon the amount of lignitic strata that will be assigned to earlier horizons. In addition to the lignites, with their interstratified sands and sandy clays, are marine strata, consisting of marls, clays, and sands with numerous typical molluscan forms, and at two localities (Grandview on the Ouachita River, and Montgomery, Grant Parish), the remains of Zeuglodon.

Vicksburg.—The limits of the Vicksburg group have been more accurately determined. The strata occupy a belt of country 10 to 12 miles in width, extending from the Ouachita River to the Sabine, and passing through Catahoula, Winn, Grant, Natchitoches, and Sabine Counties. The deposits consist chiefly of yellow and red clays, at times sandy and often very calcareous from the presence of large numbers of limestone nodules, that are filled with casts of shells. Lignitic strata are not altogether absent, though infrequent. Many characteristic Vicksburg fossils have been reported from the different portions of the area, including *Orbitoides Mantelli* and *Pecten Poulsoni.*

TEXAS.

The first information that is afforded us concerning the occurrence of Eocene strata in the State of Texas is presented by Roemer in his work entitled "Texas," etc., published in 1849. At Wheelock, Caldwell

County, he found fossils that he considered identical with those at Claiborne, Alabama. From this he drew the conclusion that—

> It is hardly to be believed that this Tertiary formation is limited only to this point on the Brazos, in Texas, but most probably it is part of a continuous band, as is the case in Mississippi and Alabama, extending along the foot of the Cretaceous, and only the detritus of the later alluvial formations prevents its exposure in most places.[1]

The supposed limits of the formations are given on a map appended to the volume. The later geological notes on this region by Schott, Hall, Conrad, Shumard, and Buckley are very meager and unsatisfactory, and give us hardly more than a general idea as to the position of the Tertiary.[2] Loughridge, in a "Report on the Cotton Production of the State of Texas"[2] of the Tenth Census, gives the general boundaries of the Eocene, although its westward deflection in the drainage of the Rio Grande, adopted on most recent maps, has been lately shown to be erroneous.[3] Hill states that the mistake originated because Conrad referred a specimen of *Cardita planicosta* to a locality (Arroyo de las Minas) in Zavalla County, which, however, upon examination, shows, in the handwriting of the collector, that it came from Mexico.

Heilprin presents an excellent general statement of the stratigraphical relations of the Texas Eocene, so far as they were known up to 1884, in his "Contributions to the Tertiary Geology and Paleontology of the United States." Hill quotes largely from the same work, so far as it relates to the Eocene, in his general summary of "The Present Conditions of Knowledge of the Geology of Texas."[4]

A recent publication of Dr. R. A. F. Penrose, jr., entitled "A Preliminary Report on the Geology of the Gulf Tertiary of Texas, from the Red River to the Rio Grande," in the First Annual Report of the Geological Survey of Texas for 1889, gives us the results of the first systematic study of the Tertiary formations of eastern Texas. The line separating the Cretaceous and Eocene, he states, runs in a general northeast and southwest direction, crossing the Red River west of Texarkana, the Texas and Pacific Railroad between Corsicana and the Trinity River, the Brazos River in the northeast corner of Milam County, the Colorado River 10 miles below Austin, and the Rio Grande River in the northwest corner of Webb County, 3 miles below the Maverick County line and half way between Eagle Pass and Laredo.

Concerning the difficulty of definitely establishing the boundary between the Cretaceous and Tertiary, Penrose says:

> The uppermost part of the Cretaceous and the base of the Tertiary strata are both composed of soft clay and sand beds, which succumb readily to the weathering action of the atmosphere and consequently the line of separation is often impossible to locate exactly.

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[1] Texas, etc., 1849, p. 372, and U. S. Geol. Surv., Bull. 45, 1887, p. 17.
[2] Tenth Census of the U. S., vol. 5, 1884 pp. 653-831.
[3] U. S. Geol. Surv., Bull. 45, 1887, p. 85.
[4] U. S. Geol. Surv., Bull. 45, 1887.

As regards the composition and origin of the strata he says:

The Tertiary deposits consist of a vast thickness of sand, clay, and glauconite beds, in some places characterized by great quantities of lignite, and in others by beds of littoral fossils. In fact the whole series represents a succession of coastal, subcoastal, or brackish water deposits, alternating with marine deposits of a littoral character, and between these two extremes we find all gradations. The lagoon or subcoastal deposits compose by far the greater part of the series, and the marine strata represent slight and temporary submergencies of the coastal area.

The strike of the strata is northeast to southwest and the dip from 0° to 5° toward the southeast, although local variations in the latter are reported by Penrose by which at times the dip is west or northwest, and one instance in the vicinity of San Ygnacio on the Rio Grande, where for 21 miles the dip is towards the northeast. The strata have been estimated to attain a thickness of 1,000 to 1,300 feet. Penrose divides the deposits into two horizons, which are given below in descending order.

2. The Timber Belt or Sabine River beds.
1. The Basal or Wills Point clays.

The lower division, the *Basal* or *Wills Point Clays*, are composed of—

Stiff laminated clay, yellow, gray, blue, or bluish green in color, frequently interbedded with seems and laminæ of sand, containing many concretionary masses of gray non-fossiliferous limestone. * * * No lignitic beds have been seen as yet in these clays.

The deposits of this division are estimated to be 250 to 300 feet thick. They are considered by Penrose to be absent on the Rio Grande.

The upper division, the *Timber Belt* or *Sabine River Beds*, are composed of—

Siliceous and glauconitic sands, with white, brown, and black clays. The clays, however, are greatly in the minority, and the siliceous sands comprise by far the greater part of the whole series. Lignite beds are of very frequent occurrence, varying from a few inches to 10 and 12 feet thick.

Of the areal distribution of these beds Penrose says that they "occupy an area over 125 miles wide in the northeast part of the State, but thin down to less than 40 miles on the Colorado." On the Rio Grande the Timber Belt Beds are found, according to Penrose, resting directly on the Cretaceous.

Dr. White,[1] however, considers that the Laramie enters into the Rio Grande section between the marine beds of the Cretaceous and Eocene. He says:

These strata (Laramie) dip gradually to the southeastward or approximately in the direction of the river's (Rio Grande) course and disappear beneath the sandy strata of the Eocene Tertiary some 10 or 12 miles above Laredo.

The Timber Belt or Sabine River beds are estimated to attain a thickness of 800 to 1,000 feet. Although the discovery of many fossils is reported from the Texas Eocene, and the identity of several forms with the species recognized in the Alabama and Mississippi strata

[1] Am. Jour. Sci., 3d ser., vol. 35, 1888, pp. 432–438.

claimed, little systematic study has been given them, so that no very definite conclusions can as yet be drawn. *Cardita planicosta*, that ranges so widely and is so characteristic of the Eocene in the Atlantic as well as the Gulf States, has been recognized among other typical forms.

CORRELATION OF DEPOSITS.

There is practical uniformity of opinion at the present time as to the delimitation of the Eocene of the Atlantic and Gulf coast region. Both paleontologically and stratigraphically, the break separating the Eocene and Cretaceous is clearly defined, and except where local details of geographical distribution have not been as yet finally established, the line may be drawn with comparative accuracy. Unconformity of contact is generally apparent, and the types of animal remains are so widely different as to afford at once, when present, a ready means of discrimination.

The Neocene is also found unconformably overlying the Eocene and with fossil forms that at once separate the two horizons, although the distinctions are, perhaps, not so strongly marked as between the Cretaceous and Eocene.

On the other hand, any attempt at a wide correlation of the various divisions of the Eocene established in the different portions of the Atlantic and Gulf coast region is rendered well-nigh fruitless from our incomplete knowledge of their stratigraphy and their fossils. Only in one locality (along the Alabama and Tombigbee Rivers, Alabama) have we even an approximately accurate section of the Eocene series. The literature is filled with incomplete descriptions of local deposits, which, for purposes of widespread correlation of the strata must be used with the greatest care. Moreover, the collections of fossils made by the many authorities cited in the previous pages of this report have been either altogether destroyed or so carelessly labeled and preserved as to be practically worthless for stratigraphical purposes. The collections of the Alabama State Survey are an exception, and I have a fragmentary series from the Atlantic coast deposits. It will thus be seen that the difficulties in the way of any general correlation of deposits are well-nigh insuperable. We are practically ignorant of the fauna, and the very foundations upon which we have to build are thus wanting. Long lists of fossils, it is true, have appeared in many articles and reports upon the region, but the establishment of any complete system of correlation upon such data, is, to say the least, hazardous. Before the work can be satisfactorily done, careful and exhaustive collections must be made. Until that has been accomplished, a provisional statement of the more apparent similarities may not be valueless. Many such attempts have hitherto been made, and it is with some reluctance that the author employs such insufficient data for widespread correlations which require the most accurate information to possess any value. In

the introduction to this report a division of the Eocene into I, Lower; II, Middle; III, Upper, was suggested. Although such a division of the strata can not be definitely established everywhere, it affords a scale to which the facts, so far as we know them, may be referred, and by which the complete series in Alabama may be best interpreted. In the succeeding pages the generalized sections recorded in the several States will be assigned, so far as possible, to a relative position in this scale, although later observations will probably necessitate many changes.

New Jersey.—The Eocene of New Jersey belongs entirely to the Lower division. Its supposed close relationship to the Cretaceous, from a stratigraphical standpoint, was long the cause of associating it with that horizon. Its fossils were subsequently found to possess an undoubted Eocene character, and although lacking some of the more widely represented species, such as *Cardita planicosta*, *Turritella Mortoni*, and *Ostrea sellæformis*, still afford none of the characteristic Cretaceous forms of the underlying rocks. The character of the vertebrate bones and the molluscan remains is a strong indication of its early Eocene age. Conrad[1] stated this position in 1848 and more fully explained the same in 1865. It has been generally held by subsequent writers.

Maryland.—There is some difference of opinion as to the correlation of the Maryland deposits. The strata exhibited at Piscataway Creek, Upper Marlboro, and other points have been generally considered to hold a position well down in the Eocene series, but whether they are to be correlated with the Claiborne, Buhrstone, or Lignitic of the south has not yet been finally determined, so that it is a matter of some doubt whether the Maryland deposits should be considered Lower or Middle Eocene. It is not at all improbable that both may be represented, though we have not sufficient data for establishing a division. That the deposits of Maryland and Virginia occupy about the same horizon is pretty clearly established, both on stratigraphical and paleontological grounds. In the main the fossils are similar. *Ostrea compressirostra*, *Turritella Mortoni*, *Cytherea Meekii*, *Cardita planicosta*, *Cucullæa gigantea*, *Panopœa elongata* are types frequent in both States, while *Turritella Mortoni*, *Panopœa elongata*, and *Cardita planicosta* have a wide geographical range in other portions of the Atlantic and Gulf coast region. Unfortunately the few forms that occur have not, so far as is known, a narrowly circumscribed range geologically, *Cardita planicosta*, for example, ranging through the entire Eocene series. Lithologically, also, the Maryland deposits are, in their widespread green-sand facies, to be intimately associated with the Virginia strata.

Virginia.—The Virginia Eocene region is, as above stated, the southward extension of the Maryland area. The upper strata may represent a higher horizon, but of that we have little to guide us. The fossils

[1] Philadelphia Acad. Nat. Sci. Jour., new ser., vol. 1, 1848, p. 129. Philadelphia Acad. Nat. Sci., Proc., vol. 17, 1865, pp. 71, 72.

are, in the main, identical, though, so far as investigation has gone, the fauna of the Virginia Eocene is more varied than that of Maryland, and in the presence of *Ostrea sellæformis* and other important forms shows a closer relationship with the more southern areas. Whether it is the representative of the Lower or Middle Eocene can not be stated with definiteness, although it seems probable that portions of each are represented. Continuous deposition under similar circumstances seems to have prevailed, and renders any division of the series difficult.

North Carolina.—The fauna of the North Carolina Eocene presents so many differences from that of other areas that it is difficult to correlate the strata. The deposits have much less in common with the Virginia region than with South Carolina, when viewed either from a paleontological or structural standpoint. *Ostrea sellæformis* and *Cardita planicosta* occur sparingly together with other forms that are found in the Middle Eocene of Alabama. Too little is known of the fossils and their range to enter much into details, but there is little doubt that the Middle Eocene is here represented, though its lower portions may be absent. There are also points of relationship between the limestone beds in the eastern portions of the State and the White limestone facies farther south. Too little is known of the fauna to pass final judgment. It seems probable, however, that the Upper Eocene is here represented.

South Carolina.—The Eocene of South Carolina is represented by portions, at least, of the Lower, Middle, and Upper members. That some of the basal and superior beds are lacking, and that there may have been interruptions in continuous deposition seems probable. The irregularly stratified arenaceous beds at the base of the series, classed with the Buhrstone in Tuomey's South Carolina report, are beyond much doubt to be correlated with the Lignitic of Alabama, and are thus Lower Eocene. Although lignitic strata are not wholly lacking, yet the conditions under which the beds were accumulated were very different from those existing in the Gulf region. The seas were open, and sands and clays were chiefly deposited, while lignitic accumulations were forming in the Mississippi embayment. The overlying argillaceous deposits are probably Buhrstone, though they may include also, in part or in whole, the Claiborne. They are of Middle Eocene age. Among the species found that occur in the Middle Eocene elsewhere, though not distinctive in all cases, are *Turritella Mortoni*, *Cardita planicosta*, *Cytherea ovata*, *Crassatella alæformis*, *Pectunculus stamineus*, and *Ostrea sellæformis*. The "calcareous strata of the Charleston Basin," which include the Santee Beds and the Ashley and Cooper Beds of Tuomey, are to be correlated with the White limestone of Alabama, and are thus upper Eocene, though the evidence for the presence of the upper horizon (Vicksburg) is by no means conclusive. The existence of Zeuglodon remains in the different members of the calcareous strata (Santee Beds and Ashley and Cooper Beds), together with the character of the mollusca, is strong proof of their identity of age with the Jackson group of Alabama and Mississippi. Some of the beds on the left bank of the

Savannah, opposite and below Shell Bluff, have been correlated with the Vicksburg, upon evidence previously stated and have been called the "Shell Bluff group."

Georgia.—Although investigated much less fully than in South Carolina, the Eocene deposits of Georgia include probably the three divisions there represented. The "Buhrstone" is described as peculiarly typical for Georgia, though as the term is here used it includes part, if not all, of the Lignitic, Buhrstone, and Claiborne of Alabama. A separation of the series into these horizons is as yet impossible from the lack of accessible data. In the southern portion of the State the Vicksburg group of the White limestone (connecting the Florida and Alabama areas) is doubtless represented, though the evidence is rather of geographical possibility than established fact.[1]

The upper portion of the section exhibited at Shell Bluff, on the Savannah River, was stated by Conrad[2] to represent a horizon underlying the "Orbitolite limestone of the Jackson group."

Hilgard, in a reply to Conrad,[3] says the statement that the *Orbitoides* occurs in the Jackson group is incorrect, and that the "Shell Bluff group" of Conrad is probably the equivalent of his "Red Bluff group," found at the base of the Vicksburg series and overlying the Jackson. Of the importance of *Ostrea georgiana* for purposes of correlation, Hilgard claims that it varies greatly from the Jackson oyster, with which Conrad compared it, but may be similar to *Ostrea gigantea* of the Vicksburg, which, moreover, is not present in the Red Bluff group. From this it appears that the evidence for the correlation of the "Shell Bluff group" is insufficient, and beyond the fact that it is included in the White limestone series and is thus Upper Eocene, it is impossible to go. From the data at hand it is evident that a decided opinion can not be given upon the different horizons represented in Georgia, though it can be stated as probable that the Lower, Middle, and Upper Eocene are present.

Florida.—The Eocene of Florida is confined to the upper division, and in its well marked White limestone phase, containing *Orbitoides Mantelli*, *Pecten Poulsoni*, and other Vicksburg fossils, is readily correlated with the upper member (Vicksburg) of the White limestone of Alabama and Mississippi. A thin layer of silicified Miocene limestone is often found irregularly overlying both the typical Vicksburg and that later phase of it which has been called Nummulitic and which contains species of Foraminifera that are limited to the Florida deposits so far as known. Johnson[4] says concerning this latter horizon that "possibly these irregular deposits may be remnants of the Nummulitic limestone, which is really a stratum oveylying the Vicksburg rocks, well

[1] Recent observations of Mr. Frank Burns show that the Vicksburg limestone with *Orbitoides* crops out 25 feet thick in Pulaski County.

[2] Am. Jour. Sci., 2d ser., vol. 41, 1866, p. 96.

[3] Ibid., vol. 42, 1866, pp. 68–70.

[4] Ibid., vol. 36, 1888, p. 232.

seen at the old iron works near Levyville, Levy County." As regards its taxonomic importance, Johnson further states that "there is no sufficient reason as yet observed to regard it as more than an upper layer, similar to such superadded layers seen in Alabama at the Lower Salt Works on the Tombigbee River."

Alabama.—The extent of the Alabama section, together with the detailed manner in which it has been studied, has led to its acceptance as the type of the Atlantic and Gulf coast Eocene. The Lignitic has been assigned to the Lower, the Buhrstone and Claiborne to the Middle, and the White limestone, with its further subdivisions into Jackson and Vicksburg, to the Upper division of the series. Such separation is locally warranted on both lithological and paleontological grounds, and may for the present at least serve an important purpose in the comparative study of the Eocene deposits of the Atlantic and Gulf Coast region. So far as the stratigraphy of the Eocene is at present known, the entire series is represented in Alabama.

Mississippi.—The deposits of Mississippi are readily correlated with those of Alabama, as most of the members persist with similar facies. The lower division, the Lignitic, as previously described, is widely represented. The Buhrstone and Claiborne, defined as siliceous and calcareous Claiborne by Hilgard, are both present, while the White limestone persists in its two divisions, the Jackson and Vicksburg.

In general the Lignitic increases in importance from Alabama westward, while the members of the Middle Eocene, although represented, form a less marked feature structurally and paleontologically. The White limestone, on the other hand, is much more prominently developed, and affords a most varied fauna in both its upper and lower members. A marked feature of dissimilarity with the eastern representatives of the Upper Eocene, in this respect connecting it with the trans-Mississippi type, is the occurrence of lignitic bands throughout the series.

Mississippi Embayment: Tennessee, Kentucky, Illinois, Missouri, and Arkansas.—The Eocene strata of the region to the north of the border Gulf States, forming the Mississippi Embayment, are chiefly to be correlated with the lower division (Lignitic). The character of the deposits affords almost the only means of comparison, since few localities have been found where fossils are found. In southern Arkansas, from the occurrence of Claiborne fossils, there is evidence of the presence of the Middle Eocene, but it is doubtful whether the Upper Eocene is anywhere represented in this area. So little is yet known of the geological range of the lignitic beds in the Gulf region that the conclusions drawn from their presence or absence have little value. In the States to the south lignitic strata have been found at every horizon of the Eocene; yet from the geographical position of the Mississippi Embayment, it seems hardly probable that more than the Lower, or at the most Middle, Eocene are represented.

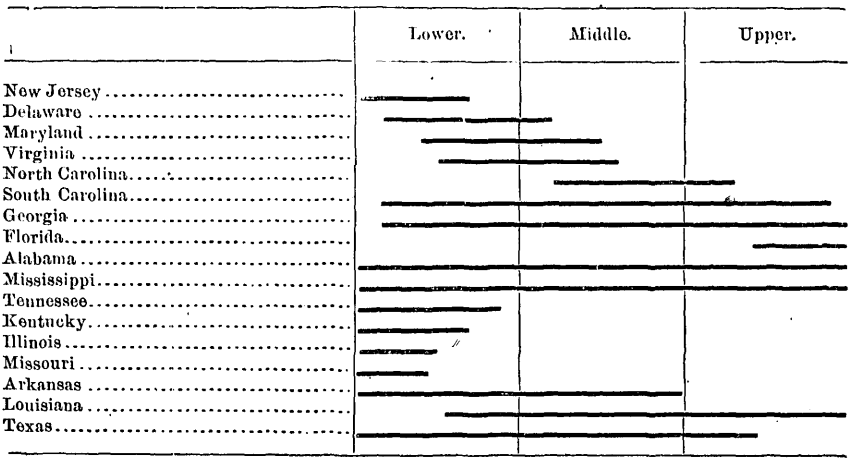
Louisiana.—In a previous chapter the evidence for the existence of the Lignitic in Louisiana was stated. That evidence was chiefly of a lithological character, and the probability that the southern extension of the "Camden series," described by Hill in Arkansas and shown to be Lower Eocene, would coincide with the deposits of northwestern Louisiana. Hilgard has described the lignitic strata of this area under the name of the "Mansfield group," and although in part shown to be Upper Eocene, they are considered by Hill to represent likewise the "Camden series" (Lignitic). The evidence for the presence of the Middle Eocene is chiefly of a geographical character. On the other hand, the Vicksburg and Jackson have a thoroughly characteristic development, the White limestone strata abounding in fossils of species identical with those of Mississippi. Intercalated beds of lignitic strata, on the other hand, are more numerous than in the White limestone series to the east of the Mississippi River.

Texas.—Heilprin[1] and Hill[2] have expressed the opinion that the Tertiary of Texas would be found to afford a tolerably complete section of the Eocene when more complete investigations had been made. Heilprin says that "it may safely be assumed that all, or nearly all, of the divisions ranging from the Eolignitic [Lignitic] to the Grand Gulf, inclusive, are represented."

Concerning the correlation of the Basal or Wills Point Clays, the lower of the two divisions of the Eocene strata established by himself, Penrose says:[3] "These clays probably represent the Eolignitic of Heilprin's Eocene section, the base of Hilgard's 'Northern lignitic' in his Mississippi section, and the Arkadelphia shales at the base of Hill's 'Camden series,' in Arkansas." He states that the upper portion of "The Timber Belt or Sabine River beds," the upper division of the Eocene as established by that writer, on the Brazos and Colorado River, "show Jackson and Claiborne species with a tendency toward an increase of the Jackson over the Claiborne as we ascend the series." The representatives of the Vicksburg seem to be quite or nearly lacking, which has been accounted for on the ground that the oscillation that caused deep-sea conditions in the Vicksburg period over the central Gulf States "may have also raised the Texas region into a land area." When more exhaustive study has been made of the Eocene fauna of Texas it may then be possible to institute more accurate correlation with the series established in Alabama and Mississippi. Until that has been done little more than the statement of the probable presence of representatives of the Lower, Middle, and Upper Eocene may be made.

[1]Contributions to the Tertiary Geology and Paleontology of the United States, 1884, pp. 37-39.
[2]U. S. Geol. Surv., Bull. 45, 1887, pp. 84-86.
[3]Geol. Surv. Texas, First Ann. Rept. for 1889, pp. 18, 19.

Tabular representation of the geological range of the Eocene in the Atlantic and Gulf coast region.



PROVISIONAL DIVISION INTO PROVINCES.

As stated in an earlier portion of this paper, the Atlantic and Gulf Coast Eocene is too imperfectly understood to admit of its direct treatment by provinces though certain indications of a paleontological and lithological character render a provisional division possible and necessary.

The Gulf region, due to the fuller representation of the Eocene series and the more exhaustive investigations, that have been there recorded, may be considered to afford the type development of that horizon, and so the standard with which other Eocene areas may be compared. For this reason even a provisional division of the Atlantic and Gulf Coast region into provinces must depend largely upon correlative data, based upon the Gulf series.

Wider investigations may show that what to-day seem restricted characters whether structural or paleontological are to be largely explained on account of our imperfect knowledge. Connecting links now wanting may unite all parts into a consistent whole, so that the wide faunal differences that now appear may be found much less prominent, even if they do not entirely disappear.

Judging from present data four more or less fully defined areas dependent upon structural and paleontological differences may be established in the Atlantic and Gulf Coast region. They are: 1, New Jersey province; 2, Maryland-Virginia province; 3, Carolina-Georgia province; 4, Gulf province.

New Jersey province.—The Eocene area of New Jersey forms an insignificant portion geographically of the Atlantic and Gulf Coast region. In the character of its deposits or its fossils the Eocene of this locality affords few points of comparison with its more southern representatives. Lithologically there is a marked difference. The "Blue Marl" of which

the New Jersey series is largely composed presents an individual type of sedimentation unlike the Eocene strata to the south. This difference, which may be directly traceable to the underlying deposits from which the Eocene has been largely derived is still further shown in the character of the fossils which the beds themselves afford. The more common Eocene types such as *Cardita planicosta*, *Ostrea sellæformis*, *Ostrea compressirostra*, *Cucullæa gigantea*, *Cytherea Meekii* and others so characteristic for the deposits in Maryland and Virginia are lacking, while with the possible exception of *Crassatella alta* none of the more southern forms appear. The species most common for the New Jersey area are with scarcely an exception confined to that region.

The question naturally presents itself in connection with the study of the Eocene deposits of New Jersey, whether the structural and faunal differences are due to differences of contemporaneous origin, upon which alone the claims to separation as a province rests, or whether the horizon of the New Jersey deposits may not be different from that of the strata immediately to the south in Maryland and Virginia, with which comparison has been chiefly made. That the latter may be the case has been by no means disproved. The evidence for or against either one of these suppositions is so inconclusive that final decision can not be rendered. However, for lack of opposing data, the New Jersey deposits may be for the present purpose best treated as a provisional province.

Maryland-Virginia province.—Of much wider geographical extent than the New Jersey region is the Eocene area of Delaware, Maryland, and Virginia, though in its turn much more circumscribed in range than the regions farther south. Although showing greater similarity in the character of its deposits and fossils with the south Atlantic and Gulf Coast Eocene, than the New Jersey province, the Maryland-Virginia province is still sufficiently distinctive in both to require complete separation as a geological unit.

The green-sand marl of which the Eocene deposits of this area are almost exclusively composed, although found elsewhere in the Atlantic and Gulf Coast region is nowhere so extensively developed as in Maryland and Virginia. It is thoroughly characteristic for the Maryland-Virginia province.

The fossils likewise are in the main distinctive and confined to the limits assigned to that province. They are quite unlike the fauna of New Jersey on the one hand and that of the Carolinas on the other. Several forms it is true are comparable with the types of the more southern representatives of the Eocene, especially the common bivalves *Cardita planicosta* and *Ostrea sellæformis*. A sufficient number, however, are limited in their geographical range and thus show that the conditions for their existence in Eocene times were such as to confine them to the Maryland-Virginia region.[1] Similar questions of doubt as

[1] Future investigations may show the differences to be much less marked than they now seem. Fuller comparisons with southern forms may show a greater number of identical species.

to the contemporaneity of the Maryland-Virginia deposits with the type series established for the Eocene arise as in the New Jersey area, but for the same reasons the provisional separation of the Maryland-Virginia region as a geological province is made. The Eocene deposits of this area are termed by Darton the Pamunky formation.

Carolina-Georgia province.—The Carolina-Georgia province affords a much more complete series of Eocene strata than the northern areas. Possessing more important representatives, however, in the Middle and Upper divisions of the Eocene than the Lower, the possibilities of comparison with northern areas are narrowly circumscribed. The earlier Eocene presents a very different facies in the Carolinas and Georgia from that in Virginia, Maryland, or New Jersey. The coarse, incongruous sands and clays show that the mode of accumulation of the deposits was very different and, moreover, ill adapted for the preservation of marine organisms, even if many had found there a congenial habitat. The few fossils that occur are mainly different from those in other areas, but the fauna is very imperfectly understood. The arenaceous character of the beds affords some points of similarity with the Lower Eocene in the Gulf States, although the lignitic strata of the latter are wanting. The later Eocene deposits, formed in a sea which almost no muddy sediment reached, are chiefly limestones and marls and possess a fauna that can have little in common with the northern Eocene, though many identical species[1] with the White limestone horizon of the Gulf States are found.

Gulf province.—The Gulf province, extending from Florida to Texas and including the Mississippi embayment, presents certain characteristic features that separate it both lithologically and paleontologically from the Atlantic coast provinces. The wide development of lignitic strata throughout the Gulf province must have required peculiar conditions for their accumulation that did not exist along the Atlantic coast. Moreover, these conditions were not confined exclusively to the earlier stages of the Eocene, although there predominating, but frequently recurred throughout the entire period. We find that even the Jackson and Vicksburg groups are not without their lignitic beds, although in the eastern portion of the region they are much less frequent.

The *Lower Eocene* of the Gulf province attains great prominence, and in the region of the Mississippi embayment reaches its most marked development. In its geographical extent it is the leading member of the Eocene. It becomes much less lignitic in the eastern portion of the region than in the central and western; its faunal characteristics are there more marine and the beds more calcareous.

The *Middle Eocene* in its two divisions, the Buhrstone and Claiborne, presents a characteristic series of deposits that acquire their most marked individuality in the State of Alabama, where a varied fauna

[1] The fact that most of the Carolina-Georgia forms occur as casts renders a comparison difficult.

characterizes the upper of the two horizons. The Buhrstone largely loses its aluminous character toward the Georgia line and becomes more fossiliferous. The Claiborne, away from the place of its typical development at Claiborne, Alabama, rapidly changes. The various horizons there represented disappear in part, or changes coming in at short distances give the beds quite a different appearance.

The *Upper Eocene*, with its widely developed White limestone beds, affords a sharp contrast to the other members of the Eocene series. In the western portion of the area the White limestone, so typically developed in Alabama, is frequently interstratified with beds of arenaceous deposits containing bands of lignite.

The fauna of the various horizons of the Eocene in the Gulf States is vastly richer than on the Atlantic Coast, and affords many species that do not exist in the latter region. The similarities to the Carolina-Georgia province, however, are much greater than to the more northern areas.

COMPARISON WITH EUROPEAN DEPOSITS.

The attempts of geologists to correlate American Eocene strata with European have decreased in about the ratio that real knowledge of the deposits has increased. The earlier geologists thought nothing of correlating individual beds with the minuter divisions of European strata. At first lithological similarities were thought sufficient, but even after the fossils themselves were considered, generic identity still afforded a basis for correlation of the most detailed character. Of late there has been more of a tendency to study American formations with reference to their own individuality rather than that of some fancied resemblance to the deposits of other lands. When our knowledge of the American Eocene has not progressed to such a point as to admit of a correlation of the strata of contiguous regions, how is it to be expected that wider comparisons can be successfully made?

Some similarities of a general character in deposits and fossils occur, however, and it is these which will be briefly examined. When we take into consideration the deposits forming along existing coast lines, we find how little value for purposes of correlation the similarity or dissimilarity of sediments can possibly have. Both in America and Europe we find a great diversity in the character of the strata. Brackish and marine facies appear, the latter with both littoral and infralittoral deposits. Moreover, the fresh-water sediments occurring in the geographically more circumscribed "basins" of Europe are lacking in the Atlantic and Gulf Coast region of America. Further, when we observe that the geographical range of shallow-water marine species is limited, we can hardly expect that many identical forms will be found common to the American and European Eocene. A few species, however, among which the *Cardita planicosta* is the most important, are widely repre-

sented in the Eocene strata of both continents. Heilprin[1] has made a comparative study of American and European Eocene species, and maintains the identity or close relationship of many forms. Conrad,[2] Morton,[3] Lea,[4] and Meyer[5] have made similar comparisons, a review of whose conclusions are presented in the article by Heilprin. Others, on the other hand, do not consider the existence of identical species in the Eocene of the two continents probable, with the possible exception of *Cardita planicosta* and one or two other less usual forms.

The general character of the faunas of the two continents is, however, sufficiently similar to render it probable that the Eocene series of Europe is represented in the American Eocene series, which latter may likewise include the Oligocene of the Old World, though it does not seem to the writer that the evidence adduced is as yet sufficient to prove either its presence or absence. As stated in the general introduction to this report, the term Eocene, as we have employed it, may or may not include both the Eocene and Oligocene as those terms are used in Europe.

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[1] Contributions to the Tertiary Geology and Paleontology of the United States, pp. 83–101.

In this article Heilprin discusses briefly the points of similarity in the species that follow:

America.	Europe.
Ostrea compressirostra, Say.	(?) O. bellovacina, Lam.
divaricata, Lea (O. falciformis, Conr.)	O. flabellula, Lam.
Cardita rotunda, Lea	(?) C. imbricata.
planicosta, Lam	C. planicosta, Lam.
Cardium Nicolleti, Conr	C. semigranulatum, Sow.
Corbis lirata, Conr	C. lamellosa, Lam.
Pectunculus idoneus, Conr.	(?) P. proximus, Wood. (?) P. polymorphus, Desh.
Limopsis aviculoides, Conr. (Pectunculus obliquus, Lea)	(?) Pectunculus (Limopsis) minutus, Philippi.
Trigonocœlia cuneus, Conr. (Nucula carinifera, Lea)	(?) Nucula (Trigonocœlia) deltoidea, Lam.
Corbula oniscus, Conr. (C. Murchisonii, Lea)	C. rugosa, Lam.
Trochita trochiformis, Lea	T. (Calyptræa) trochiformis, Lam.
Tornatella bella, Conr	Auricula (Actæon) simulata, Sow.
Solarium ornatum, Lea	S. canaliculatum, Lam.
Niso umbilicata, Lea	N. angusta, Desh.
Pyrula tricostata, Desh	P. tricostata, Desh.
penita, Conr. (P. tricarinata, Conr.; P. cancellata, Lea; P. elegantissima, Lea)	P. nexilis, Lam.
Cyprædia fenestralis, Conr.	Cypræa elegans, Defr.
Oliva bombylis, Conr. (O. constricta, Lea)	(?) O. clavula, Lam.
Voluta limopsis, Conr	(?) V. crenulata, Lam.
Cancellaria tortiplica, Conr	C. (Buccinum) evulsa, Brand.
Sigaretus canaliculatus, Sow	S. canaliculatus, Sow.
Turbinella (Caricella) Baudoni, Desh	Voluta Baudoni, Desh.
Fusus pachyleurus, Conr.	(?) F. clavellatus, Lam.
Pleurotoma denticula, Bast.	P. denticula, Bast.
acuminata, Sow.	P. acuminata, Sow.
Terebra constricta, Lea	Cerithium trilineatum, Phil.
Melania claibornensis, Heilp	(?) M. mixta, Desh.

[2] Fossil Shells of the Tertiary Formations of North America, 1832, p. 34.

[3] Synopsis of the Organic Remains of the Cretaceous Group of the United States, 1834.

[4] Contributions to Geology, 1833, p. 19.

[5] Philadelphia Acad. Nat. Sci., Proc., vol. 36, 1884, pp. 104–112.

A more detailed correlation of the several divisions of the Eocene of America seems to the writer impracticable. The Claiborne sands have commonly been considered the equivalent of the "Calcaire Grossier" of the Paris Basin and the Jackson of the "Barton Clay" of England, while the Buhrstone and Lignitic have been variously assigned to the lower horizons of the Eocene of Europe. It is unnecessary here to refer in detail to the extensive literature that has dealt with the correlation of the Vicksburg beds, which have been by many held to represent the Oligocene. As stated above, the data are not sufficient to solve the question for or against their equivalence. In short, until we comprehend more fully the complex development of the American Eocene, wider comparisons must be made with the greatest reserve.

APPENDIX.

THE BRANDON FORMATION.

Under the name of *The Brandon formation* the lignitic beds of Vermont, Pennsylvania, and Georgia are included, deposits whose taxonomy has not been yet definitely determined, but which from certain indications may be provisionally referred to the Eocene. It is by no means certain that future observations will establish the contemporaneous formation of the various deposits here described, but with the very insufficient data at hand the strata appear at present to be best interpreted by referring them to a common horizon.

Prof. Edward Hitchcock was the first to call attention to the stratigraphical importance of the lignitic beds of the eastern portion of the United States. In an article[1] in the American Journal of Science for 1853 he describes the "Brown Coal deposit" of Brandon, Vermont, and employs the data thus afforded "to determine the geological age of the principal hematite ore beds of the United States." The association of the lignitic strata with beds of iron ore, kaolin, and clay is stated, and from the occurrence of fossil fruit similar to forms described from the "newer Tertiary" strata of Europe the entire series is assigned to that horizon. On this and other grounds to be referred to later, he states that "the Brandon deposit is the type of a Tertiary formation hitherto unrecognized as such, extending from Canada to Alabama." The same conclusion is stated in a later publication,[2] in which he affirms that "no geologist has doubted that these deposits were all contemporaneous, but their true age has been a mystery."

Hodge,[3] who had examined the iron ore deposits of western New England, was of the opinion that "Hitchcock's Tertiary theory of these deposits has been too hastily adopted." Whitney[4] nevertheless

[1] Am. Jour. Sci., 2d ser., vol. 15, 1853, pp. 95–104.
[2] Geology of the Globe, 1853, p. 105.
[3] Am. R. R. Jour. No. 684, 1853.
[4] Metallic Wealth, 1854, pp. 460, 461.

accepted the conclusions of Hitchcock and referred the brown hematites of western Massachusetts to the Tertiary.

The possibility of a wide correlation of the brown hematite deposits upon the data afforded by the Brandon lignites was strongly denied by Prof. J. P. Lesley,[1] who dissented also from the opinion expressed by Hitchcock as to the contemporaneous formation of the deposits thus linked together. He says "there is no sufficient evidence upon the ground at Brandon, in Vermont, that brown hematite, the lignite, and the kaolin are related to each other in any such fixed way as to insure the fact that they are, per se, and not as a mere local and exceptional deposit, contemporaneous." The author considers in this paper that the local occurrence of lignite at Brandon is to be accounted for by the accumulation of vegetable débris in a "sink" formed in the limestone.

Prof. Hitchcock[2] presents a more exhaustive discussion of the question in his report on the geology of Vermont, in which he reaffirms his previous claim as to the contemporaneity of the Brandon deposits and correlates the iron ore beds extending from Canada to Alabama. He calls attention to the occurrence of these beds in limestone (Silurian) valleys.

In an article in the American Journal of Science for 1861 Prof. Lesquereux[3] describes the fossil fruit of Brandon and compares certain of the forms there found with species from the Lignitic of the southwest.

In a paper in the proceedings of the American Philosophical Society for 1865 Prof. Lesley[4] announces the discovery of a deposit of lignite near Chambersburg, Franklin County, Pennsylvania, that is closely analogous to the Brandon bed. He further states that of the many localities mentioned by Hitchcock as affording deposits of contemporaneous age this alone admits of comparison. The author quotes Hitchcock at length to show that he has included other deposits in describing the Brandon lignite formation. He asserts that "the lignite and iron ore are neither of the same age, nor, strictly speaking, possessed of any structural attribute common to both." The iron ore beds are considered Silurian while the lignite deposit is assigned to the late Tertiary.

In 1878 Prof. Prime[5] announced the discovery of lignite at Ironton, Lehigh County, Pennsylvania, though he referred it and the associated iron ore to the Glacial epoch.

The discovery of lignite in Montgomery County, Pennsylvania, was reported by Lewis[6] to the Academy of Natural Sciences of Philadelphia at its meeting on September 22, 1879. A month later a succinct review of the opinions that had hitherto been current in regard to the age and

[1] Iron Manufacturer's Guide, 1859, pp. 514, 518, 539.
[2] Geology of Vermont, vol. I, 1861, pp. 226-240.
[3] Am. Jour. Sci., 2d ser., vol. 32, 1861, pp 355-363.
[4] Proc. Am. Phil. Soc., vol. 9, 1865, pp. 463-480.
[5] Report DD., 2d Geol. Survey of Pennsylvania, 1878, p. 76.
[6] Philadelphia Acad. Nat. Sci., Proc., vol. 32, 1880, pp. 281-291.

correlative value of the lignite beds was presented by the same writer who gave a detailed description of the Montgomery County deposits. As a postscript to the published paper a letter is printed from Prof. N. A. Bibikov, of Augusta, Georgia, announcing the discovery of lignite in Richmond County of that State.

Concerning the association of the iron ore beds with the lignitic strata as claimed by Hitchcock and denied by Lesley, Lewis says that the iron ores of this region probably belong to four different geological ages, and he classes them as (1) Gneissic ore. (2) Primal ore. (3) Tertiary ore. (4) Drift ore. He thus separates the iron ore associated with "the deposits of lignite, plastic clay, kaolin, fire-sand, etc.," from that which has been heretofore confounded either with the primal ore or with the drift ore. "The discovery of lignite below it [the tertiary ore]," he says "proves its restratification in a later age [Tertiary] than the decomposed primal ore that is found in place."

The term Brandon period is proposed by Lewis to designate the age of the lignite beds. He says:

> Since in the present state of our knowledge it is obviously unsafe to make the age of these lignite deposits contemporaneous with any exact geological epoch, and as there is a possibility of their belonging to some period not recognized elsewhere.

Nevertheless, he suggests that they may be most closely correlated with the Oligocene of European geologists.

Vermont.—Hitchcock,[1] in the American Journal of Science and later in the geology of Vermont,[2] describes the deposits of the type locality Brandon, and also mentions other points in the State where similar deposits are found. At Brandon he states that the beds, which dip at a high angle to the northwest, rest upon "yellowish limestone," are associated with clay, kaolin, and iron ore, and are overlaid by drift. The lignitic strata were found to be 20 feet in thickness at the points where they were penetrated.

Lesquereux[3] describes in the American Journal of Science the fossil fruits found at Brandon, and compares certain of the forms with those afforded by the Lignitic of the Southwest. The following species are referred to by Lesquereux:

Carpolithes brandoniana Les.
fissilis Les.
irregularis Les.
Grayana Les.
bursæformis Les.
venosus (?) Stern.
Carya verrucosa Les.
vermontana Les.
Fagus Hitchcockii Les.
Apeibopsis Heerii Les.
Gaudini Les.
Aristolochia Oeningensis Heer.
curvata Les.
obscura Les.
Sapindus americanus Les.
Illicium lignitum Les.
Drupa rhabdosperma (?) Les.
Leguminosites pisiformis (?) Heer.
Nyssa complanata Les.
microcarpa Les.
lævigata Les.

[1] Am. Jour. Sci., 2d ser., vol. 15, 1853, pp. 99–104.
[2] Geology of Vermont, vol. 1, 1861, pp. 226–240.
[3] Am. Jour. Sci., 2d ser., vol. 32, 1861, pp. 355–363.

Concerning the other localities in the State Hitchcock[1] says:

Wherever we have found brown hematite and manganese, or beds of ochre, or pipe clay, white, yellow, or red, in connection with beds of coarse sand or gravel, all lying beneath the drift and resting on the rocks beneath, we have regarded the deposit as an equivalent of that at Brandon just described, even though not more than one or two of the substances named be present.

Proceeding upon these grounds he correlates the deposits of 26 localities lying chiefly along the western slope of the Green Mountains.

As stated above, Lesley cast doubt upon the analogous character of these different beds. The statements of Lewis afford a partial explanation of the phenomena, but much more careful investigation is needed at the type locality, Brandon, before the relations of the beds can be fully comprehended.

Pennsylvania.—Several localities have been reported in Pennsylvania where lignite deposits are found under much the same conditions as in Vermont. Lewis[2] described in considerable detail a section which he obtained at Marble Hall, Montgomery County, in an excavation sunk about 40 feet into the unconsolidated strata.

It is as follows:

	Feet.
"Top dirt" yellow, impure	10
Soft white decomposed hydromica slate or impure "kaolin," containing occasional broken seams of sharp quartzite, but no pebbles	13½
Coarse white sand and rounded pebbles; apparently a decomposed sandstone	2
Tough mottled red clay	½
Blue plastic clay	7
Lignite in a very tough dark clay	3
Coarse yellow sand, with fragments of stony iron ore and with pebbles	2

The same locality had been earlier referred to by Lesley,[3] but as the lignite was supposed to be Triassic, its discovery was considered unimportant. Later, Lesley[4] reported lignite at Pond Bank, near Chambersburg, Franklin County, where it occurs in two beds, the lower 18 feet, the upper 4 feet in thickness. They are separated from one another by a bed of sand, while clay and sand are found above the upper layer.

Prime[5] mentioned in 1878 another locality, at Ironton, Lehigh County, where the lignite occurs associated with white clay. The parallelism of the strata described by Lesley and Prime to those in Montgomery County is given on the authority of Lewis. Both Lesley and Lewis assert the analogous nature of the Pennsylvania and Vermont deposits.

[1] Geology of Vermont, vol. 1, 1861, p. 234.

[2] Philadelphia Acad. Nat. Sci., Proc., vol. 32, 1880, pp. 282-291. Am. Assoc. Adv. Sci., vol. 29, 1880, pp. 427, 428.

[3] Philadelphia Acad. Nat. Sci., Proc., vol. 13, 1861, p. 77.

[4] Am. Phil. Soc., Proc., vol. 9, 1865, pp. 463-482.

[5] Report DD, 2d Geol. Surv. of Penn., 1878, p. 76.

Georgia.—A locality in Georgia near Berzelia, Richmond County, 16 miles from Augusta, is described by Lewis[1] from notes by Prof. N. A. Bibikov, of Augusta. He says concerning the locality:

> It is described as lying back of the outcrops of gneiss and limestone, and is apparently in a very similar geological position to the Pennsylvania locality. Iron ore, plastic clay, kaolin, and decomposed sandstone occur with the lignite. * * * The fossils appear to be fragments of trees, grasses, and other land plants, none of which, however, were sufficiently perfect to be determined.

The section is given below in detail:

	Feet.
Mottled clay	4
Decomposed sandstone, with thin layers of clay and nodules of pyrite at base	24
Lignite	2
Shale and clay	1
Lignite	3
Shale and clay	2
Lignite	1
Shale and clay	3
Lignite	5
Light-colored shale with fossil plants	6
Dark-colored (bituminous) shale	1
White clay with streaks of rose color, etc	8
Sandy clay	1
Ferruginous coarse sand, with nodules of clay-ironstone, clay and quartz pebbles	9
Light-colored shale	4
Yellowish sand	2
Sandy clay	8
White, very fine micaceous sand, with clay	11

Lewis, following in great measure the opinion of Hitchcock, says that the localities previously described in Vermont, Pennsylvania, and Georgia "indicate the existence of a great inland fresh-water Tertiary formation in eastern America during the Brandon period, once 50 miles broad and nearly 1,000 miles long." As stated in the introduction to this chapter, we have not as yet sufficient evidence to warrant such broad generalizations. Indeed, the few facts accessible are hardly indications of the conclusions cited. It seems more probable that the deposits were accumulated in a series of detached bogs and swamps that had been occasioned by depression parallel to the existing coast line.

The absence of fresh-water shells or remains of other forms of life than terrestrial vegetation points to circumscribed areas of deposition.

[1] Philadelphia Acad. Nat. Sci., Proc., vol. 32, 1880, pp. 289–291.

PACIFIC COAST REGION.

PRELIMINARY REMARKS.

The geology of the Pacific coast presents many unsolved problems. By no means the least among them is the interpretation of the Eocene.

By many eminent geologists the very existence of Eocene strata on the Pacific border has been doubted, while others have included much more of the Coast Range series within its limits than is here admitted. It will thus be seen that the wide difference of opinion which prevails among those who have written upon the geology of the Pacific coast must occasion great difficulty when an attempt is made to harmonize their statements.

Meager though our knowledge is, certain characteristic features present themselves which render necessary the separation of the Pacific coast Eocene into two well defined divisions or provinces. The strata of the two divisions, together with their fossil contents, show the diverse character of the conditions attending their deposition. In the one case, an open sea with marine sediments and fauna prevailed; in the other, an estuary where the deposits and life were of brackish-water origin. Stratigraphically the relations of these two divisions to one another are not known, and as the conditions attending the accumulation of the deposits were so different the fossils are in no case identical. The marine deposit has been found in isolated regions from southern California to Washington, and has been named the Tejon group by Prof. J. D. Whitney[1] from its type locality, Fort Tejon, California. The brackish-water deposit has only been recognized in northern Washington, where it occurs in two distinct areas on the eastern and western flanks of the Cascade Mountains. It has been called the Puget group by Dr. C. A. White.[2]

The correlation of the Eocene of the Pacific coast with that of the Atlantic border is rendered difficult, due to the marked difference in the specific characteristics of the fauna as a whole, though sufficient similarity exists in generic and family types to admit of broad comparison. In the succeeding pages the history, stratigraphy, and correlation of the Pacific coast Eocene will be considered.

[1] Geological Survey of California, Paleontology, vol. 2, 1869, p. 8.

[2] Am. Jour. Sci., 3d ser., vol. 36, 1888, p. 443; U. S. Geol. Surv., Bull. 51, 1889, p. 40.

HISTORICAL SKETCH.

The earliest investigations of the later geological formations of the Pacific coast were conducted by the Wilkes exploring expedition under Prof. James D. Dana,[1] in the year 1846, when large collections of Tertiary fossils were made near Astoria, Oregon. The fossils were described and referred by Conrad to the Miocene, although later considered by the same authority to be Eocene.[2]

In an article in the American Journal of Science for 1848, Conrad[3] describes 14 new species from the same locality, while Shumard,[4] in the Transactions of the Academy of Science of St. Louis, later adds a few more.

An important contribution to the Eocene of California was made by Conrad[5] in 1855, in the Pacific Railroad Reports. He describes a group of fossils he considers to be Eocene, which Blake had discovered in a bowlder at the mouth of the Cañada de las Uvas, in southern California.

The succeeding year Trask[6] read before the California Academy of Natural Sciences a paper entitled a "Description of a new species of Ammonite and Baculite from the Tertiary Rocks of Chico Creek," in which he expresses views that have especial interest on account of the opinions subsequently held as to the geological range of those forms in the Coast Range series.

The geological survey of California, conducted by Prof. J. D. Whitney, published, in 1864, Paleontology, vol. 1, in which the Cretaceous fossils are described by W. M. Gabb.[7] In this work Gabb divides the Cretaceous into Divisions A and B, the latter (B) including the fauna previously referred by Conrad to the Eocene. He also mentions the range of species from Division A into Division B.

A review of this work was published by Conrad[8] in the American Journal of Conchology in which he states that "Mr. Gabb has included the rock of Cañada de las Uvas, which contains *Venericardia planicosta* and *Aturia zic-zac*, in the Cretaceous series, but he has failed to show one Cretaceous fossil from that rock [B]." In regard to the divisions of the Cretaceous strata (A and B), proposed by Gabb, Conrad says further, "The former [A] is, doubtless Cretaceous, and the latter [B], I am sure, will prove to be Older Eocene."

Gabb[9] replies to Conrad's criticism in a paper published in the succeeding volume of the same journal, in which he denies that "he has failed to show one Cretaceous fossil from that rock [B]." He gives a

[1] Wilkes Exploring Expedition, vol. 10, 1849, pp. 611–678.
[2] Am. Jour. Conch., vol. 1, 1865, p. 150.
[3] Am. Jour. Sci., 2d ser., vol. 5, 1848, pp. 432–433.
[4] St. Louis Acad. Sci., Trans., vol. 1, 1858, pp. 120–125.
[5] Preliminary Report Pacific Railroad Surveys, Paleontology, 8vo, 1855,; Pacific Railroad Reports, 4to, vol. 5, 1856, pp. 317–329.
[6] California Acad. Nat. Sci., Proc., vol. 1, 1856, pp. 92–93.
[7] Geol. Survey California, Paleontology, vol. 1, 1864, pp. 55–236.
[8] Am. Jour. Conch., vol. 1, 1865, pp. 362–365.
[9] Ibid., vol. 2, 1866, pp. 87–92.

list of 14 species that are common to the two divisions (A and B), and subsequently proceeds to show the Cretaceous character of some 20 other forms.

A few pages later Conrad[1] defends his earlier position in regard to the age of the strata in question and states that Gabb has only succeeded in referring "one exclusively Cretaceous genus to that division." As regards the presence of similar faunal characters in the two divisions, he suggests in a foot-note the explanation that "the Lower Eocene beds of Jamaica contain masses of Cretaceous limestone, and it may be that the California Lower Eocene strata contain similar masses." Conrad considers the several forms which are held by Gabb to prove the Cretaceous age of the deposits and shows many of them to be Tertiary in character.

The year following the appearance of Paleontology, vol. 1, of the Geological Survey of California, Professor Whitney published Geology, vol. 1. In this work the characteristics of the Upper Cretaceous (Division B—Eocene) are described in detail, and although depending upon the conclusions of Gabb for the taxonomy of the deposits, he presents an important résumé of the stratigraphical features of the beds.

In 1866 there appeared in the Smithsonian Miscellaneous Collections a "Check list of the Invertebrate Fossils of North America—Eocene and Oligocene—by T. A. Conrad." The species placed by Gabb in divison B of the Cretaceous together with five common to A and B are included in the Eocene.

At a meeting of the California Academy of Natural Sciences in November, 1866, a paper by Gabb[2] "On the Subdivisions of the Cretaceous Formation in California" was read, in which omissions in Conrad's Check List from his series of fossils from division B are mentioned. In this article the author restates his previous position in greater detail than before and gives a table showing the geological range of the different species. He enumerates sixteen forms common to the upper and lower divisions.

Two articles appeared in the American Journal of Science for 1867, by Gabb[3] and Conrad[4]. In the first, Gabb gives the substance of his paper before the California Academy of Natural Sciences; while in the second, Conrad defends himself against the charges preferred by Gabb in his latest publications, and at the same time claims, as in earlier papers, that "any evidence so far is wanting to prove the strata in question Cretaceous, and as the group of fossils is so decidedly Tertiary in their forms and some species identical, I am forced to the conclusion of their Eocene origin."

[1] Am. Jour. Conch., vol. 2, 1866, pp. 97–100.
[2] California Acad. Nat. Sci., Proc., vol. 3, 1867, pp. 301–306.
[3] Am. Jour. Sci., 2d ser., vol. 44, 1867, pp. 226–229.
[4] Ibid., pp. 376, 377.

In the preface to Paleontology, volume 2 of the Geological Survey of California, Professor Whitney proposes the name Tejon Group for Division B of Gabb's Cretaceous, from its characteristic occurrence in the vicinity of Fort Tejon.[1] Other important localities are referred to.

Two short articles by J. G. Cooper on the Eocene of California appeared in the Proceedings of the California Academy of Science[2] for 1874, in which the opinions expressed by Gabb and Conrad are commented on.

A very important contribution to the geology of the Pacific coast was published in the Report of the Chief of Engineers for 1876 by Prof. Jules Marcou,[3] being part of the Annual Report of the Geographical Surveys West of the One Hundredth Meridian. The writer defends the position taken by Conrad, but goes further in that he includes in the Eocene the Chico group, upon which the Tejon group conformably rests. In regard to the latter he says:

> I was not able to find a single Cretaceous fossil, nor even any true Cretaceous generic forms in the entire formation; and I am altogether of the opinion expressed by Mr. Conrad, many years before Mr. Gabb, in volume 5 of Pacific Railroad Explorations, pages 318–320 et. seq., who, judging from certain fossils found in an isolated block at the entrance of the Cañada de la Uvas, has very judiciously referred these rocks to the Eocene-Tertiary formation.

He further considers them upper Eocene.

Prof. Dana,[4] in the revised edition of his Manual of Geology likewise asserts the Tertiary age of the Tejon series and refers the same to the Lignitic or Lower Eocene.

Heilprin,[5] in 1882, in a communication to the Academy of Natural Sciences of Philadelphia, "On the occurrence of Ammonites in deposits of Tertiary age," states the results of an investigation of the original types described by Gabb in the reports of the Geological Survey of California. He says:

> That, with the exception of one solitary fragment of an ammonite, there was, to his knowledge, not a single distinctively Cretaceous type of organism to be found in all the rock fragments, but, on the contrary, several genera, distinctively Tertiary, and not known anywhere to have appeared before that period.

In the same volume of the Proceedings of the Academy of Natural Sciences of Philadelphia, Prof. J. S. Newberry[6] replies to Prof. Heilprin. He considers the evidence brought forward for the Tertiary age of the Tejon group not sufficient to overthrow the conclusions of Gabb and Whitney, who had the advantages of exhaustive study in the field. Dr. Newberry adds, "but there are many species common to the Tejon and Chico groups, and where one goes the other must follow."

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[1] Geol. Surv. California, Paleontology, vol 2, 1869, p. xiii.
[2] California Acad. Sci. Proc., vol. 5, 1874, pp. 419–421, 422.
[3] Report of the Chief of Engineers for 1876, Part III, pp. 378–392.
[4] Manual of Geology, revised edition, 1880, pp. 491, 508.
[5] Philadelphia Acad. Nat. Sci., Proc., vol. 34, 1882, p. 94.
[6] Ibid., pp. 194, 195.

In a later article "On the Age of the Tejon Rocks of California and the occurrence of Ammonitic Remains in Tertiary Deposits" Heilprin[1] reviews very critically the conclusions of Gabb and shows many errors in the statements of that writer. In conclusion he says:

We believe it has been satisfactorily shown from what has preceded, that the rocks of the Tejon group (Cretaceous, Div. B.,of the California Survey), despite their comprising in their contained faunas a limited number of forms from the subjacent (Cretaceous) deposits, and a few undoubted representatives of the Ammonitidæ are of Tertiary (Eocene) age, and for the following reasons:

I. The large percentage (about 80, or possibly considerably more) of specific forms that are peculiar to the group, or, at least are not found in the older deposits;

II. The large proportion of generic forms (33 out of 77) that are not represented in the underlying or older strata;

III. The presence of twenty-two more or less distinctively Tertiary genera: Ancillaria, Bulla, Bullæa (Megistomata), Bullia (s. g. Molopophorus), Conus, Crepidula, Cassidaria, Cancellaria, Cypræa, Ficus (Ficopsis). Gadus, Mitra, Massa, Niso, Olivella, (or Oliva), Pseudoliva, Rimella, Sigaretus (or Naticina), Terebra, Triton, Trochita, and Typhis.

IV. The marked absence (with the exception of about a half a dozen fragments or specimens of Ammonitidæ) of distinctively Cretaceous organic types.

V. The identity or close analogy existing between several of the specific forms and their representatives from other well determined Tertiary (Eocene) deposits.

In an article entitled "Note sur la Géologie de la Californie"[2] Prof. Jules Marcou restates his grounds for including the entire Chico-Tejon series in the Eocene.

In "Notes on the Mesozoic and Cenozoic Paleontology of California" Dr. C. A. White[3] reviews the paleontological evidence presented in the Chico-Tejon series and says:

I think the evidence which has been adduced to show the Eocene age of the upper or Tejon portion of the Chico-Tejon series is as conclusive as any evidence of that kind can be. Now, if we apply the paleontological standard for indicating the age of formations which is generally accepted by geologists, we necessarily refer the fossils of the lower or Chico portion of that series to the Cretaceous.

The more detailed reasons for these conclusions will be examined in the next chapter.

In a later bulletin the same writer[4] considers "The Occurrence of *Cardita planicosta* Lamarck in western Oregon." He cites its discovery at Albany, Willamette Valley, Oregon, in a well-digging.

In "Notes on the Stratigraphy of California" Dr. Becker[5] mentions the conformity that is found between all the beds from the Chico to the Miocene.

In "A Report of the Coal Fields of Washington Territory" Mr. Bailey Willis[6] describes deposits in the vicinity of Puget Sound, on the

[1] Philadelphia Acad. Nat. Sci., Proc., vol. 34, 1882, pp. 196–214. Reprinted in "Contributions to the Tertiary Geology and Paleontology of the United States," 1884, pp. 102–117.

[2] Bulletin de la Société géologique de France, 3e serié, tome 11, 1883, pp. 415, 416.

[3] U. S. Geol. Surv., Bull. 15, 1885, p. 16.

[4] U. S. Geol. Surv., Bull. 18, 1885, pp. 7–9.

[5] U. S. Geol. Surv., Bull. 19, 1885, pp. 12, 16, 17.

[6] Tenth Census of the United States, vol. 15, Mineral Industries, 1885, pp. 759–771.

Green River and at Wilkeson, and also on the east slope of the Cascade Mountains, that he considers to be representatives of the Laramie formation. The evidence, chiefly derived from the fossil flora, is given on the authority of Prof. J. S. Newberry.

In the American Journal of Science for 1888 Dr. C. A. White[1] characterizes the Puget group and indicates its relations to the Laramie formation on the one hand and the Chico-Tejon series on the other. The estuarine character of the fauna is commented on. The discovery of marine Eocene fossils on the Dwamish River is also adverted to.

In a later publication[2] "On Invertebrate Fossils from the Pacific Coast" Dr. White describes the Puget group in greater detail, and gives new localities in Oregon and Washington where the Chico-Tejon series is represented.

From this brief outline of the literature upon the Pacific coast Eocene it will be observed that, except at a very few isolated points the deposits have not been examined, and that even many of those who have written upon the subject have had little opportunity for close observation of the strata. As might be expected, our knowledge of the Pacific Coast region is but fragmentary, and much detailed work remains to be done before the many diverse opinions expressed will be fully harmonized.

STRATIGRAPHICAL AND PALEONTOLOGICAL CHARACTERISTICS.

We have but few facts to guide us as to the distribution of the Eocene upon the Pacific Coast. That it extends more or less widely along the east flank of the Coast Range is known from several isolated exposures that have been examined in central and southern California, and that it is not absent even farther north is proved by the discovery of fossils in Oregon and Washington. To what extent the strata of these separate districts may be continuous it is difficult to judge on account of the lack of data upon which to base conclusions.

As stated in the introduction, two clearly defined divisions have been recognized in the Eocene, the one marine, the other brackish water in character. The former, called the *Tejon group*, is found represented in California, Oregon, and Washington; the latter, the *Puget group*, in Washington alone. Stratigraphically and paleontologically, no direct ground for comparison is afforded, but that the two groups are probably wholly or in part synchronous will be later shown.

THE TEJON GROUP.

The Tejon group, first so called by Prof. Whitney, is typically developed in the vicinity of Fort Tejon, Kern County, California. From this point the strata extend northward and southward along the eastern flank

[1] Am. Jour. Sci., 3d ser., vol. 36, 1888, pp. 443-450.
[2] U. S. Geol. Surv., Bull. 51, 1889, pp. 11-32, 49-63.

of the Coast Range Mountains. They form a narrow belt, frequently interrupted as the result of denudation and volcanic outflows, though much of the irregularity is held to be "due to organic irregularity of the coast lines of the sea in which these strata were deposited."[1]

To the north of Fort Tejon the strata are prominently developed near New Idria, where they have been investigated by Dr. White.[2] In Contra Costa County a continuous belt extends from near Marshes to Martinez, while to the north of the Central Pacific Railroad the Tejon group is not known to appear again within the State of California.[3] In Oregon it has been found at Albany, in the Willamette Valley, and in the vicinity of Coos Bay, Cape Arago. Certain strata near Astoria are doubtfully referred by Dr. White[4] to the same horizon, the presence of which later investigations by Dr. W. H. Dall have fully established. Strata with marine fossils, many of them identical with those of the Tejon group of California, have been found on the Dwamish River, in Washington, and have been considered to represent that formation in the extreme north.

It will thus be seen that the marine Eocene strata have been established at many localities along the Pacific coast, and do not form an unimportant member in the Coast Range series. The deposits are chiefly conglomerates, sandstones, and shales, in which beds of lignite are not infrequently intercalated, and which less often contain bands of calcareous rock. The strata of the Tejon group conformably overlie the next older or Chico group,[5] and are in turn conformably overlain by the Miocene, a relationship which was first recognized by the members of the California Geological Survey and since substantiated by White and Becker.

The strata of the Tejon group in the vicinity of Fort Tejon, at the entrance to the Cañadas de las Uvas and de los Alisos, consist chiefly of sandstones and conglomerates.

> The conglomerates are very coarse, containing many bowlders from 3 to 6 inches in diameter of granite and metamorphic rocks. * * * Portions of the sandstones are very fossiliferous and the shells in beautiful preservation. * * * The strata are very much disturbed, both dip and strike being very variable, the former varying from northwest and southeast to northeast and southwest, while the dip is sometimes to the north and again to the south and generally at a high angle.[6]

It was from this locality that Conrad received the fossils described in volume 5 of the Pacific Railroad reports, and from whence Gabb also obtained many of the forms referred by him to Division B of the Cretaceous, in the paleontological publications of the California Geological Survey.

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[1] U. S. Geol. Surv., Bull. 51, 1889, p. 29.

[2] U. S. Geol. Surv., Bull. 15, 1885.

[3] U. S. Geol. Surv., Bull. 51, 1889, p. 29. (Whitney and Gabb, however, mention localities in Lake and Mendocino counties.)

[4] U. S. Geol. Surv., Bull. 51, pp. 31–32.

[5] The Martinez group of Gabb is considered part of the Chico group.

[6] Geol. Surv. California, Geology, vol. 1, pp. 190, 191.

In regard to the stratigraphical relations of the Tejon group to the Chico group on the one hand, and the Miocene on the other, White[1] and Becker[2] present some valuable data from the vicinity of New Idria. The former says in regard to the Chico-Tejon series of that locality, that the strata are mainly sandstones and sandy shales, and adds:

They dip to the northward, the angle of dip being high near their contact with the metamorphic series upon which they rest unconformably; but the dip materially diminishes to the northward. From the contact with the metamorphic series before mentioned the thickness of this whole strata is estimated to be about 10,000 feet.

Dr. White further says:

The whole assemblage of strata, nearly 2 miles in thickness, forms one continuous series from top to bottom, and the sedimentation which resulted in the production of these strata was uninterrupted from the beginning to the end of the time in which it occurred. * * * Although this New Idria series is understood to be practically an unbroken one, there is, near its middle, a recognizable change in the aspect of the strata, so that in appearance, and to some extent in the character of the stratification, the upper half differs from the lower half. So far as can be determined, this indistinct line accords with the necessarily artificial division that has been made of the series into the Chico and Tejon groups, since the series is recognized as containing only these two groups, and the line of demarkation between them, as before shown, can not be expected to be distinct. * * * Still the intimate relation of the Chico and Tejon groups for this particular locality is well shown by the unbroken character of the series of strata which here constitutes both groups.

Dr. Becker says in this connection that "the Tejon strata of New Idria are mostly heavy-bedded sandstones of a peculiarly light color, which thus distinguishes them from the tawny Chico sandstones."

At the same time the evidence for the Eocene age of the Tejon group is shown by Dr. White from the stratigraphical position of the deposits. He says:

The opinion that the Tejon group really represents the Eocene is further supported in that no other representative of the strata of that epoch has been discovered in California, and also the Miocene strata everywhere rests conformably upon the Tejon. This conformity was recognized by the members of the State Geological Survey of California, and it has also been observed in numerous cases by Dr. Becker, as well as in several instances by myself. One of these observations I made at the well known Tejon and Miocene locality at the head of Vallecitos Cañon, near the place mentioned as "Griswold" in the California reports, which is only a few miles from the New Idria locality just referred to. I then satisfactorily traced the strata from one formation to the other, and found that not only is the conformity of the two formations with each other clearly apparent, but no break in the order of stratification could be detected between those layers which contain characteristic Tejon fossils on the one hand and those which contain equally characteristic Miocene fossils on the other. In short, I found no room there for the existence of any Eocene strata other than the Tejon.

In regard to the stratigraphical relationship of these beds at New Idria, Dr. Becker also says,[3] "The Miocene seems as strictly conformable with the Tejon as this with the Chico."

[1] U. S. Geol. Surv., Bull. 15. [2] U. S. Geol. Surv., Bull. 19.
[3] U. S. Geol. Surv., Bull. 19, 1885, p. 17.

In Contra Costa County the Tejon group is prominently exhibited as a thick-bedded sandstone, with layers of carbonaceous matter of sufficient thickness to afford workable seams of coal. The relationship of the beds is similar to that before mentioned for the region of New Idria. Prof. Whitney states[1] that "all these strata, from the Cretaceous up to the post-Pliocene, appear to be perfectly conformable to each other." Dr. Becker[2] says upon the same point:

> The stratigraphical relations * * * show a continuous sedimentation * * * between the Chico and Tejon. Between the Tejon and Miocene there is nowhere any suggestion of a nonconformity. * * * At Mount Diablo, for example, the Miocene seems as strictly conformable with the Tejon as this with the Chico.

In regard to the position of the strata Dr. Becker[3] further says:

> Mount Diablo and the surrounding country consist of a core of metamorphic rock, inclosed, nearly or quite quaquaversally by rocks of Chico and Tertiary age. * * * The overlying Chico, Tejon, and Miocene strata are tilted, but otherwise comparatively undisturbed. Over wide areas these three series seem to be perfectly conformable, nor is there any case known on the Pacific coast where there seems any ground for suspecting a nonconformity within these limits.

To the north of Mount Diablo, in the vicinity of Martinez, the Tejon group is prominently represented by sandstones that dip southwest at an angle of 35° to 60°. This locality furnished a large number of the fossils described by Gabb.

The Tejon strata of Oregon have been found in a few widely separated localities in the central and northern portions of the State. The most southern yet observed is on Coos Bay. In the Willamette Valley, at Albany, the Tejon occurs as an "indurated dark colored shale which was found a few feet beneath the surface of the ground in digging a cistern." Inregard to the age of the deposits at Astoria Dr. White entertains doubts, though he considers it probable that the Eocene is represented. Dr. Dall has more recently established the presence of the Eocene at this point. He has found it overlain by Miocene and states that a misunderstanding as to the stratigraphical relations of the beds has hitherto existed. The Eocene is found to consist of a thin band of argilla-ceous material, through which numerous calcareous nodules are scattered, at the center of which fragments of shells are generally found.

The stratigraphy of the beds on the Dwamish River, in Washington, have been studied by Bailey Willis in reference to their relationship to the Puget group and found to afford no data for connection with the strata of that formation. As in the Oregon localities, a comparison of the deposits with those of other areas is based on the similarities afforded by the fossils rather than on stratigraphical grounds.

Having thus briefly reviewed the more striking stratigraphical fea-

[1] Geol. Surv. California, Geology, vol. 2, 1864, p. 32.
[2] U. S. Geol. Surv., Bull. 19, 1885, pp. 16, 17.
[3] Ibid., p. 15.

tures of the Tejon group, an examination of the fossils is imperative, as upon the evidence from that source the taxonomic interpretation of the widely scattered deposits above described must depend.

Conrad first and Gabb and White subsequently have described the fauna of that period and drawn conclusions as to the proper position to be assigned to the Tejon group in the geological column.

The fossils referred by Gabb[1] to the Tejon group are:

Callianassa Stimpsonii Gabb.
Aturia Mathewsonii Gabb.
Ammonites jugalis Gabb.
Typhis antiquus Gabb.
Fusus Martinezensis Gabb.
F. Mathewsonii Gabb.
F. diaboli Gabb.
F. californicus Con., sp.
? Neptunea supraplicata Gabb.
Neptunea cretacea Gabb.
Perissolax Blake Con., sp.
Surcula præattenuata Gabb.
S. sincuata Gabb.
S. claytonensis Gabb.
S. raricostata Gabb.
Bela clathrata Gabb.
Cordiera microptygma Gabb.
Tritonium diegoensis Gabb.
T. tejonensis Gabb.
T. fusiforme Gabb.
T. Hornii Gabb.
T. paucivaricatum Gabb.
T. Whitneyi Gabb.
T. californicum Gabb.
Brachysphingus liratus Gabb.
B. sinuatus Gabb.
Bullia striata Gabb.
Nassa cretacea Gabb.
N. antiquata Gabb.
Pseudoliva lineata Gabb.
P. volutæformis Gabb.
Olivella Mathewsonii Gabb.
Ancillaria elongata Gabb.
? Fasciolaria læviuscula Gabb.
F. sinuata Gabb.
F. io Gabb.
Mitra cretacea Gabb.
Whitneyi ficus Gabb.
Ficus mamillatus Gabb.
Ficopsis Remondii Gabb.
F. Hornii Gabb.
F. Cooperii Gabb.
Natica uvasana Gabb.
Lunatia Hornii Gabb.
L. nuciformis Gabb.
Neverita secta Gabb.
N. globosa Gabb.
Naticina obliqua Gabb.
Euspira alveata Con., sp.
Morio tuberculatus Gabb.
Scalaria Mathewsonii Gabb.
Terebra californica Gabb.
Niso polita Gabb.
Cerithiopsis alternata Gabb.
Architectonica cognata Gabb.
A. Hornii Gabb.
Conus Remondii Gabb.
C. Hornii Gabb.
Rimella canalifera Gabb.
R. simplex Gabb.
Cypræa Bayerquei Gabb.
C. Mathewsonii Gabb.
Loxotrema turrita Gabb.
Turritella uvasana Con.
T. martinezensis Gabb.
Galerus excentricus Gabb.
Spirocrypta pileum Gabb.
Nerita triangulata Gabb.
Margaritella crenulata Gabb.
Dentalinum Cooperii Gabb.
D. stramineum Gabb.
Gadus pusillus Gabb.
Bulla Hornii Gabb.
Cylichna costata Gabb.
Megistostoma striatum Gabb.
Martesia clausa Gabb.
Solen parallelus Gabb.
S. diegoensis Gabb.
? Corbula primorsa Gabb.
C. Hornii Gabb.
C. parilis Gabb.
Neæra dolabræformis Gabb.
Cymbophora Ashburnerii Gabb.
Gari texta Gabb.
Tellina longa Gabb.
T. Remondii Gabb.

[1] Geol. Surv. California, Palaeontology, vol. 2, pp. 207–254. The localities in Lake and Mendocino Counties are not considered. The "intermediate beds" at Clayton are included in the Tejon group.

Tellina Hoffmanniana Gabb.
T. Hornii Gabb.
T. californica Gabb.
Donax latus Gabb.
Venus æquilateralis Gabb.
Meretrix uvasana Conn.
M. Hornii Gabb.
M. ovalis Gabb.
M. californica Con.
Dosinia elevata Gabb.
D. gyrata Gabb.
Tapes Conradiana Gabb.
T. quadrata Gabb.
T. cretacea Gabb.
Diodus tenuis Gabb.
Cardium Cooperii Gabb.
C. Brewerii Gabb.
C. linteum Con.
Cardita Hornii[1] Gabb.
Lucina cumulata Gabb.
? L. cretacea Gabb.
Mysia polita Gabb.
Crassatella grandis Gabb.
C. uvasana Con.
Unio penultimus Gabb.
Mytilus ascia Gabb.
M. humerus Con.
Modiola ornata Gabb.
Septifer dichotomus Gabb.
Stalagmium concentricum Gabb. sp.
Avicula pellucida Gabb.
Arca Hornii Gabb.
Cucullæa Mathewsonii Gabb.
Barbatia Morsei Gabb.
Axinæa sagittata Gabb.
A. cor Gabb.
Nucula truncata Gabb.
Leda Gabbii Con., sp.
Pecten interradiatus Gabb.
Placunanomia inornata Gabb.
Ostrea idriaensis Gabb.
Flabellum Remondianum Gabb.
Trochosmilia striata Gabb.

To this list Dr. White[2] has added—

Zirphæa plana White.
Cancellaria Turneri White.

The presence of a sufficient number of the fossils above enumerated at each of the leading localities on the east flank of the Cascade Mountains renders their correlation probable. Although the number of forms found in the more northern and widely separated Oregon and Washington areas is not so great, yet the identification of the few forms discovered leaves little doubt as to the Eocene age of the deposits.

In the Willamette Valley at Albany *Cardita planicosta* Lamarck has been identified, while from Cape Arago Dr. White has recognized—

Nucula truncata Gabb.
Cardita planicosta Lamarck.
Meretrix uvasana Conrad.
Naticina obliqua Gabb.
Turritella uvasana Conrad.
Fusus californicus Gabb.
Perissolax Blakei (Conrad) Gabb.

Concerning the deposits at Astoria, although considering them in part Miocene, Dr. White is of the opinion that the Chico-Tejon series may be also represented. He says in regard to the similarity of their fossils:

The *Nucula divaricata* of Conrad differs, if at all, from *N. truncata* Gabb only in the asserted rounding instead of the truncation of the posterior ("anterior") extremity; and yet one of Mr. Conrad's figures shows such a truncation. The *Mactra albaria* of Conrad is exceedingly like *M. Ashburnerii* Gabb. The *Loripes paralis* of Conrad recalls *L. dubia* Gabb. The *Pyrula modesta* or Conrad is possibly identical with *Ficus* (?) *cypræoides* Gabb, and the Survey collections contain specimens of *Solen* from the Tejon group of California, which closely resemble Conrad's figure of *S. curtus*. Besides this the *Aturia angustatus* of Conrad from Astoria is much like *A. mathewsoni* Gabb of the Tejon group of California; and the presence of that genus in the Miocene strata seems out of place.

[1] Probably Cardita planicosta Lamarck.
[2] U. S. Geol. Surv. Bull. 51, 1889, pp. 15, 25.

The more recent investigations of Dr. Dall, above referred to, establish the truth of these conclusions. He finds that the earlier collections of fossils were made indiscriminately from the Eocene and Miocene horizons, and this accounts for the confusion that has hitherto existed.

The locality upon the Dwamish River, Washington, is the most northerly one yet known that affords fossils of Tejon age. In a collection made at that point the following species have been recognized:

Cylichna costata Gabb.
Conus Hornii Gabb.
Lunatia nuciformis Gabb.
Leda protexta Gabb.
Euspira alveata (Conrad) Gabb.
Fusus diaboli Gabb.
Turritella uvasana Gabb.
Tellina sp. (?)

The above forms establish beyond much doubt the presence of Tejon strata in western Washington.[1]

The faunal relationship of the Tejon group to the Chico on the one hand and the Miocene on the other is deserving of particular attention. It has already been shown that the stratigraphical individuality of the Chico and Tejon groups is not clearly defined, but that the latter rests conformably upon the former and presents but a slight lithological change in its deposits. At the same time several forms are found common to the two groups, and Gabb[2] gives in the second volume of the Paleontology of California, 15 species.

Callianassa Stimpsoni Gabb.
Aturia Mathewsonii Gabb.
Ammonites jugalis Gabb.
Fusus Mathewsonii Gabb.
Euspira alveata Conrad, sp.
Dentalium Cooperii Gabb.
D. stramineum Gabb.
Cylichna costata Gabb.
Martesia clausa Gabb.
Mactra (Cymbophora) Ashburnerii Gabb.
Tellina Hoffmanniana Gabb.
Avicula pellucida Gabb.
Cucullæa Mathewsonii Gabb.
Nucula truncata Gabb.
Leda Gabbii Conrad, sp.

Upon the forms here enumerated as common to the two groups Heilprin[3] has thrown some doubt as to the validity of three, *Mactra Ashburnerii* Gabb, *Tellina Hoffmanniana* Gabb, and *Leda Gabbii* Con., sp. That a commingling of species occurs in the Chico-Tejon series seems to be established. Dr. White[4] says in this connection: "I am satisfied that such a commingling does exist, as before indicated, and that an alternate commingling of species exists throughout the whole of the Chico-Tejon series."

On the other hand, although the Miocene conformably overlies the Tejon group, the faunal relations are not so clearly shown. No species have hitherto been considered identical, though Dr. White says that "a few of the species of each of the two formations are closely related, and it is possible that some of them may yet prove to be specifically identical."

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[1] U. S. Geol. Surv., Bull. 51, 1889, pp. 30–31.

[2] In California Acad. Sci., Proc., vol. 3, pp. 301–305, he gives 16 species. *Nautilus texanus* is omitted, however, in the State Report and *Ammonites* n. s. is determined as *Am. jugalis*.

[3] Philadelphia Acad. Nat. Sci., Proc., vol. —, pp. 18.

[4] U. S. Geol. Surv., Bull. 15, 1885, p. 13.

THE PUGET GROUP.

The term Puget group has been applied by Dr. White to a series of brackish-water deposits in Washington. They are found along the eastern side of the Puget Sound Basin on the western flank of the Cascade Range, as well as upon the eastern side of the same mountains, although the identity of the strata in the two regions has not yet been fully determined.

In the Puget Sound region the best sections have been obtained by Bailey Willis in the Wilkeson and Green River coal fields, while to the east of the Cascade Range the strata have been identified by the same observer in several localities, which are enumerated as follows:

> Near the head of the Yakima River and on the Wenatchie River, * * * near Lake Kitchelas, Lake Klealim, and on Schwak Creek, a small tributary of the Yakima from the north * * * south of the Wenatchie, on the spur of the Cascades called the Peshasten Range, which divides that river from the Yakima, and at the head of the Munastash Creek, 25 miles west of Ellensburg, at an elevation of 5,500 feet on the main Cascade Range.[1]
>
> The strata in the Puget Sound Basin consist of alternating beds of yellow and gray fine-grained sandstones and very fine gray arenaceous shales interstratified with many beds of carboniferous shale and coal; the individual strata of sandstone and shale, from 20 to 200 feet thick, maintain the same general character wherever observed, and no well defined horizon has yet been found which might serve as an index to correlate the widely separated exposures.[2]

Mr. Willis, whose description of the deposits has just been quoted, estimates the maximum thickness of the strata at over 10,000 feet. In the Wilkeson field he states that there "are 127 carbonaceous beds, of which 17 are workable coal veins, 3 to 15 feet thick." To the east of the Cascade Range a similar development of carbonaceous strata has an approximate thickness of 1,000 feet, and rests on coarse sandstone and conglomerate.

The character of the deposits and their entombed fossils show that brackish-water conditions certainly prevailed over the area in which the strata are now exposed, and doubtless over a much wider region. If the coal-bearing strata upon the eastern and western flanks of the Cascade Range prove to be of the same age the topography of the period must have been very different from the present, and since the carbonaceous strata have been found absent from the higher portions of the Olympic and Northern Cascade Mountains, it has been supposed that those ranges may have constituted an island and a peninsula respectively. Acting as barriers against the open sea the estuarine conditions necessary for the formation of the carbonaceous strata may have been developed.

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[1] Tenth Census Report, vol. 15, p. 761. [2] Ibid., p. 759.

The following invertebrate fossils have been obtained from the Puget group:[1]

Cardium (Adacna?) sp.
Cyrena brevidens White.
Corbicula pugetensis White.
Corbicula Willisi White.
Batissa Newberryi White.
Batissa dubia.
Psammobia obscura White.
Sanguinolaria? caudata White.
Teredo pugetensis White.
Neritina sp.
Cerithium? sp.

Among the plant remains examined by Prof. Newberry[2] are *Sphenopteris* (*Asplenium*) *elongata* Newberry, which, according to that distinguished paleontologist, is the same as *Gymnogramma Haydeni* Lesq., *Asplenium subcretaceum* Saporta, and *Anemia subcretacea* Gardner, an important and widespread species. *Calamosis Danæ* Lesq., *Onoclea sensibilis* Linn., *Lygodium Kaulfussi* Herr, the latter probably identical with *L. neuropteroides* Lesq., are mentioned by the same investigator as represented in the Puget group.

GROUNDS FOR THE REFERENCE OF THE TEJON AND PUGET GROUPS TO THE EOCENE.

In the preceding remarks on the Pacific Coast region the assumption has been made that the Tejon and Puget groups are the equivalents of the Eocene of other areas. As this position has been much discussed in the past, particularly as regards the Tejon group, and is not admitted by all geologists to-day, the evidence for their reference to the Eocene will be briefly outlined.

In the Historical Sketch it was stated that Whitney and Gabb considered the entire Chico Tejon series as Cretaceous, while Marcou as zealously advocated its Tertiary age. In the present paper the Chico is referred to the Cretaceous, the Tejon to the Eocene.

Before considering the grounds for this division of a conformable series of deposits that at the same time possess in common several identical species, let us first examine the evidence for referring the entire formation to the same horizon, in the one case to the Cretaceous and in the other to the Eocene.

The lower division, the Chico, contains a large number of ammonitic forms, which have been hitherto considered by paleontologists to denote the Mesozoic age of the strata in which they are found, among which species of Hamites, Turrilites, Ancyloceras, Crioceras, and Baculites are included, while the lamellibranchiate genera, Trigonia, Inoceramus, Gryphæa, and Exogyra, likewise considered Mesozoic in character, are not uncommon. In the upper division, the Tejon, *Ammonites jugalis* Gabb is found, while several genera of gasteropoda are also cited by Gabb as characteristically Cretaceous, though their determination is shown by Conrad and Heilprin to be founded on error as to the generic relations of the specimens or the localities from which they were derived.

[1] U. S. Geol. Surv., Bull. 51, p. 58. [2] Ibid., p. 51.

Concerning the reference of the entire Chico-Tejon series to the Tertiary, on the other hand, Marcou states that the Ammonites are degenerate types, and further that there is "no law which makes it necessary for Ammonites * * * to disappear entirely from the surface of the terrestrial globe with the rocks of the secondary epochs." From the Chico he cites the presence of the following genera that collectively he considers indisputable evidence for the Tertiary age of the fauna: Fusus, Lævifusus, Neptunea, Sycodes, Gyrodes, Natica, Architectonica, Straparollus, Pugnellus, Anchura, Littorina, Turritella, Nerita, Lysis, Calliostoma, Angaria, Margaritella, Dentalium, Patella, Helcion, Ringicula, Cinulia, Cylichna, Martesia, Siliqua, Corbula, Anatina, Cymbophora, Lutraria, Asaphis, Tellina, Venus, Chione, Meretrix, Caryatis, Dosinia, Trapezium, Cardium, Clisocolus, Lucina, Astarte, Anthonya, Mytilus, Modiola, Meleagrina, Meekia, Arca, Cucullæa, Nucula, Leda, Pecten, Lima, Anomia, and Ostrea.

For the Tejon he states that the Tertiary genera, Fusus, Tritonium, Trachytriton, Olivella, Fasciolaria, Lunatia, Turritella, etc., are numerous, and that Eocene species identical with those in Alabama and the London and Paris basins are found.

It seems to me, as already stated by Dana, White, and Heilprin, that the writers above quoted are in part right, in part wrong. The presence of so large a number of ammonitic forms in the Chico, together with such types as Inoceramus, Trigonia, Gryphæa, and Exogyra, is sufficient indication of the Cretaceous age of the Chico group. On the other hand, the presence in the Tejon of Lunatia, Crepidula, Turritella, Tritonium, Nassa, Mitra, Pseudoliva, Oliva, Conus, Cypræa, Rimella, and Donax, together with *Cardita planicosta* Lam. and other species identical or closely related to characteristic Eocene forms of other regions, although associated with a few ammonitic remains of a single species, is sufficiently strong evidence of its Tertiary age.

That no marked break occurred in the continuity of life in the Chico-Tejon series is proved by the fact that several species are found common to the upper and lower divisions. Deposition, from the structure of the beds and the absence of unconformity, was probably continuous. Forms that were numerous in the early part of the period gradually disappeared, and their place was taken by others that increased in importance toward its close.

To what horizon of the Eocene the Tejon should be referred can not be definitely stated. Conrad considered it Lower Eocene, while Marcou has stated that it belongs to the upper division. The presence of *Cardita planicosta* Lam. serves only for general comparison since it has been found ranging from the lower to the upper members of the Eocene in the Atlantic and Gulf Coast region. Heilprin and Marcou have shown the close relationship if not identity of several other species. *Cardita Hornii* Gabb is held to be identical with *C. planicosta* Lam. *Dosinia elevata* Gabb is thought to be the same as *Dosiniopsis*

Meekii Conrad, so common in the Maryland and Virginia Eocene. *Ficopsis* (*Hemifusus*) *Remondii* Gabb is considered to be very closely related to if not identical with *Pyrula penita* Conrad from Claiborne, Alabama. Other comparisons are made, some with forms from the Paris Basin and the English Eocene. From the fact that the Tejon conformably overlies the Chico and is in turn conformably overlain by the Miocene it is not improbable that the Tejon represents the entire Eocene series as elsewhere developed, but upon this point we have as yet too few data to draw conclusions. Further investigation may show that some important points have been hitherto overlooked.

The Puget group has been referred to the Eocene, though there is some doubt as to whether the entire formation can be properly considered such. In its flora Prof. Newberry has shown that the Puget group is to be closely compared to the Laramie, though the conditions under which the deposits of the former were accumulated were, in many particulars, unlike that of the latter. If the Puget group is to be correlated with the Laramie, it is not improbable that we have in the former the representatives of both the Chico and Tejon groups, and thus, as in both the Laramie and Chico-Tejon series, the break between the Cretaceous and the Eocene is, in part at least, bridged over. If such proves to be the case, the Puget group must be referred in part to the one horizon, in part to the other.

Prof. Newberry has compared *Sphenopteris* (*Asplenium*) *elongata* Newberry from the Puget group with *Gymnogramma Haydeni* Lesq. from the Laramie. He also has little doubt of the presence of *Onoclea sensibilis* Linn., which occurs in abundance at Fort Union. In regard to the faunal similarities of the Puget group and the Laramie Dr. White says:

> Such a comparison is especially suggested by the known floral relations of the two groups of strata, their presumble contemporaneity of origin, and the nonmarine character of the molluscan faunas of both. Upon making a comparison, however, important zoological differences appear. It is true there are two species of Corbicula in the Puget fauna that are so closely like Laramie forms as to suggest specific identity upon casual examination, but the differences between the two faunas are strikingly shown by the family and generic characters of the other members of the Puget fauna as compared with the Laramie fauna.

Teredo, Tellina, and Batissa occur in the Puget group, but are absent in the Laramie. The later genus has particular interest from the fact that it has not been found in North America before. It is confined to the Pacific Islands and Asiatic Continent.

At the same time the Puget group shows some points of similarity to the Lignitic of the Gulf border. *Calamopsis Danæ* Lesq. of Mississippi has been identified by Prof. Newberry.

INTERIOR REGION.

PRELIMINARY REMARKS.

The Eocene of the Interior region covers an extensive area on the eastern and western flanks of the Rocky Mountains. Though largely developed in broad continuous tracts, it not infrequently occurs in narrowly circumscribed basins that are found scattered from Colorado on the east to Nevada on the west, and from Montana on the north to Texas on the south. Within the limits designated similar conditions largely prevailed. From an open sea of Cretaceous age, in which the life was marine, a gradual change took place to great fresh-water lakes in which the typical Tertiary deposits of the Interior were accumulated. Although the marine and fresh-water divisions present marked paleontological differences, they are still linked together by a series of brackish-water deposits that afford many points for comparison with both the older and younger horizons. Whether these intervening beds should be referred to the Cretaceous or to the Eocene or considered to represent portions of each has been widely discussed, and no problem in American geology has perhaps furnished so extensive a literature. It seems not improbable that continuous deposition prevailed throughout the Interior region, so that the reference of each member of the series to the more or less fragmentary geological column elsewhere established is attended with great uncertainty.

The opinions of those who have studied the deposits from different points of view differ widely, though the present tendency is to disparage a narrow interpretation of any particular series of facts and to judge the evidence in its entirety.

It will be observed that the Laramie and Puerco formations, regarded by many as Cretaceous, and the Fort Union beds, which by others have been separated from the Laramie and held to be Neocene, are here discussed. The evidence for the Eocene age of all or part of the strata of these several formations will be presented in subsequent pages; and the history, stratigraphy, taxonomy, and correlation of the Eocene of the Interior, in its general and local characters, will be briefly outlined.

HISTORICAL SKETCH.

The reports of the expeditions that entered or crossed the Interior region during the first half of the century present almost nothing of importance upon the Eocene. Certain observations in areas now known

to be of Tertiary age are recorded, but neither the stratigraphical relationship of the deposits nor their taxonomy were in any degree comprehended.

The investigations of Meek and Hayden in Nebraska and the Upper Missouri River country, in 1854, afford the first scientific data upon the geology of the region that it is our province to discuss. The publication of these results appeared in a series of articles in the Proceedings of the Academy of Natural Sciences of Philadelphia for 1856, and from the fossils collected upon that expedition the authors concluded:

> It is worthy of note that some of the species contained in the collection from the most recent Cretaceous beds of the Upper Missouri country appear referable to genera which, according to high European authority, date no farther back than the true chalk, while many of them are closely analogous to Tertiary forms; so close, indeed, that had they not been found associated in the same beds with Ammonites, Scaphites, and other genera everywhere regarded as having become extinct at the close of the Cretaceous epoch we would have considered them Tertiary species.[1]

Already, at this early period, the peculiarities of the organic remains in the beds intermediate between undoubted Cretaceous and undoubted Eocene were recognized.

In a subsequent paper[2] the same authors refer the lignite deposits of the Upper Missouri River to the Tertiary. They say:

> Although there can be no doubt that these deposits hold a rather low position in the Tertiary system, we have as yet been able to arrive at no very definite conclusions as to their exact synchronism with any particular minor subdivision of Tertiary, not having been able to identify any of the mollusca found in them with those of any well marked geological horizon in other countries. Their general resemblance to the fossils of the Woolwich and Reading series of English geologists, as well as to those of the great lignite formations of the southeast of France, would seem to point ta the lower Eocene as their position.

In regard to the Judith River deposits, which Dr. Leidy[3] had already compared to the Wealden of Europe, the same writers add:

> Inasmuch, however, as there certainly are some outliers of fresh-water Tertiary in these Bad Lands, we would suggest that it is barely possible these remains may belong to that epoch, though the shells appear to be all distinct species from those found in the Tertiary at all the other localities in this region.

Notwithstanding these statements, the same authors, in a section given in later article,[4] following the conclusions of those who had examined the vertebrate and vegetable remains, refer the Judith River deposits to the lowest horizon of the Cretaceous, while the Fort Union beds are considered Miocene.

A geological map, prepared by Dr. Hayden, of the region bordering the Missouri River, appears in the next volume of the Proceedings of Philadelphia Academy,[5] on which the limits of the "Great Lignitic Ter-

[1] Philadelphia Acad. Nat. Sci., Proc., vol. 8, 1856, p. 63.
[2] Ibid., pp. 111–128.
[3] Ibid., pp. 72, 73.
[4] Ibid., p. 269.
[5] Ibid., vol. 9, 1857, p. 109.

tiary Basin" are recorded. In regard to the Great Lignitic deposit he states that "the collection of fossils now obtained show most conclusively * * * that it can not be older than the Miocene period." Small areas in Wyoming, on the Sweetwater, and to the west of South Pass are designated as Tertiary.

Similar conclusions are given in a longer paper by Meek and Hayden,[1] that immediately follows that presented by Dr. Hayden.

In the proceedings of the Academy of Natural Sciences for 1860 Meek and Engelmann refer the Bear River Estuary Beds[2] to the Tertiary.

In the same journal for 1861[3] Meek and Hayden published a complete section of the Tertiary formations of the northwest. A fourfold division is made: (1) Fort Union, or Great Lignite group; (2) Wind River deposits; (3) White River group; (4) Loup River beds.

The first two alone claim our attention. The Fort Union or Great Lignite group is described as characterized by—

Beds of clay and sand, with round ferruginous concretions and numerous beds, seams, and local deposits of lignite; great numbers of dicotyledonous leaves, stems, etc., of the genera Platanus, Acer, Ulmus, Populus, etc., 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, etc. Thickness: 2,000 feet or more. Localities: 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.

The Wind River deposits are described as—

Light-gray and ash-colored sandstones, with more or less argillaceous layers. Fossils: fragments of Trionyx, Testudo, with large Helix, Vivipara, petrified wood, etc. No marine or brackish-water types. Thickness: 1,500 to 2,000 feet. Localities: Wind River Valley; also, west of Wind River Mountains.

Concerning the position of the Wind River group in the Tertiary series they say:

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 yet 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.

Concerning the Judith River deposits, a foot-note to page 417 contains the following:

At the time we published these facts we were led by the discovery here of fresh-water shells, in such a position, to think that some estuary deposits of doubtful age, near the mouth of the Judith River, on the Missouri, from which Dr. Leidy had described some Saurian remains resembling Wealden types, might be older than Tertiary. Later examinations, however, have demonstrated that the Judith beds contain an entirely different group of fossils from those found in the rock under consideration, and that they are really of Tertiary age, and hold a position at the base of the Great Lignite series of the Northwest.

[1] Philadelphia Acad. Nat. Sci., Proc., vol. 9, 1857, pp. 117–148.
[2] Ibid., vol. 12, 1860, p. 130.
[3] Ibid., vol. 13, 1861, p. 433.

The same section of the Tertiary strata of the Northwest is repeated in the First Annual Report of the Geological Survey of the Territories for 1867. In the discussions that follow, the Judith River deposits are placed with the Fort Union beds as part of the same great series. The more southern extension of the lignitic formation is now for the first time clearly recorded from Wyoming and Colorado and southward as far as Raton Pass in New Mexico. Capt. E. L. Berthoud, whose letter upon this point is included in this first official report of Dr. Hayden, says concerning the age of the lignitic series: "Everything that I have so far seen points out that the coal is either Cretaceous or Tertiary, but I believe it to be Tertiary or of the same age as the coal near Cologne, on the Rhine." Concerning the Wind River deposits he states further on that "they occupy an area about 100 miles in length and 40 to 50 in breadth."

In an article entitled "Notes on the Lignite Deposits of the West," in the American Journal of Science [1] for March, 1868, Dr. Hayden reiterates his previous views.

The same year Dr. J. S. Newberry[2] published "Notes on the Later Extinct Flora of North America, with descriptions of some new species of fossil plants from the Cretaceous and Tertiary Strata," in the Annals of the Lyceum of Natural History of New York. In this paper the flora of the Fort Union beds is described.

Up to this time there had apparently been complete unanimity on the subject of the Tertiary age of the lignitic series, the only varying evidence being found in what Dr. Leidy considered the Wealden type of the Judith River vertebrates.

From the discovery of specimens of Inoceramus in the coal strata at Raton Pass, New Mexico, Dr. J. D. Le Conte[3] claimed that the lignitic deposits of that region were accordingly Cretaceous, though still admitting the Miocene age of the Fort Union beds.

Prof. E. D. Cope [4] raises a doubt concerning the Tertiary age of the entire lignitic series in an article in the transactions of the American Philosophical Society by mentioning *Ischyrosaurus antiquus* Leidy from the "Great Lignitic" of Nebraska as "perhaps of the Cretaceous age," and *Hadrosaurus? occidentalis* Leidy from the "Cretaceous beds" of Nebraska, while *Palæoscincus costatus* Leidy is referred to the "upper Jurassic Bad Lands of Judith River."

In the Third Annual Report of the Geological Survey of the Territories, Dr. Hayden describes the Tertiary strata under provisional "groups." The lignitic strata are thus locally divided into the Fort Union group, Cañon City group, Raton Hills group, etc., while separated from the true coal-bearing series in the vicinity of Bitter Creek

[1] Am. Jour. Sci., 2d ser., vol. 45, 1868, pp. 198-208.

[2] Annals. Lyceum Nat. Hist., New York, vol. 9, 1867, pp. 1-76.

[3] Notes on the Geology of the Survey for the extension of the Union Pacific Railway, E. D., from the Smoky Hill River, Kansas, to the Rio Grande. Philadelphia, 1868.

[4] Am. Phil. Soc., Trans., vol. 14, 1868-'69, pp. 1-252.

is the Washakie group. The Green River shales, Bridger group, and Wasatch group are characterized, though their relations are not fully understood. The Washakie group and Green River shales are held to be Middle Tertiary, the Bridger group Upper Tertiary, while the Wasatch group is simply designated as of Tertiary age.

The volume upon mining industry, of the quarto publications of the U. S. Geological Exploration of the Fortieth Parallel, appeared in 1870, and includes a chapter upon the Green River coal basin, in which the author, Mr. Clarence King, states that the coal-bearing strata are mainly Cretaceous and are unconformably overlain by fresh-water deposits of Tertiary age. In this connection he says:

> The fossil life, which clearly indicates a Cretaceous age for the deepest members up to and including the first two or three important coal beds, from that point gradually changes with a corresponding alteration of the sediments, indicating a transition to a fresh-water period. The coal continued to be deposited some time after the marine fauna had been succeeded by fresh-water types. The species of fossils are in no case identical with the California Cretaceous beds, which occupy a similar geological position on the west of the Sierra Nevada. Their affinities decidedly approach those of the Atlantic slopes, while the fresh-water species which are found in connection with the uppermost coal beds seem to belong to the early Tertiary period.[1]

He states furthur concerning the unconformity of the Tertiary beds and the underlying coal-bearing strata:

> 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 and the horizontal fresh-water strata above them.[2]

In a letter from Mr. Meek, published in the same chapter, that writer concludes from the presence of Inoceramus and Anchura and the unconformity that exists between the coal-bearing strata and the fresh-water beds that "from all the facts now known I can, therefore, scarcely doubt that you are right in referring these beds to the Cretaceous."[3] He states further that "these beds belong to one of the very latest members of the Cretaceous; or, in other words, that they were probably deposited when the physical conditions favorable to the existence of those forms of molluscan life, peculiarly characteristic of the Cretaceous period, were drawing to a close, or had in part ceased to exist."[4] Concerning the Bear River beds which Meek and Engelmann had referred in 1860 to the Tertiary, the former now admits that they may be Cretaceous, and suggests "the inquiry whether we ought not to carry up the line between the Cretaceous and Tertiary here, so as to include these estuary beds also in the Cretaceous."[5] The similarity of the Judith River deposits is stated in support of this position, "from the fact that there is a formation on the Upper Missouri, near the mouth of the Judith River, the exact age of which has long been regarded as somewhat doubtful, though Dr. Hayden and the writer have generally placed

[1] Op. cit., p. 453. [2] P. 455. [3] P. 461. [4] P. 462. [5] P. 464.

it in the Tertiary, that contains an exactly similar brackish-water group of fossils, some of which are identical with those found in these Bear River estuary beds."

Nevertheless, in summing up, at the close of the letter, the changes that took place during and subsequent to the formation of the coal-bearing strata Meek still clings to his previously expressed idea. He says:

Whether or not this change from marine to estuary conditions was exactly contemporaneous with the close of the Cretaceous and the commencement of the Tertiary of Europe we may perhaps never know, but that it corresponded in the sequence of geological changes here with the change of physical conditions that closed the Cretaceous epoch and ushered in the Tertiary of Europe, especially in France, seems to me scarcely to admit of any well grounded doubt."[1]

Although he thinks grounds may be found for including portions of the lignitic strata in the Cretaceous, yet he says that all the molluscan remains "seem to point to a later origin."

In an article in the American Journal of Science for 1871,[2] entitled "On the Geology of the Eastern Uintah Mountains," Prof. Marsh gives the results of an expedition of the "Yale College Scientific Party" the previous summer into the Green River Valley. The topographical and stratigraphical characteristics of the early Tertiary deposits of the region are given, together with some general remarks on the character of the vertebrate fauna. In regard to the lignitic deposits Prof. Marsh says:

As the age of the coal deposits of the Rocky Mountain region has of late been much discussed, a careful examination was made of the series of strata containing the present bed, and their Cretaceous age established beyond a doubt. In a stratum of yellow calcareous shale which overlies the coal series conformably, a thin layer was found full of *Ostrea congesta* Conrad, a typical Cretaceous fossil; and just above, a new and very interesting crinoid, allied apparently to the Marsupites of the English chalk. In the shales directly below the coal bed, cyclodial fish scales and coprolites were abundant, and lower down remains of turtles of Cretaceous types, and teeth of a Dinosaurian reptile resembling those of Megalosaurus, were also discovered.

In the Fourth Annual Report of the Geological Survey of the Territories for 1870 (published in 1872), Dr. Newberry maintains the Tertiary age of the Fort Union beds, a position that had been generally accepted for the northern lignitic strata. Concerning the age of the lignitic deposits of Wyoming, Dr. Hayden states in the same report that "so far as we can determine the coal beds of the Laramie plains are of Eocene age, although the plants are more closely allied to those of the Miocene period in the Old World."[3] Further he says:

That there is a connection between all the coal beds of the West I firmly believe, and I am convinced that in due time that relation will be worked out and the links in the chain of evidence joined together. That some of the older beds may be of Upper Cretaceous age I am prepared to believe, yet until much clearer light is thrown upon their origin than any we have yet secured I shall regard them as belonging to my transition series or beds of passage between the true Cretaceous and the Tertiary.[4]

[1] Op. cit., p. 466.
[2] Am. Jour. Sci., 3d ser., vol. 1, 1871, pp. 191-198.
[3] Op. cit., p. 164.
[4] Op. cit., p. 165.

The Tertiary age of the lignitic strata is claimed in the same report by Lesquereux, who had studied the fossil plants collected in both Wyoming and New Mexico.

The same volume contains an extended description by Dr. Hayden of the Tertiary basin of Southern Wyoming. The following terms: (I) Washakie group, (II) Wasatch group, (III) Green River group, (IV) Bridger group, are used. The strata are considered Miocene in age and unconformable to the underlying deposits. The lithological and topographical characteristics of the several groups in their local developments are given and the occurrence of fossils noted.

A letter from Dr. Newberry, published in Hayden's report, assigns the Green River shales to an earlier period than that stated by Hayden and presents plant evidence for their Eocene age. Concerning the Washakie group Hayden says:

> Although I have hitherto regarded the group of beds which I have denominated the "Washakie group" as separated from those of Green River and 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.[1]

The Wasatch group is shown to be below the Bridger group and probably synchronous with the Green River shales. The position of the Bridger group above the Green River group is established.

The Fifth Annual Report of the Geological Survey of the Territories for 1871 (published in 1872) contains an attempt by Lesquereux to correlate the lignitic deposits of the numerous localities hitherto described with the different horizons of the Tertiary recognized in Europe.

Strong evidence for the Cretaceous age of the lignitic deposits had been up to this time brought forward by King, Marsh, and Cope, and, as we have seen, reluctantly accepted by Meek, so that the evidence from plant remains was alone left to establish the Tertiary age of the strata.

The discovery, during the summer of 1872, of the remains of a Dinosaurian reptile at Black Butte station, on the Union Pacific Railroad, in Wyoming, tended more completely to establish the Cretaceous age of the lignitic deposits. Prof. Cope, who examined the fossils collected from this locality, says:

> From the above description it is evident that the animal of Black Buttes is a Dinosaurian reptile. * * * It is thus conclusively proved that the coal strata of the Bitter Creek Basin of Wyoming Territory, which embraces the greater area yet discovered, were deposited during the Cretaceous period, and not during the Tertiary, though not long preceding the latter.[2]

In another article[3] he says: "this discovery places this group without doubt within the limits of the Cretaceous period." The separation of the "Bitter Creek series" as a distinct group had been already recorded by Prof. Cope in the previous paper.

In the Sixth Annual Report of the Geological Survey of the Territories for 1872 (published in 1873) Lesquereux reasserts his former conclusions

[1] Op. cit., p. 73. [2] Am. Phil. Soc., Proc., vol. 12, 1872, p. 483. [3] Am. Nat., vol. 6, 1872, pp. 669–671.

as to the Tertiary age of the entire coal bearing series which he denominates the "American Eocene." The Washakie group he assigns to the Upper Eocene, while the Green River group is considered Miocene. In the same report Meek considers the "Bitter Creek series" to be of Cretaceous age, and describes many fossils therefrom. The Bear River deposits he thinks may still be Tertiary. In regard to the lignite deposits of Wyoming he says:

But the most surprising fact to me, supposing this to be a Cretaceous formation, is that we found directly associated with the reptilian remains at Black Butte a shell I can not distinguish from *Viviparus trochiformis*, originally described from the lignitic formation at Fort Clark, on the Upper Missouri, a formation that has always been regarded as Tertiary by all who have studied its fossils, both animal and vegetable. * * * The occurrence of this last mentioned species here, along with a Cretaceous type of reptile and a *Corbicula* apparently identical with *C. cytheriformis* of the Judith River brackish-water beds, together with the presence of Corbulas very closely allied to Judith River species, at lower horizons in this series, and the occurrence of some vertebrates of Cretaceous affinities at the Judith River localities, would certainly strongly favor the conclusions not only that this Judith formation, the age of which has so long been in doubt, is also Cretaceous, but also that even the higher fresh-water lignite formation at Fort Clark and other Upper Missouri localities may also be Upper Cretaceous instead of Lower Tertiary.[1]

In the same report Cope has an article "On the Extinct Vertebrata of the Eocene of Wyoming." The genus Amyzon is described from Osino, Nevada.

Dr. Newberry[2] presents a paper in the April number of the American Journal of Science of the same year, in which he asserts that much of the flora that Lesquereux had described from New Mexico as Eocene he is certain is Cretaceous, while other forms from the Fort Union beds, referred to the same horizon, he is confident are Miocene. Lesquereux[3] defends his position in a later number.

Prof. Cope states in the Bulletin of the U. S. Geological and Geographical Survey of the Territories, No. 1, that—

Believing, as I do, that the evidence derived from the vertebrate remains requires the reference of the Bitter Creek coal series to the Cretaceous period, and having pointed out, on similar grounds, that the horizon of the Great Lignite from which vertebrate remains have been procured on the Missouri River is undoubtedly Mesozoic, although usually regarded as Tertiary, I suspect that the corresponding strata in Colorado will be found to pertain to the same section of geologic time.[4]

In Bulletin No. 2 the same writer has an extended discussion "On the mutual relations of the Cretaceous and Tertiary formations of the West." In a second paper the Tertiary fishes from Middle and South Parks, Colorado, are described. The first article is reproduced in much the same form in the Seventh Annual Report of the U. S. Geological and Geographical Survey of the Territories for 1873 (published in 1874). In this paper the author, considering the Fort Union and

[1] Op. cit., p. 460.
[2] Am. Jour. Sci., 3d ser., vol. 7, 1874, pp. 399-404.
[3] Ibid., pp. 546-557.
[4] Op. cit., p. 10.

Bitter Creek series of like age. but at the same time accepting the evidence offered on the side of paleobotany, says:

> There is, then, no alternative but to accept the result *that 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.[1]

The same volume contains reports by Marvine and by Lesquereux, in which the latter still defends his position of the Eocene age of the greater part of the lignitic strata, though the Evanston beds are considered younger and are placed in the upper portion of the series. To the Miocene (middle) he refers the coal basin of Carbon, the Washakie group, and other deposits. To the Miocene (upper) the Green River group; the coal of Elko, Nevada; the Florissant, Colorado, beds; and the deposits of Middle Park. Cope, in the same volume, maintains that from the evidence of vertebrate paleontology the deposits of the Wasatch group are synchronous with the Green River. The same writer speaks of the "Bridger Eocene."

Dr. George M. Dawson[2] published in 1874–'75 several articles bearing on the age of the Fort Union beds, and is decidedly of the opinion that they are Eocene.

Two important contributions from the pen of Prof. Cope appeared in 1875. In the first,[3] which included an account of the vertebrates collected by Dawson on the British boundary, the author finds that "the list of species, short as it is, indicates the future discovery of a complete transition from Cretaceous to Eocene life."

The second contribution is the final report on Cretaceous vertebrates, published as Vol. II of the U. S. Geological Survey of the Territories. It contains the paper already twice referred to. Concerning the occurrence of identical forms in the Fort Union and Judith River deposits, he says:

> The presence of gar fishes of the genus *Clastes* in this formation is as yet peculiar to this and the Judith River localities. As these gars have not heretofore been found in North America below the Eocene, they constitute the first case of apparent commingling of Tertiary and Cretaceous animal life yet clearly determined.

Prof. J. J. Stevenson published about this time, in several articles, evidence of a stratigraphical character to show the Cretaceous age of the lignitic deposits.[4]

In the annual report for 1875 of the U. S. Geographical Surveys west of the One Hundredth Meridian, Prof. Cope characterizes the Puerco group and refers it without qualification to the Eocene. He estimates the thickness of the strata at 1,200 feet.

The published results of Maj. J. W. Powell's explorations of the Colo-

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[1] Op. cit., p. 442.

[2] Canadian Naturalist, vol. 7, 1874, p. 241. British North American Boundary Commission, Montreal, 1874. Ibid., 1875.

[3] Philadelphia Acad. Nat. Sci., Proc., vol. 27, 1875, pp. 9, 10.

[4] New York Lyceum Nat. Hist., Proc., 2d ser., No. 4, 1874, p. 93; U. S. Geog. Surys. west 100th Mer., vol. 3, 1875, pp. 404–410; Am. Phil. Soc., Proc., vol. 14, 1875, pp. 447–475.

rado River of the West appeared in 1875. In this report, the section of Eocene strata exposed on the Green River south of Green River Station, on the Union Pacific Railroad, is described in the itinerary of the journey.

The Eighth Annual Report of the Geological and Geographical Survey of the Territories for 1874 (published in 1876) contains far more than any previous publication concerning the lignitic strata. In that portion contributed by Dr. Hayden "the coal-bearing beds of the Laramie Plains and Colorado" are correlated with "the vast group in the Northwest," though exception is made of "the Bear River and Coalville group," which is considered Cretaceous.

Dr. A. C. Peale published in this volume a comparative table setting forth the various opinions that had prevailed as to the several "groups" under consideration. Concerning the Green River and Bridger groups he says that "Profs. Cope, Leidy, and Marsh consider them Eocene, basing their conclusions on the discovery of vertebrate organic remains, while Lesquereux refers them to the Miocene, from his investigations of their fossil flora, calling the 'Lignitic' group Eocene."[1] He considers that "the lignite-bearing beds east of the mountains in Colorado are the equivalent of the Fort Union group of the Upper Missouri, and are Eocene Tertiary; also that the lower part of the group, at least of the locality 200 miles east of the mountains, is the equivalent of a part of the lignitic strata of Wyoming," while "the Judith River beds have their equivalent along the eastern edge of the mountains below the Lignite or Fort Union group, and also in Wyoming, and are Cretaceous, although of a higher horizon than the coal-bearing strata of Coalville and Bear River, Utah."[2] Lesquereux gives an extended argument for the Tertiary age of the lignitic deposits.

In his final report on Invertebrate Paleontology Meek states that it "is certainly highly probable" that the Judith River beds are Cretaceous, although he still maintains that the Fort Union beds are lower Eocene. Further, he says, "the presence or absence of lignite proves nothing of itself, as lignite undoubtedly occurs in both Cretaceous and Tertiary rocks in the far West." The Wind River group he considers to be Miocene, and "probably wholly or in part equivalent to that since called the Bridger group."[3]

The geological report by J. S. Newberry of the exploring expedition under Capt. J. N. Macomb in 1859 appeared in 1876. In this report the deposits that had been given the name of Puerco group by Cope are described and referred to the upper portion of the Cretaceous.

The geology of the Uinta Mountains, by Maj. J. W. Powell, was published in 1876. In this report the Bitter Creek series is fully discussed by Maj. Powell and Dr. White. At a point between Black Buttes and Point of Rocks a "physical break" is announced that

[1] Op. cit., p. 140. [2] Op. cit., p. 155. [3] U. S. Geological Survey of the Territories, vol. 9, 1876.

affords grounds for drawing there the line of separation between the Mesozoic and Cenozoic formations. The Point of Rocks group below the break is referred to the Cretaceous, the Bitter Creek group, above the same, to the Tertiary. Maj. Powell says:

All of the plants described by Prof. Lesquereux and collected by himself and others within this province have been referred by him to divisions in the Tertiary and are found in strata above the physical break, and hence I agree with him in considering them Tertiary. * * * The conclusions reached from a study of the vertebrate paleontology by Profs. Leidy, Marsh, and Cope entirely harmonize with this division of the Cenozoic and Mesozoic.[1]

A single exception is cited.

Dr. White arrived at conclusions similar to those of Maj. Powell. He says:

There is no physical break in the Cretaceous strata from the base of the series to the top of the upper, or Point of Rocks group, at which horizon there is at all observed points, extending over a large region, considerable unconformability by erosion of the lower strata of the Bitter Creek group upon the upper strata of the Point of Rocks group.[2]

Overlying the Point of Rocks group, considered the top of the Mesozoic, are the following groups, that were held by Powell and White to represent the Eocene: (I) Bitter Creek, (II) Lower Green River, (III) Upper Green River, (IV) Bridger, (V) Browns Park. Each group is fully characterized.

The Report on Descriptive Geology, by Messrs. Arnold Hague and S. F. Emmons, of the U. S. Geological Exploration of the Fortieth Parallel, appeared in 1877. In this work the term Lignitic is replaced by that of *Laramie*, which, however, was first used on advance sheets of the atlas, map 1, that appeared in 1875. The deposits of that formation are referred to the Cretaceous. The terms (I) Vermilion Creek, (II) Green River, (III) Bridger, (IV) Uinta are employed for the overlying horizons, which are considered Eocene. Localities in Utah, Wyoming, and Nevada are mentioned and described.

Concerning the taxonomy of the lignitic deposits of the interior, Prof. Marsh says, in his vice-presidential address delivered before the American Association for the Advancement of Science in 1877:

The boundary line between the Cretaceous and Tertiary in the region of the Rocky Mountains has been much in dispute during the last few years, mainly in consequence of the uncertain geological bearings of the fossil plants found near this horizon. The accompanying invertebrate fossils have thrown little light on the question, which is essentially whether the great lignite series of the west is uppermost Cretaceous or lowest Eocene. The evidence of the numerous vertebrate remains is, in my judgment, decisive and in favor of the former view.

The higher vertebrate life of the Tertiary is discussed at length and in the table appended the Eocene is separated into four divisions. (I) Coryphodon beds. (II) "Green River beds." (III) Dinoceras beds. (IV) Diplacodon beds.

[1] Op. cit., pp. 71, 72.

[2] Op. cit., p. 87.

In the Ninth Annual Report of the U. S. Geological and Geographical Survey of the Territories for 1875 (published in 1877), Mr. F. M. Endlich describes the Puerco marls, together with the "Post-Cretaceous" beds of the Trinidad region.

The volume upon Paleontology of the final reports of the U. S. Geographical Surveys West of the One hundredth Meridian contains descriptions of Eocene invertebrate fossils by Dr. White, and vertebrate fossils by Prof. Cope. The latter characterizes the Puerco marls at considerable length, which he states are overlain by sandstones and marls of the Wasatch Group. He says:

> The Puerco marls may belong to the Eocene series, in view of their strict conformability with the superincumbent rocks of that age. But they may represent the Fort Union or lignite beds of the Upper Missouri, some of whose strata they resemble in color and consistence.[1]

The same year Dr. C. A. White published the first of his "Paleontological Papers" in the Bulletin of the U. S. Geological and Geographical Survey of the Territories. The late Mesozoic and Cenozoic fauna are chiefly described in these contributions. In No. 3 a table of the different groups is given, in which the term *post-Cretaceous* is suggested to include the Laramie of King, together with the lower portion of the Wasatch. In this table the Judith River beds are correlated with the Laramie and the Fort Union with the Wasatch. After showing that a few forms of Inoceramus at a doubtful horizon of the Laramie and a single species of Odontobasis, considered by Meek a genus characteristic of the Cretaceous, afford the only invertebrate evidence for the Mesozoic age of the lignitic deposits, he maintains that many forms show a marked similarity to Wasatch species. In this connection he says:

> It is in view of the facts here stated, and also because I believe that a proper interpretation of them shows the strata of the Laramie group and the base of the Wasatch to be of later date than any others that have hitherto been referred to the Cretaceous period, and also earlier than the Eocene epoch, that I have decided to designate those strata as post-Cretaceous, at least provisionally.[2]

In the Tenth Annual Report of the U. S. Geological and Geographical Survey of the Territories for 1876 (published in 1878) Dr. White presents a "table of correlated general sections," in which the Laramie group[3] is made equivalent to the Lignitic group of Meek and Hayden, and the Laramie group of King, while it includes all of the Point of Rocks group of Powell, together with the lower portions of the Bitter Creek group of the last-named author. The remainder of the Bitter Creek series is shown to be commensurate with the Wasatch group established by Hayden, and later termed the Vermilion Creek group by King. The Green River and Bridger groups are exhibited as similarly delimited by the several authorities quoted, while the Uinta group equals the Plioceneof Hayden and Brown's Park group of Powell. The charac-

[1] Op. cit., p. 18. [2] Vol. 3, p. 629. [3] The more general term, post-Cretaceous, is still retained.

teristics of each group are given at considerable length, together with type localities.

Abandoning the position as to general unconformity between the Point of Rocks and Bitter Creek groups, as earlier maintained by Powell and himself, he says:

The fact that this series (Laramie) passes insensibly into the Fox Hills group and into the Wasatch group above renders it difficult to fix upon a stratigraphical plane of demarkation either for its base or summit. I have therefore decided to regard this group as essentially a brackish-water one, referring all strata below that contain any marine Cretaceous invertebrate forms to the Fox Hills group, beginning this series with those strata that contain brackish and fresh water forms, and ending it above with those strata in which the brackish-water forms finally cease. Thus defined, the whole series seems to form one natural paleontological group, as well as to be a sufficiently distinct stratigraphical one, for which I have adopted the name of Laramie group of King. * * * I believe that, upon the evidence of invertebrate paleontology, the Fox Hills group is later than the latest Cretaceous strata of Europe, and I therefore regard the Laramie group as occupying transitional ground between the well marked Cretaceous and Tertiary groups; but the opinion is only tentatively held until further facts are obtained.[1]

In the fourth volume of the Bulletin of the U. S. Geological and Geographical Survey of the Territories, published in 1878, Dr. White contributes three more "Paleontological Papers" (6, 7 and 8), in which the invertebrate fauna of the Laramie is discussed. In the second of these papers the Laramie group is given a much wider significance than hitherto. He says:

The term Laramie group is here used to include all the strata between the Fox Hills group of the Cretaceous period beneath, and the Wasatch group (= Vermilion Creek group of King) of the Tertiary period above. That is, it includes, as either subordinate groups or regional divisions, both the Judith River and Fort Union series of the Upper Missouri River, the Lignite series east of the Rocky Mountains in Colorado, the Bitter Creek series of southern Wyoming and the adjacent parts of Colorado, and also the Bear River Estuary beds, together with the Evanston coal series of the valley of Bear River and adjacent parts of Utah. Strata of this great Laramie group are known to exist in other large and widely separated districts of the western portion of the national domain.[2]

Concerning the stratigraphical relations of the series of deposits overlying the Laramie in the Green River Basin, he says:

In the great region now drained by the Green River there are three well marked groups of strata that come in their order above the Laramie group, and which all agree in referring to the Tertiary period. These are the Wasatch, Green River, and Bridger groups, named in ascending order. The Wasatch group is the lowest of a series of three fresh-water Tertiary groups, all of which are intimately connected, not only by an evident continuity of sedimentation throughout, but also by the passage of a portion of the molluscan species from one group up into the next above. Not only were the three groups, aggregating more than a mile in thickness, evidently produced by a continuous sedimentation, but it seems equally evident that it was likewise uninterrupted between the Laramie and Wasatch epochs, although there was then a change from brackish to fresh waters and a consequent change of all the species of invetebrates inhabiting those waters.

[1] Op. cit., p. 33. [2] Op. cit., p. 721.

The seventh volume of the Final Reports of the U. S. Geological Survey of the Territories is by Mr. Leo Lesquereux on "Tertiary Flora." In this exhaustive treatise the author gives a full expression of his views upon the Laramie group, which he still holds to be Tertiary.

The same year Mr. Clarence King published volume I (Systematic Geology) of the U. S. Geological Exploration of the Fortieth Parallel. In this report the views expressed by Messrs. Hague and Emmons in volume II (Descriptive Geology) are more fully presented. The Laramie is held to be Cretaceous and the Eocene Tertiary is divided into (I) Vermilion Creek group, (II) Green River group, (III) Bridger group, (IV) Uinta group. These different divisions are individually characterized at considerable length. The Fort Union beds are held to be Miocene, and the northward extension of the White River group of Nebraska. He states that unconformities separate the Laramie and Vermilion Creek deposits as well as the members of the Eocene series themselves.

Vol. 5 of the Bulletin of the U. S. Geological Survey of the Territories contains an important article by Cope on "The Relations of the Horizons of Extinct Vertebrata of Europe and North America." In this paper the various groups of the American Eocene are compared with those of Europe upon the evidence afforded by the vertebrates. Concerning the Laramie he says that "its necessary position is between the Tertiary and Cretaceous, but on the Cretaceous side of the boundary,"[1] though later than the latest horizon of the French Cretaceous. According to Cope the post-Cretaceous embraces both Laramie and Puerco, the former commensurate with the Judith River and Fort Union deposits. The same volume contains an article by Peale on "The Laramie Group of Western Wyoming and Adjacent Regions."

The Eleventh Annual Report of the U. S. Geological and Geographical Survey of the Territories for 1877 (published in 1879) contains an article by Endlich upon the geology of the Sweetwater region. The Laramie group is assigned to the post-Cretaceous. The Sweetwater group is placed above the Bridger group, which, with the Green River group, are considered Miocene. The Wasatch group is alone referred to the Eocene.

Dr. White presents a most valuable contribution in the same volume, based upon much enlarged collections of invertebrate fossils that had been made by him from the Laramie and later groups during the previous field season. He believes in "the unity of all the principal brackish-water deposits hitherto known in the western Territories, and * * * their recognition as a comprehensive group of strata under the name of the Laramie group, which represents a great period in geological time, and especially such in the geological history of North America."[2] After admitting the Cretaceous aspect of the ver-

[1] Op. cit., pp. 38, 39.

[2] Op. cit., p. 252.

tebrate fauna of the Laramie on the one hand and the Tertiary aspect of the flora on the other, he states that the invertebrate fauna is "silent on the subject" of the taxonomy of the deposits.

Referring to the appearance of mammalia in great variety of forms in the beds immediately overlying the Laramie, he says:

Such suddenness of introduction makes it almost certain that it was caused by the removal of some physical barrier, so that ground which was before potentially Tertiary became so by actual faunal occupancy. In other words, it seems certain that these Tertiary mammalian types were evolved in some other region before the close of the Laramie period, where they existed contemporaneously with at least the later Laramie Dinosaurians of Cretaceous types, and that the barrier which separated the faunæ was removed by some one of the various movements connected with the evolution of the continent. The climate and other physical conditions which were essential to the existence of the Dinosaurians of the Laramie period having evidently been continued into the Tertiary epochs that are represented by the Wasatch, Green River, and Bridger groups, they might doubtless have continued their existence through those epochs as well as through the Laramie period but for the irruption of the mammalian horde, to which they probably soon succumbed in an unequal struggle for existence.[1]

The same volume contains a "Report on the Geology of the Green River District," by Dr. A. C. Peale, in which the Laramie is referred to the post-Cretaceous, the Wasatch, Green River, and Bridger groups to the Tertiary, the two latter to the Miocene. Detailed descriptions are given of these various groups in the area investigated.

In the American Naturalist for 1879 Prof Cope[2] describes "The Amyzon Tertiary Beds" of Osino and Elko, Nevada.

The following year the same writer,[3] in the Proceedings of the American Philosophical Society, again refers to the Amyzon beds, and also describes the "Manti" beds of Utah. The latter deposits are further characterized in the American Naturalist[4] of that year.

The sixth volume of the Bulletin of the U. S. Geological and Geographical Survey of the Territories, published in 1882, has two important contributions upon the Eocene; the first by Prof. Cope, "On the Vertebrata of the Wind River Eocene Beds of Wyoming," the second by Prof. Scudder on "The Tertiary Lake Basin of Florissant, Colorado, between South and Hayden Parks."

The Twelfth Annual Report of the U. S. Geological and Geographical Survey of the Territories for 1878 (published in 1883) contains further contributions by Dr. White on the Laramie and later groups, with descriptions of many new species.

In the same volume is a report by St. John on the geology of the Wind River district. The character of the Wind River Eocene and its relations to the other deposits are stated.

A paper upon the "Tertiary Lake Basin at Florissant, Colorado," by Dr. Scudder, appears in the same report, reprinted with additions and alterations from the Bulletin.

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[1] Op. cit., p. 265.
[2] Am. Nat., vol. 13, 1879, p. 332.
[3] Am. Phil. Soc., Proc., vol. 19, 1880, p. 60-62.
[4] Am. Nat., vol. 14, 1880, pp. 303, 304.

In the Second Annual Report of the U. S. Geological Survey, Capt. C. E. Dutton contributes a paper upon "The Physical Geology of the Grand Cañon District," in which he states that the Lower Eocene only is represented in that region. To the north, first the Middle Eocene, and then the Upper Eocene appear, while the entire series becomes represented as the Uinta Mountains are approached. He thinks the Middle and Upper Eocene were never deposited in the Grand Cañon country. Similar conclusions are maintained by the same writer in Monograph II of the U. S. Geological Survey, entitled "The Tertiary History of the Grand Cañon District."

In the American Naturalist for 1882 Prof. Cope[1] contributed an important paper on "The Tertiary Formations of the Central Region of the United States." In this article the leading characteristics of the Puerco, Wasatch, Bridger, and Uinta groups are presented.

In an article in the Proceedings of the American Philosophical Society, a "Synopsis of the Vertebrata of the Puerco Eocene Epoch"[2] is given by the same writer. Some points of difference shown in the Puerco deposits from true Eocene strata are stated.

The Third Annual Report of the U. S. Geological Survey, published in 1883, contains "A Review of the Nonmarine Fossil Mollusca of North America," by Dr. White. In this paper Dr. White reiterates his former statements as to the transitional position of the Laramie group. He says:

> Geologists are not agreed as to whether this great group should be referred to the Tertiary or Cretaceous period, some contending for the former and some for the latter reference. The truth appears to lie between the two opinions, and I have elsewhere presented reasons for regarding this group as occupying a transitional position between the Cretaceous and Tertiary, * * * and therefore as representing a period partaking of both the Mesozoic and Cenozoic ages.[3]

Concerning the extent of the Laramie he says:

> The "Judith River group," "Fort Union group," "Lignitic group," "Bitter Creek Coal series," "Point of Rocks group," and "Bear River Estuary beds" are all parts of the great Laramie group.[4]

The position to be assigned to the overlying deposits is thus stated by Dr. White:

> The "Wasatch group," "Vermilion Creek group," and "Bitter Creek group" are regarded as at least approximately equivalent strata, constituting the oldest member of the purely fresh-water Eocene Tertiary series of deposits in the West. The Green River and Bridger groups are respectively the second and third members of that fresh-water Eocene series. The Wind River group of Wyoming is regarded as of Eocene age.[5]

The same year there appeared in the American Journal of Science a paper by Dr. White,[6] entitled "Late Observations concerning the Mol-

[1] Am. Nat., vol. 16, 1882, pp. 177–195.
[2] Am. Phil. Soc., Proc., vol. 20, 1882, pp. 461–470.
[3] Op. cit., pp. 414–416.
[4] Op. cit., pp. 415, 416.
[5] Op. cit., p. 416.
[6] Am. Jour. Sci., 3d ser., vol. 25, 1883, pp. 207–209.

luscan Fauna and Geographical Extent of the Laramie Group," in which he says:

> That any true Laramie strata ever alternate with those of the Fox Hills group or any other marine Cretaceous group, or that any true marine fossils were ever collected from any strata of the Laramie group, I can not admit. I regard all such statements as a result of a misunderstanding of the stratigraphical geology of the region in which such observations are said to have been made.

In volume VIII of the Final Reports of the U. S. Geological Survey of the Territories upon "Cretaceous and Tertiary Flora," published in 1883, the author, Mr. Leo Lesquereux, still maintains the Eocene age of the Laramie group.

In an article in the Neues Jahrbuch für Mineralogie, Geologie, and Palaeontologie for 1884, M. Neumayr places the Laramie group in a parallel position with the Intertrappean beds of the Deccan in Hindostan, and between the Cretaceous and the Eocene. Lists of similar fossil plants from the two areas are given.

"A Review of the Fossil Ostreidæ of North America," by Dr. White, appears in the Fourth Annual Report of the U. S. Geological Survey, published in 1884. In this article the author compares the conditions of the Laramie Sea to the Caspian, in which the waters are fresher than those of the ocean.

Prof. Cope[1] presents a short paper on "The Relations of the Puerco and Laramie Deposits" in the American Naturalist for 1885, in which he says:

> Some writers having suspected the identy of the formations above named and the consequences which follow that the Puerco mammalian fauna was contemporary with the dinosaurian fauna of the Laramie age, the following observations on their stratigraphic relations are now given. At the locality where best developed the Puerco beds have a thickness of about 850 feet and contain mammalia to the base. The Laramie beds succeed downward conformably, it is thought by Mr. Baldwin, and have a thickness of 2,000 feet at Animas City, New Mexico. They rest on Fox Hills marine Cretaceous of less thickness.

Concerning the taxonomy of the Puerco group, Prof. Cope now recedes from his formerly expressed opinion that the beds are Eocene, and maintains their Cretaceous affinity on account of "the absence of Perissodactyla and Rodentia, and of course of mammalian orders not found below the Miocene. * * * and in the constitution of the mammalian fauna by Condylarthra, Bunotheria, and Marsupialia." The Puerco group is placed in the post-Cretaceous, which "as a whole may be ultimately distinguished from the Tertiary by these peculiarities [given above], together with the reptilian genus Champsosaurus."

In a presidential address upon "The Application of Biology to Geological History," delivered by Dr. White[2] at the Fifth Anniversary Meeting of the Biological Society of Washington, January 24, 1885, the author reviews briefly the conflicting nature of the evidence afforded

[1] Am. Nat., vol. 19, 1885, p. 985.

[2] Washington Biol. Soc., Proc., vol. 3, 1886, pp. 1–20.

by the vertebrate and invertebrate faunas and the flora of the Laramie group.

In the Fifth Annual Report of the U. S. Geological Survey, and later in Monograph X of the same, Prof. Marsh divides the Eocene into four groups, basing his divisions upon the vertebrate fossils: (I) Coryphodon [Wasatch] beds, (II) Heliobatis [Green River] beds, (III) Dinoceras [Bridger] beds, (IV) Diplacodon [Uinta] beds.

The most exhaustive treatise upon the literature of the Laramie is to be found in a "Synopsis of the Flora of the Laramie Group," by Prof. L. F. Ward, that appeared in the Sixth Annual Report of the U. S. Geological Survey, published in 1885. It has afforded an outline for the present chapter, so far as the history of opinion upon the Laramie is concerned. This important paper presents us with the latest views that paleobotany has to offer upon the interesting problems presented by the Laramie formation.

The writer says:

> The discussions with regard to the age of the Laramie group, which have been rapidly passed in review, have perhaps sufficiently shown that it is impossible to refer that group either to the Cretaceous or the Tertiary, and in so doing harmonize all the facts that the group presents with those in conformity with which other deposits in other countries of the world have been so referred; but they have also sufficiently shown that this is not the fault of the investigators, but, so to speak, of the facts, and that the real disagreement is in the organic forms and the nature of the deposits, so that omniscience itself could never harmonize them with all kinds of forms and deposits in all parts of the world. It is, therefore futile, and indeed puerile, longer to discuss this question, and we may well afford to dismiss it altogether and settle down to the more serious study of the real problems which still lie before us.[1]

In this report Prof. Ward shows that over 20 species of plants are common to the Laramie and Green River groups.

The "Relation of the Laramie Molluscan and Fresh-water Eocene Faunas" is discussed by Dr. White in Bulletin 34 of the U. S. Geological Survey, published in 1886. In this report Dr. White states that there is no known case of a marine Cretaceous form having lived on into Laramie time, though it is probable that some estuarine species may have done so. He mentions the persistence, however, of Laramie fresh-water forms into the Wasatch. The Bear River Estuary beds are placed intermediate between the Cretaceous and Eocene, and probably synchronous with the Laramie, though possessing a wholly different fauna. The Puerco beds are shown to possess an entirely different vertebrate fauna from the Laramie below and the Wasatch above, with both of which they are conformable. The author thinks they may represent the lower portion of the Wasatch of Utah. The upper portion of the Fort Union beds is provisionally correlated with the base of the Wasatch.

In Bulletin 37 of the U. S. Geological Survey, published in 1887, Mr.

[1] Op. cit., p. 435.

L. F. Ward discusses the "Types of the Laramie Flora," in which new data are added to the earlier "Synopsis" that appeared in the Sixth Annual Report.

The same year Dr. White published in the American Journal of Science an important paper[1] entitled "On the Inter-Relation of Contemporaneous Fossil Faunas and Floras." In this article he says: "That faunas and floras of Cretaceous and Tertiary types should have existed contemporaneously is not strange, for a similar diversity now exists as regards the living faunas and floras of different parts of the world." The sudden appearance of so many various mammalian types he maintains was due to "the removal from time to time of certain physical barriers which previously restricted the dispersion of those faunas." He considers that sedimentation from "the Laramie to the Bridger groups inclusive was at no time everywhere interrupted," and thus there is an "unbroken continuity of invertebrate and plant life."

A year later an article by the same writer "On the Relation of the Laramie Group to Earlier and Later Formations"[2] contains reference to the Laramie of Texas and its position as regards the marine Eocene of the Gulf States. The author inclines to the view that the coal-bearing strata of the Laramie are the equivalent in part at least of the "Northern Lignitic" of Hilgard.

In the American Naturalist for 1887[3] and American Geologist for 1888[4] Prof. Cope presents reports upon the "Mesozoic and Cenozoic Realms of the Interior of North America." In each of these papers the Laramie and Puerco are referred to the "Post-Cretacic system," while the Eocene is divided into the (I) Wasatch, (II) Wind River, (III) Bridger, (IV) Diplacodon beds, or Uinta. Two other formations that he considers "contemporary with one or more of these" are the Amyzon beds and the Green River shales.

The stratigraphical relations of certain deposits in the vicinity of Denver that had hitherto been considered Laramie are discussed by Mr. George H. Eldridge[5] and Dr. Whitman Cross[6] in the Proceedings of the Colorado Scientific Society for 1888. These beds are readily divided on both lithological and stratigraphical grounds into two groups; the lower called the Arapaho,[7] unconformable to the Laramie; the upper, the Denver, unconformable to the Arapaho. The more detailed evidence for their separation from the Laramie will be given later.

In the Eighth Annual Report of the U. S. Geological Survey, published in 1889, Prof. Ward contributes a paper on "The Geographical

[1] Am. Jour. Sci., 3d ser., vol. 33, 1887, pp. 364–374.
[2] Ibid., vol. 35, 1888, pp. 432–438.
[3] Am. Nat., vol. 21, 1887, pp. 445–462.
[4] Am. Geologist, vol. 2, 1888, pp. 265–267, 285–299.
[5] The Mining Industry, vol. 3, 1888, No. 3, pp. 24, 25; No. 4, pp. 33–35; No. 5, pp. 44–45, and Colorado Sci. Soc., Proc., vol. 3, 1888, pp. 86–118.
[6] Colorado Sci. Soc., Proc., vol. 3, 1888, pp. 119–133. Am. Jour. Sci., 3d ser., vol. 37, 1889, pp. 261–282.
[7] In earlier articles called the "Willow Creek beds."

Distribution of Fossil Plants." The Eocene localities throughout the Interior region where fossil leaves have been found are cited and the literature of the subject freely quoted. A map showing the distribution of fossil plants in the United States is added.

The vice-presidential address of Dr. White[1] at the Toronto meeting of the American Association for the Advancement of Science is a most valuable contribution to the present discussion of the application of the European scheme of classification to the strata of the North American continent. That minute correlation is impracticable is clearly shown. The Laramie group is discussed in the light of recently acquired data.

In the Bulletin of the Geological Society of America, volume I, published in 1890, is an abstract of a paper upon "The Laramie Group," presented by Prof. J. S. Newberry. In this article Dr. Newberry declares "that the floras of the Laramie and Fort Union groups are totally distinct, and that these formations should be referred to different geological systems—the Fort Union to the Tertiary, the Laramie to the Cretaceous."[2] In the discussion that follows he says: "In my judgment the Laramie is the top of the Cretaceous system. I do not know why it should be called post-Cretaceous. It is true there must be somewhere connecting links between the Cretaceous and the Tertiary, * * * but I know of no evidence that the Laramie is such a passage-bed." Dr. Newberry maintains "the interlocking of the Laramie and Fox Hills formations from several localities." In the discussion Prof. Ward admits that the floras of the Fort Union beds and the Laramie of Colorado, Wyoming, and New Mexico "are not identical—they are very different," yet he maintains that there are eight or ten identical species; not one, as stated by Dr. Newberry. Further he says: "Whatever may be true in regard to a difference of age—and it seems to me that the two must go together—I am quite satisfied that a warmer climate prevailed during the period of the deposition of the Wyoming and Colorado beds than that which prevailed during the deposition of the Fort Union beds."

An important contribution to the structural relations of the Interior Eocene was presented at the same meeting by S. F. Emmons[3] in a paper on the "Orographic Movements in the Rocky Mountains."

The reader has doubtless observed that in the present chapter much more attention has been devoted to the Laramie and Puerco groups than to the later horizons. This has been rendered necessary on account of the wide difference of opinion that has existed among those who have studied these groups and the much more extensive literature that has resulted therefrom. Where there has been practical agreement as to the interpretation of facts simple reference to the articles of importance has been deemed sufficient. For the reasons cited the lit-

[1] Am. Assoc. Ad. Sci., Proc., vol. 38, 1889, pp. 205–226. [2] Op cit., p. 525.
[3] Geol. Soc. America, Bull. vol. 1, 1890, pp. 245–286.

erature of the Interior region has thus required fuller treatment than that of either the Atlantic and Gulf Coast or Pacific Coast regions.

STRATIGRAPHICAL AND PALEONTOLOGICAL CHARACTERISTICS.

GENERAL REMARKS.

From what has been stated in the previous pages, it is obvious that very diverse opinions have existed as to the delimitation of the Eocene of the Interior. Quite general unanimity prevails at the present time as to the position to be assigned to the boundary between the Eocene and the Neocene, while hardly two writers agree as to the line of demarcation between the Eocene and Cretaceous.

This wide divergence of opinion among those who have had opportunities for extensive observation may be found in the use of different classes of facts and in the investigation of different areas. In the case of many writers stratigraphical data alone have been employed in the consideration of the Eocene, while paleontological evidence has been for the most part ignored. Others, holding the stratigraphical relationship of the beds to be less important, essayed by the use of paleontological data to interpret the taxonomy of the deposits. Of the latter, two classes of investigators have been prominent, the one judging the evidence entirely from the standpoint of paleobotany, the other from that of vertebrate paleontology. As the development of the plants and animals in the Interior region has not been along the same parallel lines as in other areas, much confusion has resulted from an attempted correlation of the strata. By the vertebrate paleontologist much has been included within the Cretaceous that the paleobotanist has referred to the Eocene. Fortunately there appears, at the present time, a tendency to view the evidence in its entirety rather than to employ any single class of facts in determining the age of the various deposits.

The physical changes that took place during and subsequent to the formation of the Eocene deposits have so fully determined the character of the strata that a brief statement of the more important is imperative. For the elucidation of these points geology is indebted to Dr. White, and in the succeeding statement his ideas are largely followed.

Previous to the opening of the Eocene period an open sea had long prevailed over the western Interior region, in which a series of argillaceous and arenaceous sediments of great thickness had accumulated.

Throughout these deposits are found widely represented the typical marine forms of the Cretaceous.

With the elevation of physical barriers to the south the salt waters become brackish, the previous types of marine life could no longer maintain themselves within the area, and gave place to other forms better adapted to the changed habitat. Although the influence of these altered conditions is manifested in the aqueous fauna, the continental animal life of the previous age was able to maintain itself for a longer time.

dinosaurian types, characteristic of the Cretaceous, persisted till the close of the brackish-water period.

With the still further increase of the physical barriers the brackish-water conditions were changed to fresh water; in some cases the invertebrate forms continued their existence, but on account of unknown causes a marked change occurred in the vertebrate life. There was a sudden appearance of highly developed mammalian types that must have existed for a long time without the Interior region, and contemporaneously with the dinosaurian fauna within the area. Whether, as has been suggested, the disappearance of certain barriers to their migration suddenly admitted the mammalia that in the struggle for existence soon overcame the reptilian fauna that had continued here to a later date than elsewhere will probably never be solved, but the explanation given affords a good working hypothesis.

The great fresh-water lakes continued with successively diminished areas during the remainder of the Eocene period. With the advent of the Neocene an extensive region was again covered with fresh-water lakes which finally became drained in the orographic movements accompanying the elevation of the Rocky Mountains. A few salt lakes alone remain to mark their former extension.

During late Tertiary and post-Tertiary times the great elevation that the Interior region received has admitted of extensive denudation throughout the area covered by Eocene strata. This, added to the arid climatic conditions prevailing widely throughout the territory, has afforded advantages for geological investigations not to be found in either the Atlantic and Gulf Coast or Pacific Coast regions. Largely on account of these facts the stratigraphy of the Interior Eocene has been more accurately determined than that of either of the regions previously described. Accordingly, a consideration of the Eocene of the Interior under geographical limitations may be dispensed with and the formation discussed under its various subdivisions.

LARAMIE GROUP.

The strata of the Interior region, described under the name of the Laramie group, have been, for reasons already briefly cited, referred by some writers to the Cretaceous, by others to the Eocene. In the face of this conflicting evidence, and for reasons stated later, I have considered that the Laramie strata are to be referred partly to the one horizon, partly to the other.[1] As the investigation of the deposits has thus far failed to reveal any satisfactory evidence as to the exact position of the dividing line, the entire series will be briefly outlined.

The term Laramie was first employed by members of the U. S. Geological Exploration of the Fortieth Parallel, and finds expression in Vol. I, Systematic Geology (1878), and Vol. II, Descriptive Geology (1877) of the reports of that organization. It had already appeared on

[1] This position has already been taken by Dr. C. A. White in several of his published writings.

map 1 of the atlas, which was distributed in 1875. Hitherto the name Lignitic group, early proposed by Dr. Hayden, had been the generally accepted taxonomic term, though certain lignitic deposits, not correlated with that formation, had, at the same time, received local names from the place of their occurrence. The Judith River beds, the Fort Union beds, the Bear River Estuary beds, etc., had been thus designated by different writers and referred to various horizons in the geologic column. The term post-Cretaceous, suggested by Dr. White,[1] found acceptance for a time, but has been now for the most part abandoned, as it soon was by himself.

The territory in which the Laramie group is represented covers a wide area along the eastern flank of the Rocky Mountains, extending from the region of its typical development in Wyoming and Colorado northward across Montana into Canada, and southward across New Mexico and Texas into Mexico. From the Rocky Mountains it extends eastward to the Great Plains. To the west of the Rocky Mountains it is found somewhat less widely represented, occuring in Wyoming, Utah, Colorado, and New Mexico.

The deposits are chiefly sandstones, shales, and lignites. King has estimated the thickness of the strata on the eastern flank of the Rocky Mountains in Colorado at 1,500 feet, while in southwestern Wyoming the same observer has placed the thickness at 5,000 feet.

Over wide areas the strata lie approximately horizontal, though due to the great orographic movements that have taken place in the Interior region the beds are often highly tilted. The Laramie is found resting conformably upon the next older or Fox Hill group, of whose Cretaceous age no doubts have been expressed. Overlying the Laramie conformably at some points, though unconformably at others, is the Wasatch group, of whose Eocene age similar unanimity of opinion is found. The question that presents itself then is whether the Laramie is to be placed with the Cretaceous on the one side or with the Eocene on the other of the Mesozoic-Cenozoic dividing line.

We have found that the evidence presented by vertebrate paleontology unhestitatingly points to the Cretaceous, from the presence of Dinosauria, which elsewhere are not found later than the closing epoch of the Mesozoic. In fact the uppermost beds of the lignitic series have afforded dinosaurian remains. Cope, however, holds to the term "post-Cretacic" for the Laramie and Puerco groups, thus conceding a later age to the lignitic series of the West than many vertebrate paleontologists.

The weight of authority of the paleobotanists has afforded the chief support to the Eocene position. The types of plant life are decidedly late and several are identical or closely allied to living forms. Moreover, the Tertiary floras of other parts of the world are closely parallel to that of the Laramie. So late is the general aspect of the flora that

[1] U. S. Geol. Surv. of the Territories, Bull., vol. 3, 1877, p. 608

many, including so distinguished a paleobotanist as Heer, have held the deposits to be Miocene.

The evidence afforded by invertebrate paleontology, upon which so great confidence is usually placed for purposes of correlation, is of little value. The conditions that obtained during the accumulation of the brackish-water Laramie deposits were such as to greatly change the invertebrate fauna that had hitherto found a peculiarly favorable habitat in the marine waters of pre-Laramie time. It seems not improbable that outside the barriers of the Laramie sea the marine forms still continued for a time their existence contemporaneously with the brackish-water species. The latter, on the other hand, ceased to exist as the waters became fresh, though in certain areas brackish and fresh water conditions prevailed at the same time, so that the fresh-water species of the Laramie continued their existence into the Wasatch period. The brackish-water types of the Laramie are not distinctive of the age of the deposits. The Cretaceous character of the marine invertebrates of the previous period has never been doubted, while the fresh-water forms of the succeeding period have been for the most part considered Tertiary. The brackish-water species might be either Cretaceous or Eocene, and are doubtless both.

As to the supposed incongruity of evidence afforded by the vertebrates and plants, it seems most fully to coincide with the present method of geological reasoning to suppose that the conditions were favorable for the continued existence of the Mesozoic dinosaurian forms to a later period here than in other areas. The supposition that has been advanced that physical barriers precluded the entrance into the area of the mammalian fauna, that from its highly developed state in the succeeding period must have, before the close of the Laramie, commenced its existence outside, seems fully to accord with the facts. That the plants may have here presented forms that have elsewhere not been known till a later epoch is not improbable when we consider that the development of fossil faunas and floras have not been in many other portions of the globe always along identical lines.

From the evidence above presented there seems no incongruity in supposing that in the Laramie group we have represented the closing events of Cretaceous and the opening epoch of the Eocene.

Concerning the approximately synchronous age of most of the lignitic strata of the Interior region, there is a rather general agreement of opinion. However, the lignitic strata of certain local areas, although held by many geologists to be identical with the typical Laramie, are by others thought to be of widely different age. Among these local deposits, in regard to which considerable discussion has hitherto taken place, may be mentioned the Fort Union beds of Montana, the Bear River Estuary beds of Utah, the Arapaho and Denver beds of Colorado.

FORT UNION BEDS.

The deposits in the vicinity of Fort Union, on the Missouri River, were the first lignitic strata to be scientifically examined, having been, before 1860, explored by Dr. Hayden. During the progress of the U. S. Geological and Geographical Survey of the Territories frequent investigations of the region were made and the results published in the various reports of that organization.

Although the same discussions as to the Cretaceous or Tertiary age of the deposits have been maintained here as in the more southern representatives of the Laramie, there has been a much more general willingness to concede the Tertiary age of the former than of the latter. Prof. Ward,[1] it is true, states that there would be "no inconsistency in assigning to the Fort Union an age as ancient as the closing period of the Cretaceous system." Prof. Newberry,[2] who has for many years studied the Laramie and Fort Union floras, thinks that the two formations should be referred to different horizons, the former to the Cretaceous, the latter to the Tertiary. He says:

> The Fort Union flora may be distinguished from that of the Laramie at a glance by its abundant species of Viburnum, Populus, Platanus, and Corylus, and it includes several species now living, such as *Onoclea sensibilis*, *Taxodium distichum*, and two hazels which can not be distinguished by their leaves from *Corylus rostrata* and *C. Americana*.

Prof. Ward, discussing these statements of Dr. Newberry, says "that although the difference in flora exists," yet the Laramie and Fort Union "must go together," and offers in explanation "that possibly the latitude, taken in connection with a different topography, such as may have existed in the two regions, might account for the great difference in the floras." Prof. Ward further gives a list of 8 identical species from the Laramie and Fort Union groups. Dr. White, from a study of the molluscan fauna, likewise asserts the identity of the Fort Union beds with the Laramie group.

BEAR RIVER ESTUARY BEDS.

The lignitic strata upon the Bear River in western Wyoming and northwestern Utah have greatly puzzled the stratigraphical geologist and paleontologist. The deposits are unconformably overlain by the strata of the Wasatch group, while the fossils show little similarity with those of the typical Laramie from other regions. From what is known of the beds, their position, if they are to be assigned to the Laramie at all, is undoubtedly low down in the series. They will probably be found to be of earlier age.

ARAPAHO BEDS.

The stratigraphical relations of the Arapaho beds, so named from Arapaho County in eastern-central Colorado, where the formation is

[1] Geol. Soc. America, Bull., vol. 1, 1890, p. 530. [2] Ibid., pp. 524-527.

best exhibited, have been investigated by Mr. George H. Eldridge,[1] of the U. S. Geological Survey.

The strata of this horizon are confined to a comparatively small area on the eastern flanks of the Rocky Mountains in the vicinity of Denver. The formation "is composed of a basal member of conglomerate, or gritty sandstone, according to its distance from the foot-hills, with an overlying zone of gray argillaceous or arenaceous shales containing lenticular masses of hard quartzose sandstone with an occasional ironstone; where confined between under and overlying groups, it has a thickness varying between 600 and 1,200 feet. The conglomerate at its base has a thickness over a greater portion of the field of about 200 feet, though this may become the bulk of the formation, as in its type locality, or may decrease to the merest edge, as at its northern limit. It is extremely characteristic, containing as it does pebbles derived from every formation that lies below it in the Denver field, but also from others lying far beyond, especially the Carboniferous." Although the angle of dip is not materially different from the Laramie in some localities, "it is not uncommon to meet with the younger formation resting in the eroding hollows of the older, and containing rolled clays, ironstones, and pieces of sandstone evidently derived from the underlying beds."

The Arapaho beds have afforded dinosaurian remains that show their paleontological affinity to the true Laramie, with which they have generally been confounded.

The marked stratigraphical separation above cited, together with the fact that the fossils, hitherto relied upon to associate this and the succeeding group with the Laramie, have been collected without reference to the horizons represented, afford us no definite evidence that the Arapho formation should be allied directly with the Laramie. When careful collections are made from the different horizons of what in the past has been termed Laramie, wider differences in fauna and flora may be shown to exist than have hitherto been recognized.

Whether the Arapaho group then should be considered as representing a later epoch in the Laramie proper or separated entirely from it is a matter of considerable doubt.

DENVER BEDS.

The Denver beds, so called by Dr. Whitman Cross,[2] are confined to a limited area in the vicinity of Denver, Colorado, where they are found to occupy a basin within the Arapaho formation.

The strata are composed very largely of andesitic materials in which both basic and acid types appear. In general the lower beds of the group are fine grained though very variable in texture, while the upper are represented by coarse conglomerates in which a considerable admixture of materials derived from the Archean and sedimentary rocks is found.

[1] Colorado Sci. Soc., Proc., vol. 3, pt. 1, pp. 97, 98, 100–102, 1888.
[2] Am. Jour. Sci., 3d ser., vol. 37, 1889, pp. 261–282.

In explaining the origin of these andesitic materials Dr. Cross[1] says:

> There is no known source which can be assigned with plausibility for any one of the many andesitic types represented in the Denver strata. * * * The andesitic masses which furnished the materials for the lower part of the Denver sediments were so situated as to effectually prevent the access of all Archean and sedimentary débris to the lake of that epoch. That is to say, in the interval between the Arapaho and Denver epochs there was an outpouring of andesitic lavas completely covering the Archean and sedimentary rocks of the area afterward contiguous to the Denver lake. When sedimentation began again only eruptive débris could appear in the deposits until erosion and general degradation had laid bare, here and there, small areas of granite, of gneiss or of sandstone.

Within these deposits is found an extensive fossil flora the true character of which is but imperfectly known. Hitherto the specimens collected from this formation have not been separated from those obtained from the underlying Laramie deposits, so that great confusion prevails. So far as they can be distinguished, many forms not found elsewhere occur.

In the vertebrate fauna the presence of Dinosaurs is interesting, showing that they were able to "survive the changes of condition attending a period of folding and another period of great volcanic activity."

The same difficulty in an attempted correlation of the Denver beds is found as in that of the Arapaho beds.

MIDDLE PARK BEDS.

An occurrence in many particulars similar to the Denver formation is to be found in Middle Park, Colorado, where a series of andesitic breccias and conglomerates, with interstratified sands bearing plant remains, rests unconformably upon the Cretaceous. This series is estimated by Marvine[2] to reach 800 or 900 feet in maximum thickness. Overlying the andesitic beds are sandy shales, sandstones, and grits, chiefly of granitic origin, that in places are found unconformably resting upon the Cretaceous. Seams of lignitic material and numerous fossil leaves are found scattered through the series.

PUERCO BEDS.

The Puerco beds, first described by Cope[3] in the Annual Report of the U. S. Geographical Surveys west of the One Hundredth Meridian for 1875, were long considered by that writer to belong to the Tertiary, although later referred to the "post-Cretaceous." Endlich[4] regarded the beds as a subdivision of the Wasatch.

The geographical extent of the Puerco is limited to northwestern New Mexico and southwestern Colorado, where it is found resting upon the Laramie and in turn overlain by the Wasatch.

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[1] Am. Jour. Sci., 3d ser., vol. 37, 1889, p. 271.

[2] U. S. Geol. and Geog. Surv. of the Territories, Ann. Rep. for 1873, p. 156.

[3] Ann. Rep. of the Chief of Engineers for 1875, appendix 44, p. 89.

[4] U. S. Geol. Surv. of the Territories, Ann. Rep. for 1875, p. 189.

Lithologically it is characterized by sandstones and gray and green marls, the latter soapy in texture and giving a highly characteristic appearance to the country. At the point of its typical development, at the headwaters of the Puerco River, west of the Jemez and Nacimiento Mountains, in New Mexico, it reaches a thickness of outcrop of about 850 feet.[1]

Cope[2] thus characterizes the faunal relations of the beds:

> The fauna of this horizon is well distinguished from that of the Laramie in the absence of the numerous Dinosauria of the latter, and the presence of numerous Placental Mammalia in the former. On these grounds I at first referred the formation to the Cenozoic series, but further reflection induced me to place it as now arranged. The reason is as follows: Although Placental Mammalia are not known otherwise from the Mesozoic beds, the other forms of the Puerco are especially Mesozoic in character. Such are the Choristodere Reptilia and the Multituberculate Marsupialia, neither of which occur above, while both occur below the Puerco, the Multituberculata down to the Trias, inclusive. Then the Placentialia are entirely peculiar in the absence of the Diplarthra and of the Rodentia, orders always found in the Cenozoic beds. Then the characters of the Condylarthra and Amblypoda and many of the Creodonta, which represent Tertiary types, are so peculiar that we are led to suspect that where the Cretacic Mammalia are fully known they can not differ widely from those of the Puerco.

Concerning the stratigraphical position of this unique formation Dr. White[3] says:

> The lowest strata in which the remains of this fauna have yet been found closely coincide in position with the top of the Laramie group; and they disappear suddenly upon a certain higher horizon which seems to come within the basal portion of the Wasatch group. Moreover, the known area within which this Puerco fauna has been found is only a small part of that within which the Laramie and the Wasatch groups occur. That is, the Puerco fauna has not been recognized at the majority of the localities where the Wasatch has been found overlying the Laramie. In some of the latter cases the two formations have been found to be clearly connected, not only by strict conformity of the strata, but also by an intermingling of their molluscan faunas; and in none of them has any indications of a missing formation been observed.

It will thus be observed that the relations of the Puerco beds to the Laramie and Wasatch in the area where represented is peculiar and "appears to mark an epoch in the history of vertebrate life of North America of which the invertebrate and plant remains, and the stratigraphical conditions of the series of deposits in which they occur, give no indication."

Whether the Puerco beds should be considered Cretaceous or Tertiary the evidence is as yet inconclusive, though it seems probable that they should be referred to the latter. If the upper portion of the Laramie may be considered such, the Puerco beds would necessarily be so interpreted, unless, perchance, they do not rest upon the latest horizon of the Laramie.

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[1] Am. Nat., vol. 19, 1885, p. 985.
[2] Ibid., vol. 21, 1887, pp. 450, 451.
[3] Am. Jour. Sci., 3d ser., vol. 33, 1887, p. 368.

WASATCH GROUP.

The Wasatch group, so called from the Wasatch Mountains of Utah, upon the flanks of which deposits of this age are extensively developed, is fully characterized by Dr. Hayden in the various Annual Reports of the Geological Survey of the Territories. It is described by the members of the U. S. Geological Exploration of the Fortieth Parallel under the name of the Vermilion Creek group. The former term is, however, generally employed and is here retained by the writer.

The strata are found in four chief areas.

The region of southwestern Wyoming and northwestern Utah has been most extensively explored and consists of reddish sandstones and marls that according to King reach 5,000 to 5,500 feet in thickness.

In northwestern New Mexico a considerable tract of similar strata has been described by Cope, who estimates the thickness of the beds at 2,500 feet.

Intermediate between these two areas in the San Pete Valley of central Utah Dr. White has further determined the presence of Wasatch strata with a varied fresh-water molluscan fauna.

In northwestern Wyoming, also, the Wasatch group has been identified and the beds estimated to reach 4,000 feet in thickness.

The Wasatch strata throughout much of their extent are conformable to the Laramie, but in western Wyoming and eastern Utah a marked unconformity is exhibited. As previously mentioned, the taxonomic position of the lignitic beds of the Bear River area is doubtful, so the existing unconformity may possess less interest when the deposits are more fully comprehended. The stratigraphical relations of the Wasatch and Laramie have been differently interpreted by White[1] and King,[2] the former considering that deposition was in part continuous during the Laramie and Wasatch periods, the latter that it was wholly interrupted.

The fauna of the Wasatch presents a varied series of invertebrate forms, chiefly molluscan in character, and of a typical fresh-water habitus. Some few are identical with species found in the fresh-water strata of the Laramie and others are found to persist into the later horizons of the Eocene. The vertebrate fauna is chiefly mammalian, and from the prevalence of the genus Coryphodon, Marsh has designated the Wasatch group the Coryphodon beds.

Cope[3] in characterizing the vertebrate life of the Wasatch states that it is marked by the "presence of Tæniodonta, Condylarthra, and Pantodonta. Absence of Tillodonta, Dinocerata, Palæosyops, Hyrachyus, Amynodon, Achænodon, Trilpopus, and suilline and selenodont Artiodactyla."

[1] U. S. Geol. and Geog. Surv. of the Territories, Tenth Ann. Rept. for 1876, p. 35.
[2] U. S. Geol. Expl., 40th Parallel, vol. 1, Systematic Geology, 1878, p. 353 et seq.
[3] Am. Geologist, vol. 2, 1888, p. 287.

GREEN RIVER GROUP.

The Green River shales have a much more contracted range than the deposits of the previous group and are confined in their typical development to the basin of the Green River in southwestern Wyoming and western Colorado. Here they reach a thickness of about 2,000 feet, and consist "of calcareous sands and slightly siliceous limestones which are overlaid by remarkable fissile calcareous shales."[1] The lower member is about 800 feet in thickness, the upper 1,200 feet. The coarse materials of the preceding period are not present, and in general the sedimentation denotes deep and quiet water. According to King the deposits rest unconformably upon the Wasatch.[2]

The fauna of the Green River group has quite a different character from that of the preceding or succeeding horizons, and consists chiefly of fishes, insects, and mollusks. The molluscan forms predominate in the lower division, while the fishes and insects are confined to the upper member of the series. A common molluscan genus is the Goniobasis that ranges widely throughout the Eocene. The vertebrate fauna, represented by vast numbers of very perfectly preserved individuals of a few species of fishes is, according to Marsh, characterized by the genus Heliobatis, and for that reason the Green River shales are designated in his classification as the Heliobatis beds. The fish-bearing strata contain numerous remains of insects. The types of fish are characteristically Eocene, and in the case of several genera begin to appear in the Wasatch, while two genera range from the latter into the Bridger.

WIND RIVER GROUP.

Although the beds occupying the upper basin of the Wind River and described by Hayden as the Wind River group in the various publications of the U. S. Geological Survey of the Territories do not afford, upon stratigraphical grounds, a basis for a satisfactory correlation with any of the divisions of the southwestern Wyoming area, yet for reasons to be presently mentioned it is generally conceded that the Wind River group represents the Green River group, although Scott[3] would consider it Lower Bridger in age.

Hayden states that the deposits consist of "light gray and ash-colored sandstones, with more or less argillaceous layers," and that "the strata are most beautifully variegated with various shades of pink or brick-red color, so that they sometimes remind one of the Jura-Trias red beds." The deposits extend along the Wind River basin about 100 miles, and are from 1 to 5 miles in width. The aggregate thickness of the strata is estimated at 1,000 feet or more.

Cope[4] states that "the vertebrate fauna consists of the mammalian

[1] U. S. Geol. Expl. 40th Parallel, vol. 1, Systematic Geology, 1878, p. 380.
[2] Ibid., p. 377.
[3] Am. Phil. Soc., Trans., vol. 16, 1889, p. 465.
[4] Am. Geologist, vol. 2, 1888, p. 287.

types Condylarthra, Tæniodonta, Pantodonta, Dinocerata, Palæosyops, and Hyrachyus." He further says:

This fauna indicates the transition between the Wasatch and Bridger, since types are here associated which are elsewhere peculiar to the two horizons named. Thus of the above zoological divisions the following are exclusively Wasatch, Tæniodonta and Pantodonta. The remaining ones are Bridger, excepting the Condylarthra, which probably occur in both Bridger and Wasatch.

Upon paleontological grounds, then, the Wind River group occupies a position intermediate between the Wasatch and Bridger groups of the southwestern Wyoming section, and may be considered the representative of the Green River group.

MANTI BEDS.

In Sevier and San Pete Counties, in eastern Utah, calcareous shales somewhat similar to the Green River strata in lithological character, and known as the Manti beds, are found. The vertebrate fauna is different, although Crocodilus and Clastes occur, forms which are represented in deposits that are found both above and below the Green River group. The Manti beds are generally considered of Green River age. They have been described at length by Prof. Cope.[1]

AMYZON BEDS.

Under the name of the Amyzon beds Cope[2] includes deposits at Osino and Elko, Nevada, South Park, Colorado, and in central Oregon. As to the taxonomic position of the beds he expresses doubt, though he considers that they are probably late Eocene or early Miocene.

King[3] considers the Nevada strata of identical age with the Green River group and has so described and mapped them.

There are no species identical with Green River forms, although Trichophanes is reported by Cope to be closely allied to Amphiplaga of the Green River group. On the other hand Amyzon and Trichophanes, which occur in Nevada, are also found at South Park, Colorado, together with Rhincaster and Amia, neither of which appear in the Green River group.

The beds at Florissant, Colorado, have been investigated by Peale and Scudder,[4] the latter of whom has described the remarkable insect fauna that the beds contain. The strata consist of shales and sandstones and were deposited in a lake basin of limited area.

BRIDGER GROUP.

The deposits of the Bridger group are found chiefly in southwestern Wyoming, on the northern flanks of the Uinta Mountains, and on both

[1] Am. Phil. Soc., Proc., 1880, vol. 19, p. 6; Am. Nat., vol. 14, 1880, pp. 303, 304; Am. Nat., vol. 21, 1887, p. 453.

[2] Am. Nat., vol. 13, 1879; p. 332, Am. Phil. Soc., Proc., vol. 19, 1880, p. 61.

[3] U. S. Geol. Expl. 40th Parallel, vol. 1, Systematic Geology, 1878, p. 393.

[4] U. S. Geol. and Geog. Surv. of the Territories, Bull., vol. 6, pp. 279-300, and Twelfth Ann. Rept. for 1878, 1883, pp. 271-293.

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. Both by Hayden and Scott the deposits of these two "basins" are considered to represent different horizons of the Bridger proper, and Hayden not infrequently speaks of the Bridger and Washakie as separate formations. Scott[1] says that but few vertebrate forms are common to the two areas. He considers the types of the Washakie Basin younger than those of the Bridger Basin, since the former area affords forms more closely allied to the Uinta fauna.

King states that the stratigraphical relations of the Bridger and Green River are with difficulty made out, though he thinks the "evidence is in favor of a true nonconformity."[2]

The deposits consist largely of sands and clays, with frequent layers of chert and limestone. King estimates the thickness of the formation in the Bridger Basin at 2,500 feet and Cope that in the Washakie Basin at 1,200 feet. A very rich vertebrate fauna is found in which the mammalian genus Dinoceras is held by Marsh to be the most characteristic. He has designated the Bridger group as the Dinoceras beds on that account.

Of the molluscan types Unio, Planorbis, Goniobasis, and Viviparus are the most common, and according to Dr. White "correspond closely with those of the Green River, some of the species being common to both, all indicating a purely fresh-water condition of the waters in which the strata of both groups were deposited." Remains of birds, reptiles, and fish in considerable numbers are also found in the deposits.[3] Cope states that the Bridger is characterized by the "presence of Tillodonta, Condylarthra and Dinocerata, Hyrachyus, Palæosyops, Amynodon, Triplopus, and Achænodon, absence of Tæniodonta, Pantodonta, and selenodent Artiodactyla."

HUERFANO BEDS.

On the eastern side of the Rocky Mountains, in Huerfano and Las Animas Counties, Colorado, an extensive series of Eocene deposits have been found resting unconformably upon strata of the Laramie and Colorado groups and containing vertebrate fossils (Tillotherium, Hyrachyus, Glyptosaurus, Palæosyops) that point to the equivalence of the beds with the Bridger group of southwestern Wyoming. The strata attain great thickness and their character is shown in the following section by Hills:[4]

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[1] Am. Phil. Soc., Trans., vol. 16, 1889, pp. 464, 465.

[2] U. S. Geol. Expl. 40th Parallel, vol. 1, Systematic Geology, 1878, p. 395.

[3] Am. Geologist, vol. 2, 1888, p. 288.

[4] Colorado Sci. Soc., Proc., vol. 3, pt. 2, 1889, p. 218.

	Feet.
Marls, clays, soft shales, and sands, of red, gray, yellow, green and purple colors, red predominating	3,300
Pink and white massive sandstone	300
Soft sandstones and fine conglomerates of a yellowish tint, with occasional bands of yellow clay or marl	3,500

The discovery of fossils has hitherto been limited to the upper division of the series.[1] The beds have been folded and in the vicinity of Spanish Peaks extensively altered "by proximity to the laccolithic mass of the mountains and by the numerous radiating dikes."

UINTA GROUP.

The Uinta group, so named by King,[2] is known only from the northern and southern flanks of the Uinta Mountains, in northern Utah and southern Wyoming. It has been called the Brown's Park group by Powell.[3]

According to Dr. White the strata are unconformable to the other Tertiary beds, and—

it is possible that this group was deposited continuously, at least in part, with the Bridger group, but at the places where the junction between the two groups has been seen in this region there is an evident unconformity, both of displacement and erosion. The group consists of fine and coarse sandstones, with frequent layers of gravel, and occasionally both cherty and calcareous layers occur. The sandstones are sometimes firm and regularly bedded, and sometimes soft and partaking of the character of bad-land material. The color varies from gray to dull reddish brown, the former prevailing north of the Uinta Mountains and the latter south of them. The only invertebrate fossils that have been known to be discovered in the strata of this group are some specimens of Physa very like a recent species. Therefore, invertebrate paleontology has furnished no evidence of its assumed Tertiary age and lacustrine condition of its deposition. Its fresh-water origin, however, seems unquestionable, because of its intracontinental position, its limited extent, and the fact that none but fresh-water deposits are known in this part of the continent that are of later date than the close of the Laramie period.[4]

From the presence of the characteristic mammalian genus Diplacodon the strata have been called by Marsh the Diplacodon beds.

According to Cope its vertebrate fauna is characterized by the "presence of Amynodon and selenodont Artiodactyla; absence of Pantodonta and Dinocerata (Scott)."

Scott[5] says that the mammalian types of the Uinta are closely related to those of the Washakie Basin of the Bridger group.

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[1] In a more recent publication Hills (Abstract Colorado Sci. Soc., Proc., Feb. 17, 1891) reclassifies the Huerfano beds as follows:

Huerfano series (Eocene)	Huerfano beds.	=	Bridger group.
	Cuchara beds.	}	Lower Eocene.
	Poison Cañon beds.		

[2] U. S. Geol. Expl. 40th parallel, vol. 1, Systematic Geology, 1878, pp. 405–407.

[3] U. S. Geol. and Geog. Surv. of the Territories, II Div., Geology of the Uinta Mts., 1876, pp. 62, 63.

[4] U. S. Geol. and Geog. Surv. of the Territories, Tenth Ann. Rept., for 1876, pp. 37, 38.

[5] Am. Phil. Soc., Trans., vol. 16, 1889, pp. 466–468.

SUMMARY OF CORRELATIVE EVIDENCE.

The limits assigned to the Eocene of the Interior and the different divisions that have been established for it have been presented in the previous pages.

When the attempt is made, however, to correlate the various horizons of the Interior Eocene with the divisions of that series elsewhere recognized, we have but little to guide us. The conditions under which the deposits were here accumulated afford no parallel in any portion of the earth's surface investigated up to this time. Great inland basins that changed from brackish water to fresh water during this epoch supported an aqueous fauna that presents almost no points of comparison with the fauna of other regions. The vertebrate animal and plant life, although affording unequivocal proof of the Eocene age of the strata from the Wasatch on, does not give grounds for more detailed correlation.

The Laramie has afforded a few plant forms that by Newberry, Lesquereux, and Ward have been shown to be identical or closely related to types recognized in the Puget group of the Pacific Coast and the Lignitic of the Gulf border; but when so little is known of the plant remains of the American Eocene, or even with certainty of the geological range of plant species in general, correlations based upon such evidence can have but little value. That the upper portions of the Laramie may represent a part at least of the Lignitic of the Gulf border and thus the Lower Eocene, as established for the Atlantic and Gulf Coast region, has been advanced by Dr. White, and, as it seems to the writer, upon good grounds. Further correlation of the various members of the Interior Eocene with divisions elsewhere established is at present impossible.

From a stratigraphical standpoint it has been customary to place the Wasatch group in the Lower Eocene; the Green River and Wind River groups, which are considered equivalent to one another, in the Middle Eocene, and the Bridger and Uinta groups, which occur in stratigraphical sequence, in the Upper Eocene. There is no evidence, however, that these divisions are equivalent to those similarly named in the Atlantic and Gulf Coast region.

The Wasatch, Green River, Bridger, and Uinta groups, which occur in stratigraphical sequence in the Green River Basin, may be said to afford the typical Eocene series of the Interior, though it is doubtful whether deposition was continuous throughout the time of their accumulation. The isolated occurrences of fresh-water Eocene elsewhere are interpreted generally by comparison with the southern Wyoming section; still direct parallelism can not always be established.

The evidence for referring the upper portions of the Laramie to the Eocene has been already mentioned. What proportion of Eocene time this horizon of the Laramie should be held to represent can not be

definitely stated, but that an appreciable amount should be so included seems probable.

Overlying the Laramie, in northern New Mexico, are the Puerco beds, that, both from their stratigraphical position and fossil remains, since they lie above the Laramie and below the Wasatch and contain types of life that point to their Tertiary affinity, have been placed in the Lower Eocene. Whether they rest upon the latest horizon of the Laramie or reach to or beyond the base of the Wasatch in other areas is an open question. The supposed break between the two is represented in the accompanying table as bridged over by the Puerco beds.

The Arapaho beds are found resting unconformably upon the Laramie, but there is no evidence that it is the top of that formation elsewhere exposed. In fact the Arapaho itself has been hitherto called Laramie. Certainly the faunal relations of the Arapaho and the overlying Denver beds point to their close affinity with the Laramie, though the structural relations of the deposits of these several horizons show a wide hiatus between them in the area of their occurrence. It seems probable that the Arapaho and Denver beds should be placed in the Lower Eocene, and doubtless below the base of the Wasatch group, since the life indicates an earlier period.

A large part of the Lower Eocene is supposed to be represented in the Wasatch group. The fauna was in a marked degree different from that of the preceding period and the conditions must have altogether changed to have admitted of its existence.

The Green River group is placed as the representative of the Middle Eocene. Correlated with this is the Wind River group, whose contemporaneity it is impossible to show, since the stratigraphical relations of the deposits to the Wasatch and Bridger of the Green River Basin are unknown. The fauna, however, affords forms which show the intermediate position of the Wind River group between the Wasatch and Bridger, and thus in part, at least, its place as the representative of the Green River group. The limits of the two horizons may not be identical.

The Amyzon and Manti beds each afford a fauna that points to their dentity with the Green River group. The evidence presented admits, however, of only the most general comparisons, since but few identical forms have been recognized.

The Bridger and Uinta groups, which are found in superposition, have been referred to the Upper Eocene.

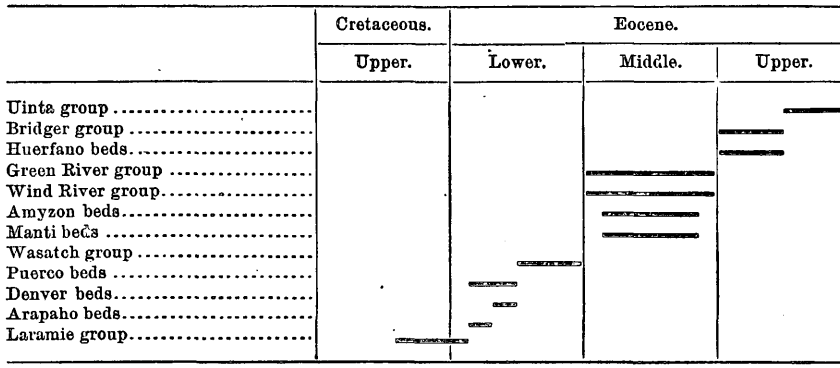
East of the Rocky Mountains a small area in southern Colorado presents a series of deposits that have been called the Huerfano beds, in which vertebrate types similar to those afforded by the Bridger group of the Green River Basin have been found.

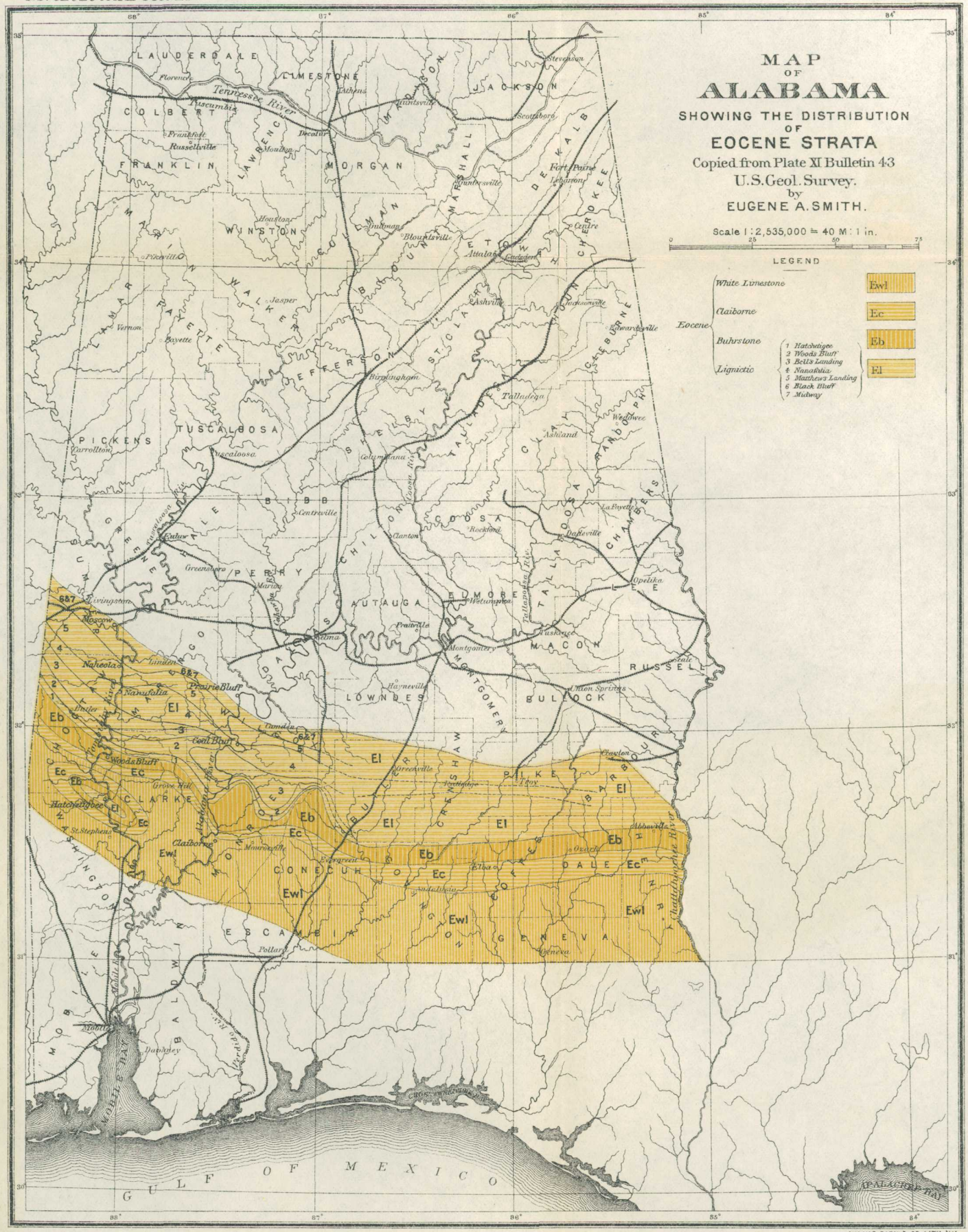
Many isolated occurrences of fresh water deposits throughout the Rocky Mountain area have been referred to the Tertiary, but as evi-

dence is lacking to prove their Eocene age, reference to them is omitted here.

A table is given below in which the approximate position of the deposits just mentioned in the Eocene series is presented. The lines do not indicate the relative thickness of the beds, but rather the proportionate part of Eocene time that may be tentatively assigned for their accumulation.

Table showing the relative position of the Interior deposits in the Eocene series.





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EXPLANATION OF THE MAP.

The Eocene area designated upon the map embraces the extreme limits of outcrop of the deposits of that horizon and not necessarily continuous exposure. More recent deposits frequently cover much of the surface, the Eocene outcropping only along the deeper river channels.

In the Interior region the Laramie is omitted on account of the difficulty of separating that portion to be referred to the Cretaceous, which in extent probably greatly exceeds that belonging to the Eocene.

Any adequate representation of the Eocene of the Pacific coast is wholly out of the question on account of the lack of available information. The limits of the areas designated are unknown.

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